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Yoshiki Wakabayashi
Takashi Morita *Editors*

Ubiquitous Mapping

Perspectives from Japan

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Preface

Since the last decades of the twentieth century, the circumstances surrounding map use and map-making have drastically changed, owing to the advancement of information and communication technologies (ICTs). Specifically, the spread of web maps and mobile devices has altered people's interactions with maps. For example, Google Maps, launched in 2005, has transformed map use methods, offering satellite or aerial photography, street maps, interactive panoramic views, real-time traffic conditions, and route planning for travelers. Additionally, OpenStreetMap, founded in 2004, enables us to join the collaborative work of online map-making and freely use a map of the world.

This book features the latest works on the theoretical and practical issues of these changes by designating them as "ubiquitous mapping." This term refers to the use and creation of maps by users anywhere and at any time. It is strongly influenced by advancements in information technologies, such as wireless systems for broadband communication, high-density data storage, and the mobile devices of computers, which enhance dynamic and personalized map-making. Specifically, the development of the telecommunications infrastructure (e.g., wireless communication networks), spatial positioning methods (e.g., Global Positioning System (GPS) and radio frequency identification (RFID)), and mobile computing systems has enhanced the use of pervasive maps and map-making.

Since map use and map-making have become ubiquitous, cartographers have been required to rethink basic concepts about map design and map use. The Commission on Ubiquitous Mapping in the International Cartographic Association (ICA), established in 2003, has been dealing with a "well-mapped society" where people can use and make maps anywhere and anytime. Most of the contributions to this book are based on the activities of the Commission on Ubiquitous Mapping in ICA.

Previous studies on this subject have focused on the technological aspects of this trend. With the advancement of pervasive map use and map-making, however, diverse people, including novices, are involved in map use and map-making. Moreover, the context of map use has diversified with the spread of mobile devices connected to the Internet. Hence, we should consider the variations of map users and the context of map use in examining the effects of ubiquitous mapping. This book intends to consider not only technological bases, but also human/social aspects based on a multidisciplinary perspective; the contributors to this book are numerous professionals from the fields of cartography, geography, information science, and psychology.

This book addresses the following matters: the evaluation of ICT-based technologies for context-aware mapping, the theory and application of crowdsourced geospatial information and collaborative mapping, and the positive/negative effects of ubiquitous mapping on human society. It is organized into three parts. As an introductory remark before entering the main issues, Prof. Morita, who founded the Commission on Ubiquitous Mapping, outlines the background and aims of our research projects. First part focuses on the technological issues and applications of ubiquitous mapping. Second part explores the human aspects of this trend by focusing on its positive and negative effects. Third part deals with various social and practical issues and applications of novel mapping technologies.

When we discuss the social aspect of this trend, we cannot help but consider the context of the study area and the author's perspective. Hence, we added the phrase "perspectives from Japan" to the title of this book. Next, we should examine the universality of the findings obtained by comparing those with other countries. We hope that this book will contribute to a comprehensive understanding of the current status of map use and map-making.

Finally, we would like to thank the Japan Society for the Promotion of Science (JSPS), which financially supported our research through a Grant-in-Aid for Scientific Research A (ID: 17H00839, FY 2017-2020, Representative: Yoshiki Wakabayashi).

Tokyo, Japan Yoshiki Wakabayashi
November 2021 Takashi Morita

Contents

On the Establishment of Theoretical Cartography and Meta-cartography and the Subsequent Development of Ubiquitous Mapping

Takashi Morita

Abstract The digital revolution began during the latter half of the twentieth century. The role of maps in society is changing due to this revolution. The International Cartographic Association (ICA) established the Commission on Ubiquitous Mapping in 2003. Its emergence was derived from the concepts of theoretical cartography and meta-cartography that had been acting since the establishment of the ICA in 1959. They had discussed the question of what a map is, what characteristics it has, what specific function it has, and how it differs from other fields of spatial representation. The demand for meta-cartography has been requested when a paradigm shift is occurring in the mapping field worldwide. Several books were published to discuss on the map languages and the cartographic methods to build a conceptual framework. The Commission on Ubiquitous Mapping was established for the purpose of conceptualizing the basic structure of the needs required for the era of "network socialization". The commission tried to clarify the process of dynamic and egocentric spatial expressions required for map-making and use in real space. Ubiquitous mapping expresses the position of today's maps, but it proposes more of a "methodology" than a "field".

Keywords Theoretical cartography · Meta-cartography · Map language · Cartographic communication · Ubiquitous mapping · Mapping literacy

1 Introduction

The digital revolution began during the latter half of the twentieth century. The accompanying changes in the information and communication environment, including the recent situation of the coronavirus crisis, the use of video visual image plus audio, and multi-person plus two-way communication via the Internet, have brought us the transformation of the behavior of communication. Also, the role of maps in society is changing due to these revolutions. Every day, we see maps and diagrams reporting disasters. Therefore, the reasons for the existence and advantage of maps are always

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asking and being evaluated. To reflecting the theme, the external and internal observations of the map are necessary to recognize the societal role of maps as well as the functions incorporated inside these maps and the dynamic interchanges between them. Indeed, these facts are used to understand a "method of mapping" in society rather than a "field of maps" built by specialists.

The International Cartographic Association (ICA) established the Commission on Ubiquitous Mapping in 2003. Its emergence was derived from the concepts of theoretical cartography and meta-cartography that had been acting since the establishment of the ICA in 1959. What those contexts are, how they are developed, what the significance of their objectives is, and what will be the future direction of the ubiquitous mapping are remaining questions.

2 Theoretical Cartography

Maps are sign systems. In order to produce appropriate maps according to one's needs and if the procedure of teaching this was to be accomplished, one would have to acquire some theory in advance to proceed with the method systematically. Since the sign system is expressed by the operation of abstraction through the symbolization of facts and their systematic organization, the operation requires a logical structure of organization. In other words, theory is indispensable in map-making. Therefore, the term of theoretical cartography may not be entirely applicable since maps are always made theoretically. The term "theory" is not adequate here since it is the theory on the cartography or meta-cartography which discusses the question of what a map is, what characteristics it has, what specific function it has, and how it differs from other fields of spatial representation. To reflect them, it is preferable to recall briefly the evolution of map-making (Harley and Woodward 1987–2015). The symbols used in maps are said to have appeared earlier than letters. In fact, in the "Bedolina map"(Anati 2008) in the Camonica Valley in Italy around BC 2000, there was no use for letters to describe words; instead, abstract symbols were arranged in a regular manner representing the aspect of the given map. This method involves expressing pictures which are clearly different from those of concrete landscape depictions. Techniques for surveying the measure and plot spaces, Euclidean geometrical methods, coordinate concepts, and the concept of spherical earth and latitude and longitude emerged as a lead-up involving around BC to AD.

Likewise, we could address these topics by describing things onto some media spaces using symbols to express familiar dimensions. Then, we can extend it regarding a reference line or network (roads, rivers, mountains…) to cover them and arrange them into an abstract homogeneous network (coordinate system) to fix their relative positions. This is also useful for arranging those partial spaces into a vast space which could be intuitively understandable as one continuous space. Consequently, we can visualize a space which is infinitely extended through the abstract symbol system. Since no one can see such a large space directly with their eye, one's imagination, logical abstraction, symbolic expression, and intuition for the space, which are combined here through the representation method of the mapping procedure.

After that, various projection methods and height depth expressions such as isolines/contour lines and step-color shading expressions using color gradations were conceived, and expressions such as statistical maps in which quantities and their distribution were represented with map symbols were developed. Hence, the map expression system was extended. Then, with the progress of the management of each country, including the military and industrial activities, the creation of various thematic maps according to the specific purpose became usual, and various maps were provided by a group of cartography specialists. Eventually, in 1959, after World War II, the ICA was established (Ferdinand and Ormeling 1984), where the concept of theoretical cartography emerged.

The establishment of ICA was due to the cross-border internationalization of the drastic increase of activities of people after the postwar economic development and the need to obtain various kinds of overseas information. Until then, the military often created basic maps which required a large amount of money and manpower, and which did not adequately meet the general needs responding to various kinds of spatial understanding. After World War II, map-making became independent of the military, and thus, the democratization of maps began. Since, map creation and the utilization conditions of each country have differed depending on their cultural traditions, language, geographical condition, economic situation, etc. Thus, since a common understanding for information acquisition and expression was needed, discussions in international organizations became indispensable especially when creating maps across borders.

At a first glance, maps are often regarded as an international common language. However, a universal language as a natural language has not been established up to now. By the time of World War I, up to one-million international maps had been produced, although they have been abandoned today. Under the conditions of such incidents, map-making by the means of universal map expression has not been established but it could be re-established if it had a strong special subject such as a nautical chart. In such a situation, issues regarding the commonalities and differences between maps of different countries, the kinds of expressions which are easy to understand, and the types of expression forces which are an unnecessary effort on map reading could be discussed. Furthermore, it is important to understand the kinds of subjects which are adequate for mapping. Therefore, the meta-cartographic perspectives based on map language, map communication, and theoretical cartography became required.

A book (in Japanese) was published by Toshitomo Kanakubo in 1991 (Kanakubo 1991) on the details of the development of theoretical cartography in ICA. Until then, various theories had been presented from the standpoint of how to produce a map. However, in linguistic and communication theories, users were presented as the recipients of the expression information. Indeed, the importance of this situation is more clearly understandable when maps are provided and received across national borders. However, many map symbols differ from one country to another.

Moreover, the demand for meta-cartography, which has been called when a paradigm shift is occurring in the mapping field worldwide. This represents the time of transition where map creation and use are significantly changed. They include the (a) standardization, (b) quantification, (c) computer information processing, and (d) network socialization of maps.

These changes first appeared in the standardization and quantification of maps, which were aimed at the distinctiveness and development of science and technology in field of the mapping. The idea was to build a conceptual model based on linguistic and communication theories, and to express the problems which required scientific and objective solutions together with the background of the quantitative revolution based on numerical data. Subsequently, the digital revolution accompanied by the arrival of computers enabled the expression not only of base maps but also the thematic information superimposed onto these bases, represented by digital operations based on digital data and digital processing systems. The computer information processing change was developed as a specialized automation technology at first and then as an interactive GIS technology. At the same time, the modeling and systematization of processing advanced the conceptualization of the domain as a science. Since then, maps have become widely used in public due to network socialization; new discussions have emerged regarding what the characteristics of map-based thinking and recognition are, and the conditions required to advance their situation. A few years after the publication of Kanakubo's book (Kanakubo 1991), "How Maps Work" (MacEachren1995) was published, comprehensive discussions emerged regarding how meaning is extracted from maps, how maps emanate meaning, and how maps are used. Work was then conducted to develop the domain of visualization (1995–1999), visualization and virtual environments (1999–2007), and geo-visualization (2007–2015) as ICA commissions.

3 Meta-cartography

The ICA did not have a commission called meta-cartography. As mentioned in the previous section, a brief history of theoretical cartography followed but unfortunately, the commission on theoretical cartography ended at the ICC2015 in Rio de Janeiro, Brazil. Nevertheless, it is useful to continue making observation in order to get the perspective of this field, and indeed, the word "meta" might be a key concept for deepening the characteristics of the field.

It is undeniable that World War II stimulated the initiation of ideas regarding meta-cartography. At that time, numerous new maps were created, the number of users increased greatly, the types of maps were diverse, and the efficiency of the use of aerial photographs was discovered. In such a situation, the fundamental questions on map-making appeared again, including what features could be represented by a map and how this could be carried out. These led to postwar E. Raisz's General Cartography (Raisz 1938) and Robinson's Elements of Cartography (Robinson et al. 1953). Eventually, in Theoretical Geography (Bunge 1966) by Bunge, the second chapter dealt with meta-cartography. Bunge studied the capabilities of maps when compared with spatial representation methods other than maps, and he insisted on the existence of the field of mapping by making comparisons with pre-maps, maps, and mathematics. Meanwhile, J. Bertin of France wrote Sémiologie Graphique (Bertin 1967) summarizing the relationship between the semantic features of represented information and the capacity of perception. Different expression techniques were summarized from a semiotic point of view. He classified various expressions as monosemic, polysemic, and pansemic, and declared that maps seek a monosemic nature among them and that the concept of visual variables was the method to secure their monosemic representation. Later, A. F. Aslanikashvili wrote Meta-cartography in Georgian in 1968, translated in Russian in 1974, and translated in Japanese in 1998 (Aslanikashvili 1998). There, he mainly delved into "map languages" and "cartographic methods". He discussed the conceptual framework of "map language" as enquiring about what kind of expressive properties it has, what advantages it has compared to other languages, and how it can be appropriately operated as a language system. The other concept "cartographic method" aimed to provide a conceptual framework for the visual models and visual thinking styles. They were based on the thinking process of object recognition using such "map languages". At that time, computer information processing and network socialization had not yet progressed sufficiently. However, with the current technological progress, the need for such discussions is increasing. It could thus be said that these authors were ahead of the times.

Table 1 lists the commissions in ICA related to theoretical cartography in a successive order. As mentioned above, there were already some movements before the establishment of ICA after World War II, but soon after the establishment of ICA, the first two commissions began to work to respond to the needs of those times.

After that, as the information network environment was improving, questions were imposed regarding the advantages of map-like expressions over other linguistic expressions. These should inevitably include the response for the kinds of object and purposes which are suitable to apply such methods. It has also been questioned, what demands have become obvious since 2000 for map immediacy, interactivity, variability, and superimposition onto real space (augmented reality: AR), which are

Table 1 ICA commissions related to theoretical fields

Year 60 70 80 90 00 10 20	ICA Commissions and Working Groups	Chair
1960-1970	Working Group on Cartographic Information	A. Kolacny
1972-1984	Commission on Communication in Cartography	L. Ratajski, C. Board
1984-1987	Working Group o Concepts and Methodlogy in Cartography	U. Freitag
1987-1991	Commission on Concepts in Cartography	T. Kanakubo
1987-1991	Working Group on the Definition of Cartography	C. Board
1991-1995	Working Group to Define the Main Theoretical Issues in Cartography	T. Kanakubo
1995-199	Commission on Theoretical Issues in Cartography	T. Kanakubo
1999-20	Commission on Theoretical Cartography	A. Wolodtschenko, Q. Du
2003-	Commission on Ubiquitous Mapping	T. Morita, M. Arikawa, Y. Wakabayashi

derived from the advantages of the contemporary information technology environment. Thus, cartography has become as a dynamic process. Which are characteristics of the cartographic method is the question which has always appeared at the turning points of the field of mapping. The insights for “meta-cartography”, “cartographic language”, and “cartographic method” are essential to further develop this field and its methodology.

4 Development of Ubiquitous Mapping

At the International Cartographic Conference (ICC) 2019 held in Tokyo, the slogan for the conference was “Mapping everything for everyone” (Fig. 1). This concept followed the direction of the “Commission on Ubiquitous Mapping” launched in 2003, and this commission was derived from the “Commission on Theoretical Cartography” as mentioned above. It was established for the purpose of conceptualizing the basic structure of the needs required for “network socialization”. The commission tried to clarify the dynamic and egocentric spatial expressions required for map-making and use in real space. If computers and networks are technologies that extend the function of the human brain to the outside, the maps represented there are maps that exist in the brain of the map maker and map user. They can also be externalized using map symbols and manipulated bidirectionally between images in the brain and the represented map according to the context.

The evolution referring to the key concepts of the commission before and after its foundation was as follows. The author studied at the laboratory of Professor Bertin in France during the latter half of the 1970s and translated and published Bertin’s second book “La Graphique” (Bertin 1977) in Japan in 1982. After that, the commission on “Map Language” was established in 1985 at the Japan Cartographers Association under the supervision of Dr. Toshitomo Kanakubo to encourage research

Fig. 1 Slogan for the ICC2019TOKYO

in this field. Since 1987, the author has regularly attended the ICA conference every two years and at this conference, the ICA's Commission on Concepts in Cartography (Chair: Toshitomo Kanakubo) was established. The author presented the evaluation of Bertin's visual variables by the eye movement measurement method (Morita 1987) at the same conference. The commission had summarized the research trends in ICA using the ICA's International Yearbook of Cartography up to those years by themes and authors via a bibliographic survey. The result was published in 1993 (Kanakubo and Morita 1993). GPS and car navigation systems were made available to public use in the 1980s, and mobile phones capable of displaying images on their screens began to be used in 1990s; their reception by the public was relatively early in Japan regarding the international context (60% of the population owns a mobile phone and 30% of new cars are equipped with a car navigation system) and various experiences were obtained in advance. Under such circumstances, the Commission of Theoretical Issues in Cartography (Chair: Toshitomo Kanakubo) conducted a questionnaire survey on the definition of cartography, and the results were presented at the seminar of the Commission of Theoretical Cartography (Chair: Alexander Wolodtschenko) held at Gdansk in Poland in 2002. In the report (Morita 2002), since it was recognized that the changes in the surrounding environment of maps could not be defined in a highly fixed manner, it was rather necessary to have further discussions and observations made for the changing phenomena, and necessary to construct a frame to describe their interrelationships. The diagrams of the key concepts used there in those days were the Map Communication Model (Morita 1990), Map Action (Morita 1993), and the Mapping World based on Three-Axis (Morita 2002). To respond to those subjects, the Commission on Ubiquitous Mapping (Chair: Takashi Morita) was established in 2003.

The word "ubiquitous" was first encountered by the author in a lecture by Professor Bertin in the late 1970s. The explanation was that the visual perception is ubiquitous and can be observed instantly anywhere on the map, and map representation should adopt it effectively by using its exceptional ability. The concept of ubiquitous computing began to be used around 1990 in computer science, and it refers to the situation where computers are minimized and incorporated everywhere and can be used anytime online. If maps adopt using this situation, it could be called "ubiquitous mapping". Additionally, the reason why we chose "mapping" instead of the term map is because it is a dynamic process like computing and not "computer". Ubiquitous cartography (Gartner et al. 2007) was used instead of mapping for a while, but it made it difficult to recall dynamic processes. The English "-ing" has a special meaning in that it is difficult to translate into many other languages. To discuss these concepts in the context of meta-cartography, a commission on "ubiquitous mapping" was established at first in early 2003 at the Japan Cartographers Association. Subsequently, a commission with the same name was approved by the ICA in the summer of the same year. After that, the development of the commission was as follows:

(1) **Chronological events**

- In 2003, the Commission on Ubiquitous Mapping (Chair: Takashi Morita) started its activities at the ICC in Durban, South Africa. It was decided that the commissions on "Map and the Internet" and later "Location-Based Services" should be worked on closely.

- In 2004, the three abovementioned commissions jointly held a seminar (Ubiquitous, Pervasive and Internet Mapping (UPIMapTokyo 2004) in Tokyo to discuss the future directions of the domain. Elements of the discussions were emphasized on "spatial context", "four basic components (map, image, IT infrastructure, real world)", "map to mapping", "comparative study of cases", and some research subjects which included the egocentric easy-to-understand map, pseudo-three-dimensional dynamic map expression, use of augmented reality, building of explicit location reference systems using IT, the use of existing sign systems and IC tags, the construction of participatory systems, and information aggregation and display. Discussions were also detained on methods ensuring information security and privacy, the impact of ubiquitous mapping on society, differences in social tolerance in each country, and changes of the means of spatial sensing. At the end we inspected the current situation of car navigation systems, mobile phones, and traffic control center in Tokyo.
- In 2005, the results of the Tokyo seminar in the previous year were reported at the ICC in A Corunya, Spain (Morita 2005).
- In 2006, a seminar was held in Seoul, South Korea (UPIMapSeoul 2006), and the study reports were presented in five sessions: basic concepts and methods, system design, data and spatial information, visualization, and application software. The keywords were "cultural differences and commonalities", "real-scale maps", and "side-view landscape maps".
- In 2007, the concept of "spatial references" and "side-view landscape maps" were presented at the ICC in Moscow, Russia.
- In 2008, a workshop (UPIMapUSA 2008) was held in Shepherds Town, USA, and the modern situations in Japan and in USA were reported.
- In 2009, a paper on the perspective of "cultural differences" in ubiquitous mapping was presented at the ICC in Santiago, Chile.
- In 2010, the ICA joint seminar (map design in the digital age) was held in Hong Kong, and reports on ubiquitous mapping and the "Bertin's theory" were presented.
- In 2011, a small workshop was held at IGN St. Mandé prior to the ICC in Paris, France. Reports on the incomprehensible information of news for the "Tohoku Earthquake and Tsunami Disaster" distributed in March, and the "relationship between the side-view landscape photographs and shooting positions" were presented. There was also a report on "the characteristics of sights from side, diagonal, and vertical views". The continuation of the commission was approved at the ICA General Assembly, and Professor Masatoshi Arikawa of Japan took over the role of the chairperson.
- In 2012, two workshops were held; one in Tokyo, and the other in the city of Kesennuma in the Tohoku region which had been damaged by the Tsunami for on-site inspections to verify the adaptability of the concept of ubiquitous mapping.

- In 2013, at the ICC in Dresden, Germany, a paper on “the effectiveness of non-homogeneous coordinates for human-interfaces” was presented.
- In 2015, a joint international symposium of the three commissions, “Maps and the Internet”, “Theoretical Cartography”, and “Ubiquitous Mapping” was held in Tokyo. A paper on “the effectiveness of the displacement of buildings in bird’s eye view when showing the route” was presented. There were also discussions on the disaster maps.
- In 2015, a joint workshop on Theoretical Cartography and Ubiquitous Mapping was held as a pre-meeting for the ICC in Rio de Janeiro, Brazil. A report on “the quality of expression affecting intuition” was also presented.
- In 2017, a joint workshop with three commissions: “Maps and Internet”, “Education and Training”, and “Ubiquitous Mapping” was held in Williamsburg, USA, just before the ICC meeting in Washington, USA. A report on “the spatial literacy support interface design utilizing human-centered IT” was presented.
- In 2019, just before the ICC meeting in Tokyo, a joint workshop of commissions on “Maps and the Internet” and “Ubiquitous Mapping” was held in the city of Akita, Japan. Reports on “the combination of spatial information” and “displacement and scale” were presented. The ICA General Assembly approved the continuation of the commission, and Professor Yoshiki Wakabayashi of Japan took over the role of chairperson.

(2) **Key concepts**

The key concepts can be summarized as follows.

- The “Map Communication Model” (Fig. 2) (Morita 2007) is the starting point. This is a modification of Ratajski’s model, but its most important aspect is the emergence of map users. This evolves bidirectional communication due to the development of Information and Communication Technology (ICT).
- At the same time, when bidirectional and interactive conditions were satisfied, the maps changed in response to events which led to the concept of a static map in response to dynamic “mapping”. If the actions differed depending on the environment, the notion of “differences in context” was used.
- There are four “basic components” (Morita 2007a): map, image in the brain, ICT infrastructure, and the real world. With reference to the three axes of syntax, semantics, and pragmatics of Morris (Morris 1938), the maps operated with the four abovementioned basic components are expressed by three axes: (1) spatial representation from two dimensions to multiple dimensions (syntax), (2) spatial articulation from general to individual (semantics), and media from fixed to flexible (pragmatics). Various maps will be situated in the “mapping world” (Fig. 3) (Morita 2007a) consisting of these three axes.
- Since the appearance of the “mapping world” in different societies in which the influence of their culture and history is necessary to understand “commonality and differences” through “comparative research of different societies” will have to be studied (Morita 2009).

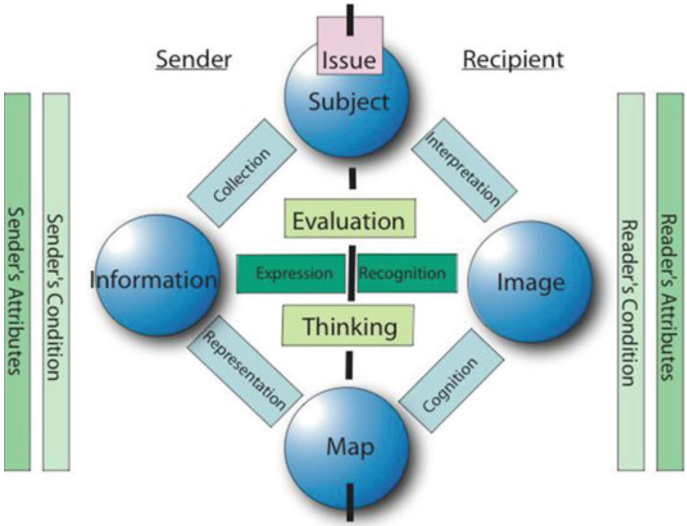
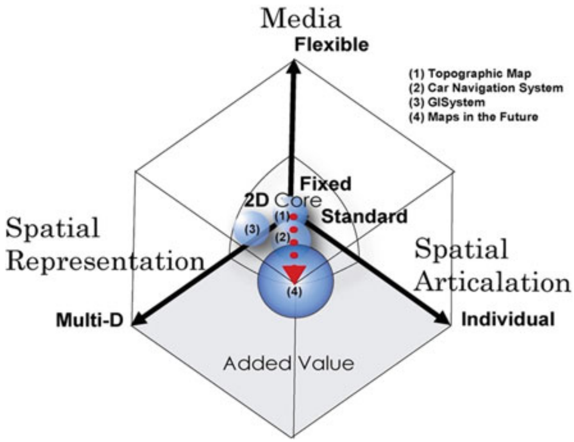


Fig. 2 Map communication model

Fig. 3 Mapping World



- When referring to a map in real space, sign systems (Maruyama and Morita 2007) such as traffic signs, addresses, and directions are installed in real space to connect the map to the real space. However, it could be considered that a "real-scale map" (Morita 2007b) materialized by the real sign boards and the real edge lines of roads and buildings in the real space gives people a feeling of spatial structure (Fig. 4) (Morita 2007b). It is then represented as a map using map symbols and annotations corresponding to the real space.
- When the user refers to the real-scale map, they collect information from the side views of the real space (Fig. 5) (Morita 2007). The user may also refer

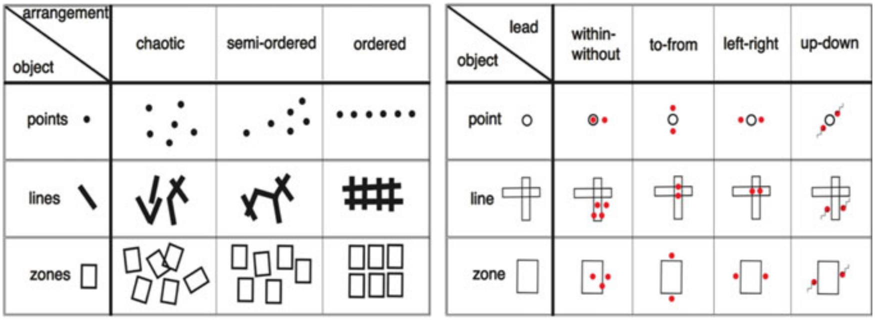


Fig. 4 Spatial structure and egocentric reasoning

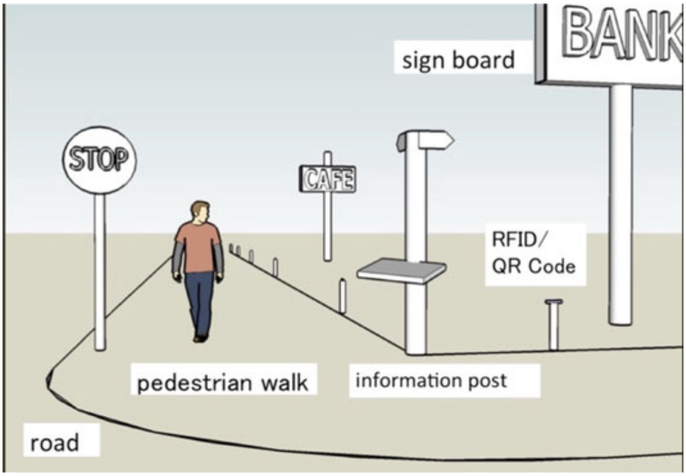


Fig. 5 Connection between real space and spatial model

to a small screen which indicates an actual image of the landscape as well as a "mapped" image which is simplified by the cartographic method "generalization" through exaggeration and omission. These "mapped views" may have different angles (Morita 2015)—side, diagonal, and vertical—and may change dynamically. There, considerations for dynamic spatial recognition are needed.

- The ubiquitous nature of maps may be strongly expected especially in the case of a disaster. There is a great need for immediacy, represented, for example, as real-time danger information, disaster distribution information, and hazard maps used in advance, and recovery support information after the event. In addition, a process for the evaluation of adequacy and comprehensibility of information should be established.
- Generalization is a basic skill for map-drawing which characterizes map-making. There, the issues of the harmonization of theoretical correctness and intuitive

conviction such as the exaggeration and omission, displacement, interruption, and scale conversion are always required. In modern times, old maps and hand-drawn maps were excluded from the practical printed maps because they were considered "inaccurate", although they were often easy to understand and easy to use. Incorporating them has led to the concept of use of "non-homogeneous coordinates" (Fig. 6) (Lu and Arikawa 2015). This has been made possible through the superposition of the two coordinates using digital technology. An easy-to-understand map based on non-homogeneous coordinates as an interface correlated to homogeneous coordinates behind the scenes achieves both functions: ease of comprehension and accuracy.

- Maps offer a lot of intuitive understanding (Fig. 7) (Morita 2021). However, they may be considered from not only a human's intuitive sensing but also from their learning ability. People can learn a basic aspect of drawing in school education and to improve spatial literacy through social life, but it is also preferable to provide a support system for map use. In this case, issues regarding the quality of expression that affects intuitional understanding, and the diversity and connectivity of different spatial information that affect the persuasive usability of dynamic processes, are the next problems that should be solved.

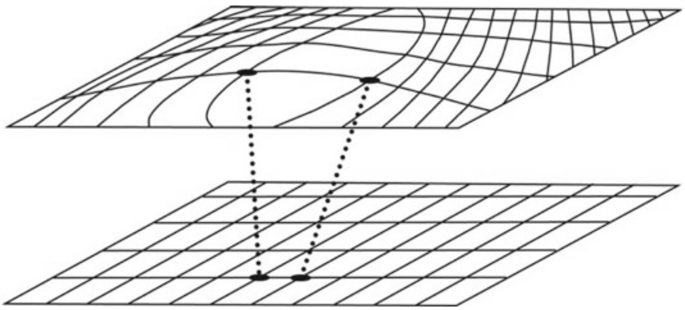


Fig. 6 Non-homogeneous coordinates

Fig. 7 A bird's eye view regional sightseeing guide map by Hatsusaburo Yoshida (Hakone-meishozue) (Collection of International Research Center for Japanese Studies. *Source* https://iiif.nichibun.ac.jp/YSD/area/kanto.html)

After all, ubiquitous mapping expresses the position of today's maps, but it also indicates the "methods" of creating and using maps. In fact, maps are more of a proposal "methodology" than a field.

5 Conclusions

As we have followed the stream of the development of ubiquitous mapping, the progress of ICT infrastructures is not only an increasing convenience, but also due to the changes in information and communication methods, the positioning of maps in society is changing. Therefore, a paradigm shift is arising. The effectiveness of using maps has become widely recognized by well-known incidences, especially through of hazard map for disaster prevention, inspections of COVID-19 infections, and identifying issues and stimulating decision making in SDGs, for example. Furthermore, literacy education for maps and GIS has started to become introduced in school education in Japan. In this situation, it could be understood that maps used to communicate and make decisions are becoming indispensable in daily life as a "map language". Indeed, they are becoming a social infrastructure like is the case of speaking a natural language in society.

On the other hand, the remaining issues to be verified are how far from the subjects of each map have been recognized, and how and when users have unconsciously received incorrect information and thus made incorrect decisions. The difference between the image given by the map and the reality should therefore be checked. However, this is an element which has already been pointed out in the map communication diagram. The objective of cartography is to minimize the difference between the image of a subject recognized by the sender (cartographer) and that of the recipient (user). The sender and the recipient could represent a mass social group. There is a concept of critical cartography where existing social values represented by a map are criticized by a new opinion using a cartographic method. Further discussions at a level of everyday life might thus also be desirable.

In recent years, machine-readable maps have been employed for autonomous driving. Under such circumstances, an opinion that maps are no longer necessary appeared. However, as we have seen, maps promote decision making by aggregating various strands of information on a map as a platform by combining figures and their attributed information in an interactive way via coordinate systems, representing a variety of information and meanings. In addition, machine-readable maps have an appealing power in that they can send the meaning as a "form". The idea behind maps revolves around being able to represent multiple and holistic perceptions using a space-like model.

Finally, recent experiences of online meetings have med us keenly aware that communication and understanding are much influenced by the context of meetings whether they are "real", "online", or both. An awareness between the reality and the abstraction is being questioned. Cartographic communication uses symbols which represent the abstraction aspect of things. Is online video communication resembling cartographic communication? Cartographic methods and ubiquitous mapping have no end for the challenges.

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Part I
Technological Issues and Applications

Ubiquitous Digital Storytelling with Local and Dynamic Georeferencing of Analog Maps

Masatoshi Arikawa and Min Lu

Abstract Maps are important vehicles for storytelling. Although the ubiquity of current web-mapping services has contributed greatly to the creation of map-based content, these services have also imposed restrictions on map representation. Conventional analog maps are still being created and remain widely used. Some of the most well-designed analog maps are highly contextual, and they are as such more suitable for storytelling with related backgrounds. To utilize analog maps in location-aware mobile environments for storytelling, local and dynamic georeferencing, which attaches geospatial information to analog map images without distorting the maps or destroying their artistic designs, is introduced. A data format, extended from a popular GIS data standard, was designed for creating and sharing storytelling content more easily by permitting the attachment of multimedia resources to georeferenced map images. In cooperation with local communities, prototype applications were developed and tested in walking tours to assist in the creation and browsing of map-based storytelling content.

Keywords Map-based storytelling · Location-based audio tours · User-generated content · Analog maps · Georeferencing · Data standard

1 Introduction

Storytelling is a common and efficient way of sharing knowledge. Indeed, people have used stories to convey information, cultural values, and experiences for as long as modern humans have existed (Gershon and Page 2001). Storytelling was once regarded informally, and its capacity for knowledge sharing was greeted with much skepticism, but it is now recognized as a valuable resource in knowledge sharing environments (Mitchell 2005). It has been suggested that sharing experiences through

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storytelling has various benefits, such as building trust, cultivating norms, transferring tacit knowledge, facilitating unlearning, and generating emotional connections (Sole and Wilson 1999; Ohler 2006). Maps are important vehicles for spatial communication, and they have been used for visual storytelling in human society since ancient times. With the technological development of maps and mapping in the digital era, map-based storytelling is no longer restricted by static media or limited by difficulties in mapmaking. People can use web-mapping services to create their own stories more easily by deploying point and line features linked to multimedia resources. At the same time, map-based and location-based mobile services have become popular in assisting with and enhancing people's real-world experiences.

However, although the ubiquity and convenience of current web-mapping services have great advantages, they also have drawbacks (Muehlenhaus 2014), like lack of diversity and freedom in map communication and aesthetic designs. On the other hand, conventional paper-based maps, such as tourist maps in leaflets of local communities, illustrated maps in guidebooks and magazines, signboard maps, and hand-drawn maps, continue to be created and widely used. Although the functions of such maps are limited by static media, they have the advantage of representing highly specified and contextual information with well-designed map representations.

This research aimed to provide users with a platform and tools for map-based storytelling that is free from the limitations of web mapping but can include all kinds of maps collected or created by the users. Users can employ the platform to position multimedia content on the maps and attach georeferences easily. This user-generated, map-based storytelling content can be shared with and experienced by other users with location-aware mobile devices in real-world settings. For this purpose, studies have focused on local and dynamic georeferencing techniques, data formats for georeferenced map-based storytelling and content sharing, and the development of prototypes of content editing tools and mobile browsing applications.

2 Cartographic Fundamentals of Human-Centered Mapping

The geographic visualization and graphic communication functions of maps, especially for conveying spatial knowledge, have been clarified in the past decades. By reviewing the lexical and functional traditions of conventional mapmaking, the current research revealed that map communication is essential to human-centered mapmaking, while the functionality, storytelling capacity, aesthetics, and potential inconsistency of such maps can be considered as some of their most important characteristics. The bird's-eye-view maps produced by the great Japanese cartographic artist, Hatsusaburo Yoshida (吉田初三郎, 1884–1955), are introduced in this work as examples of well-designed, human-centered maps to demonstrate their functional deformations.

The lexical and functional traditions of conventional mapmaking have been interlaced throughout the evolution of maps. As shown in Fig. 1, the media applications and functions of maps have shifted many times due to the emergence of new technologies. Among them, modern surveying has made maps more accurate and earth-centered, while information technologies have separated the storage and representation functions of maps. Although current digital maps appear to be primarily computer-centered, increased opportunities to focus more on their essential function—that is, communication—have clearly emerged.

The rapid development of web-mapping services has had a measurable impact on cartography and has changed mapmaking and map usage. New features of maps, including hypermedia, dynamics, interactivity, and accessibility, have extended the capabilities of map communication. However, such potential has not been well explored for human-centered maps. The drawbacks of current web-mapping services include *Googlization* in map design (Muehlenhaus 2014), restrictions on the creation of mash-up mappings, and a lack of diversity in map usage. As shown in Fig. 2, there is a hierarchy of maps, from computer-centered data maps to human-centered story maps. Current web mapping mainly focuses on the level of base maps. Mash-up maps based on digital base maps can be considered as a preliminary realization of digital thematic maps. At higher levels, which was the target of this research, maps are

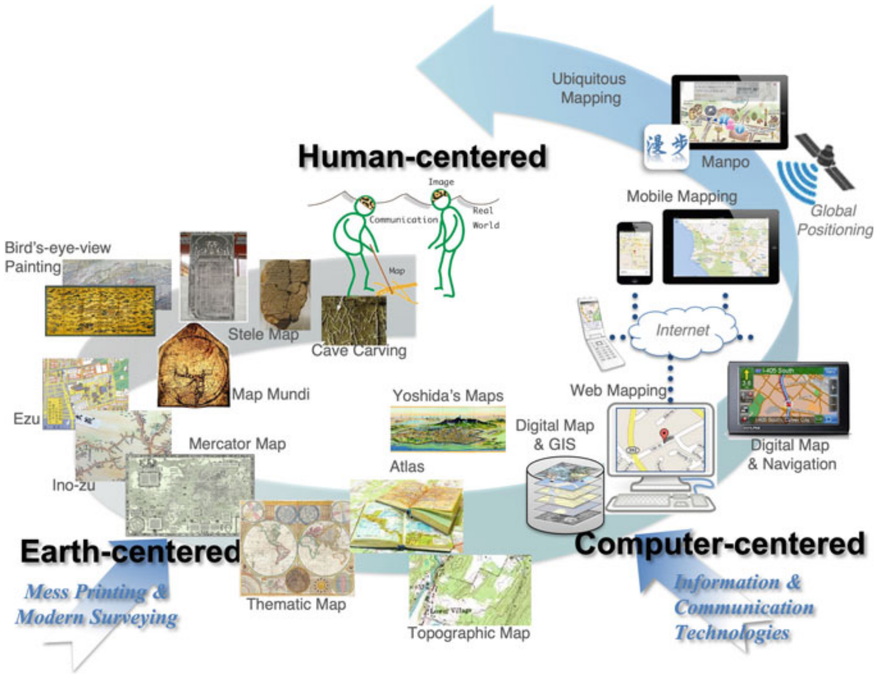

Fig. 1 Evolution in the appearance, media applications, and functions of maps with respect to the impacts of new theories and technologies

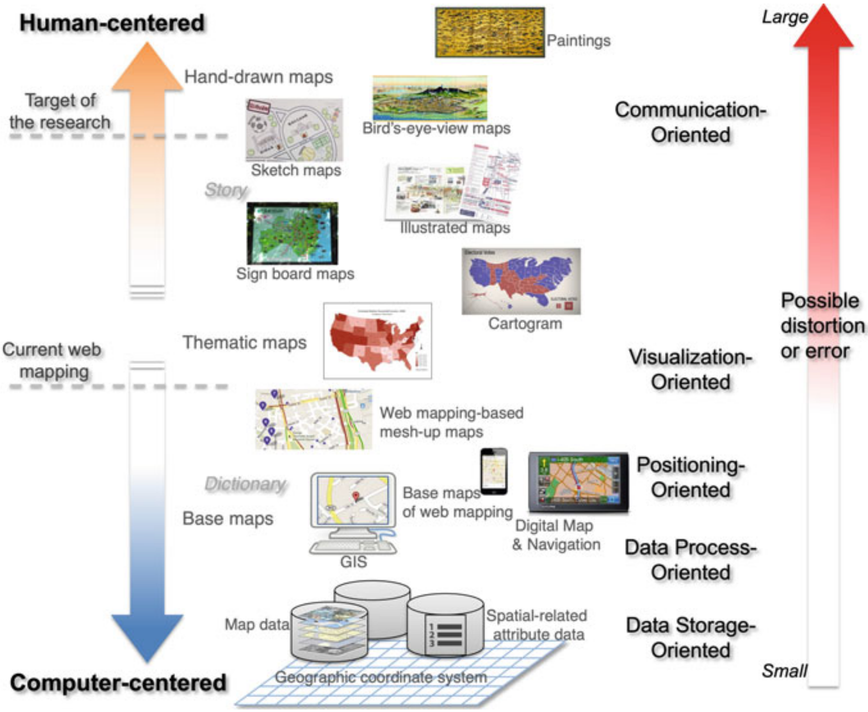

Fig. 2 Hierarchy from computer-centered maps to human-centered maps

more communication-oriented, but they are still deficient in terms of current mobile mapping.

In our study, a survey was distributed to young users of mobile mapping, with the results revealing that current web mapping does not take the place of conventional printed maps when used for specific purposes, such as sightseeing (Lu and Arikawa 2015). This further indicates that well-designed, conventional maps made by humans are preferred when such maps permit the integration of the advantages of mobile devices, especially GPS positioning. Examples of existing mobile applications that use maps other than web mapping have been investigated, and their limitations have been highlighted.

3 Maps and Storytelling

Before computers and Geographic Information Systems (GIS) came into being, maps were static. They told stories through static map images, illustrated figures, and texts, and they had to present all information, including map symbols, titles, legends, illustrations, and texts, at the same time. The tradition of integrating cartographers' stories (knowledge, notions, beliefs, etc.) with maps has existed since ancient times, when maps had additional functions beyond presenting visual representations of the real world. These functions included promoting worldviews, religious beliefs, and royal authority against the backdrop of culture-specific aesthetics and norms. In such maps, inconsistent scales, projections, symbols, etc., that were created with intentions, can often be found. Some may argue that such inconsistency was caused simply by undeveloped survey technologies. In fact, in the modern age, numerous examples of story maps simultaneously occurring alongside well-surveyed maps can still be found. However, as mapmaking is a professional activity, it is usually very difficult for ordinary users to create map-based storytelling on their own.

The development of web mapping and mobile mapping services has changed this situation, as these technologies provide accurate and detailed global base maps and data with interactive and customizable functions. Storytellers can, for instance, link story events to their relevant locations on the base map. They can also illustrate their stories with different maps, each showing locations and areas related to story events. This makes map-based storytelling much more convenient, as there is no need to create the base maps. At the same time, location-aware devices with mapping services make it possible to easily generate location-related content and intuitively browse map-based stories based on the user's current location. At present, one of the simplest ways to share a story is to tweet a location (Papacharissi and Oliveira 2012).

However, as current web-mapping services typically generate maps from the latest data for multiple purposes, they are often not the best choice for telling a story comprising specific backgrounds, topics, times, and places. For example, using only modern maps as the background for a historical story would likely overlook the circumstances in which the story events occurred. Also, the projections, map symbols, and generalizations of a web-mapping service are determined solely by the service, which means these features cannot be modified according to story specifics. Likewise, the aesthetic designs of map representations cannot be chosen by the storytellers according to the story topics, as multipurpose-oriented web mapping tends to use universal designs. In contrast, in the analog world, a wide range of map designs can be found. These highly contextual and purpose-specific map designs are quite suitable for stories that share the same context. For example, when tourists want to tell stories about their trips, tourist maps of the places they visited can be very suitable base maps.

4 Local and Dynamic Georeferencing for Analog Maps with Inconsistencies

Map-based storytelling in real places can be a good experience, as it can evoke intuitive feelings about the places among users, who can then compare the maps and the associated stories with their current realities. When using analog maps, however, the experience can be limited by the relative ability of users to read maps as well as by variations in spatial cognition. One practical way to assist users in overcoming difficulties with locating their positions on analog maps and connecting the maps with the real world is to directly apply the benefits of the latest multimedia and location-aware platforms. For this purpose, the application of georeferencing to analog maps is a promising approach.

Analog maps, such as hand-drawn maps, illustrated maps, and bird's-eye-view maps, often contain irregular deformations and geometric and semantic inconsistencies. Examples of geometric inconsistencies include inconsistent map projections, scales, and directions, whereas semantic inconsistencies include different depictions of objects of the same type and size. Such inconsistencies are the result of multiple factors, such as selective depictions of objects and exaggerations or simplifications of different regions. When a mapmaker is trying to achieve functionality, aesthetics, and effective storytelling in a map, accuracy and consistency are often compromised. However, without addressing inconsistency, mapmakers cannot directly incorporate location-based services (LBS) or location-aware devices into their maps.

Appending additional georeference data to analog maps and adjusting the maps to certain projections are common methods for aligning old, often inaccurate maps and sketch maps with far more accurate modern web mapping (Fleet et al. 2012). However, doing so can sometimes distort the original maps and destroy their original designs, even rendering them unreadable after corrections. As map design and representation are salient aspects of map-based storytelling, georeferencing methods that do not change the appearance of maps are required.

For this purpose, the present research proposes the application of local and dynamic georeferencing to accurately map geographic information (e.g., user location information obtained from a mobile device) onto the graphic space of analog maps without changing—or damaging—their appearance. The primary methodology in this regard is to dynamically search nearby georeferences and use them to make local corrections. Such corrections are not processed onto the map image but instead onto the inputted geographic information (e.g., the user's current location). This research used experimentation to realize the following local and dynamic georeferencing method.

Three-point-based georeferencing is a georeferencing method based on control points, which are pairs of corresponding coordinates on the geographic coordinate system (e.g., in latitude and longitude) and the graphic coordinate system of a map image (e.g., in x and y). The deployment of the control points over the maps does not require the control points to be evenly distributed, but they should sufficiently cover the area that the map users intend to visit. The points of interest (POIs) on the map can be utilized as natural control points. Additionally, places and objects that can be clearly confirmed on the map image and geographic information source (e.g., web mapping) can be chosen as control points. For example, road intersections and corners are suitable control points. The control points are preprocessed to form a triangulated irregular network (TIN). Consider a triangle Eq. (1) on the graphic coordinate system ($G_{a_i}\left(lon_{a_i}, lat_{a_i}\right)$ means the coordinates of a vertex in *longitude* and *latitude*) and its corresponding triangle Eq. (2) on the geographic coordinate system ($P_{a_i}\left(x_{a_i}, y_{a_i}\right)$ means the coordinates of a vertex in x and y):

$$TG_i = \left(G_{a_i}\left(lon_{a_i}, lat_{a_i}\right), G_{b_i}\left(lon_{b_i}, lat_{b_i}\right), G_{c_i}\left(lon_{c_i}, lat_{c_i}\right)\right) \tag{1}$$

$$TP_i = \left(P_{a_i}\left(x_{a_i}, y_{a_i}\right), P_{b_i}\left(x_{b_i}, y_{b_i}\right), P_{c_i}\left(x_{c_i}, y_{c_i}\right)\right) \tag{2}$$

$$f_{v_i} = \begin{cases} x_{v_i} = m_{1i} \cdot lon_{v_i} + m_{2i} \cdot lat_{v_i} + m_{3i} \\ y_{v_i} = m_{4i} \cdot lon_{v_i} + m_{5i} \cdot lat_{v_i} + m_{6i} \end{cases}, v_i \in \{a_i, b_i, c_i\} \tag{3}$$

$$\begin{cases} m_{1i} = \frac{(x_{c_i}-x_{a_i})-m_{2i}(lat_{c_i}-lat_{a_i})}{lon_{c_i}-lon_{a_i}}, lon_{c_i} \neq lon_{a_i} \\ or: m_{1i} = \frac{(x_{b_i}-x_{a_i})-m_{2i}(lat_{b_i}-lat_{a_i})}{lon_{b_i}-lon_{a_i}}, lon_{b_i} \neq lon_{a_i} \\ m_{2i} = \frac{(x_{b_i}-x_{a_i})(lon_{c_i}-lon_{a_i})-(x_{c_i}-x_{a_i})(lon_{b_i}-lon_{a_i})}{(lat_{b_i}-lat_{a_i})(lon_{c_i}-lon_{a_i})-(lat_{c_i}-lat_{a_i})(lon_{b_i}-lon_{a_i})} \\ m_{3i} = x_{a_i} - m_{1i} \cdot lon_{a_i} - m_{2i} \cdot lat_{a_i} \\ m_{4i} = \frac{(y_{c_i}-y_{a_i})-m_{5i}(lat_{c_i}-lat_{a_i})}{lon_{c_i}-lon_{a_i}}, lon_{c_i} \neq lon_{a_i} \\ or: m_{4i} = \frac{(y_{b_i}-y_{a_i})-m_{5i}(lat_{b_i}-lat_{a_i})}{lon_{b_i}-lon_{a_i}}, lon_{b_i} \neq lon_{a_i} \\ m_{5i} = \frac{(y_{b_i}-y_{a_i})(lon_{c_i}-lon_{a_i})-(y_{c_i}-y_{a_i})(lon_{b_i}-lon_{a_i})}{(lat_{b_i}-lat_{a_i})(lon_{c_i}-lon_{a_i})-(lat_{c_i}-lat_{a_i})(lon_{b_i}-lon_{a_i})} \\ m_{6i} = y_{a_i} - m_{4i} \cdot lon_{a_i} - m_{5i} \cdot lat_{a_i} \end{cases} \tag{4}$$

TP_i is transformed from TG_i through *affine transformation* Eq. (3). Therefore, each pair of triangles can drive a group of six parameters Eq. (4) for the transformation.

As shown in Fig. 3, for mapping a geographic location onto a map image, this method will first search for the triangle that contains the location on the geographic coordinate system; when there is no such triangle, then the closest one is chosen. Hence, the affine transformation parameters of this triangle are used to calculate the corresponding graphic coordinates of the location onto the map image with Eq. (3).

Limitations in current story map applications include external sources, such as the deficient functions of human-centered mapmaking tools, as well as internal defects of human-centered maps, especially positioning difficulties due to immeasurable distortions. From both the author's and the user's viewpoints, this research studied use cases to clarify the requirements of the proposed approach. A human-centered mobile mapping framework, including both authoring tools and user applications, has been proposed (as shown in Fig. 4). The framework is designed to import conventional human-centered maps to mobile devices, after which the maps can be converted into interactive and geo-enabled mobile maps by integrating geo-metadata and multimedia content with originally static maps. Geo-metadata are designed to be the key to geo-enabling the printed human-centered maps. The concept model of geo-metadata is introduced in detail in the next section, which includes the model's graphic components and their associated georeference patterns. Frequently used geo-events and geo-interactions are also enumerated and discussed.

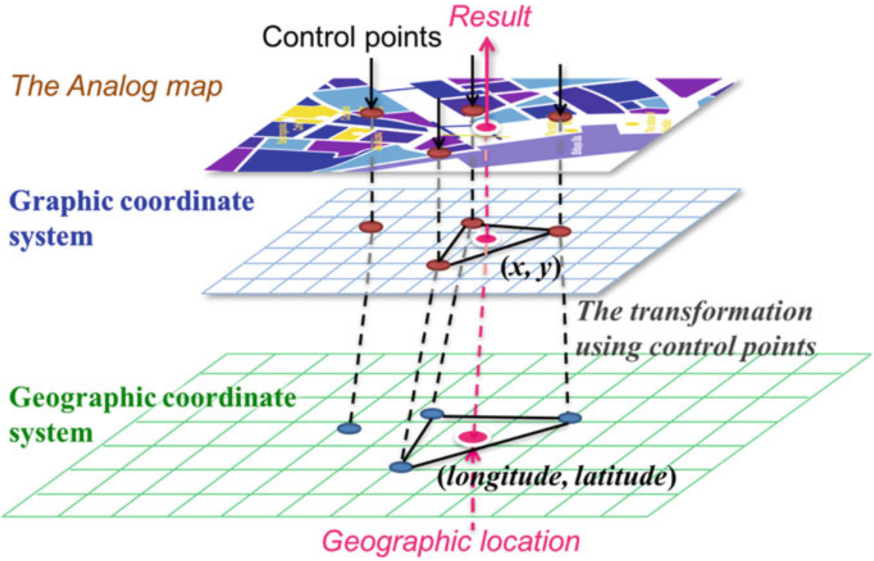

Fig. 3 Process for mapping a geographic location onto an analog map image with triangle-based affine transform

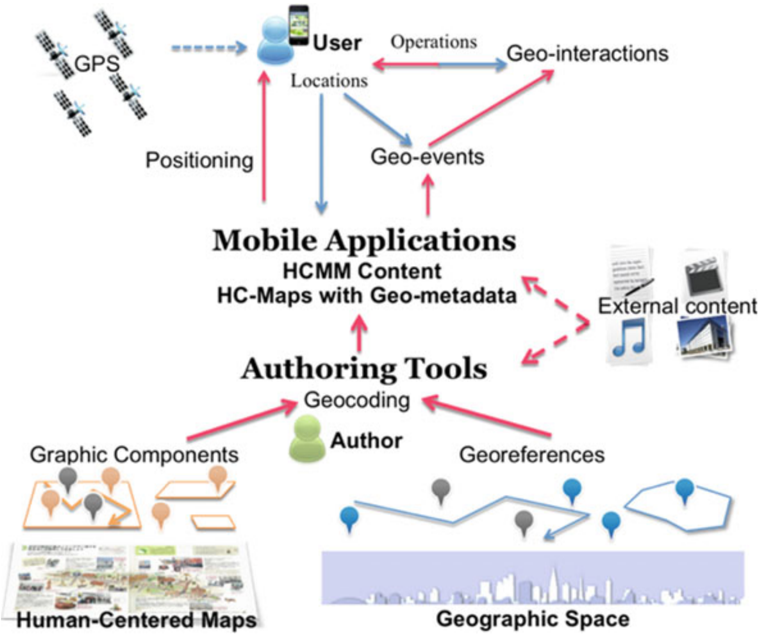

Fig. 4 Structure of the framework of the human-centered mobile mapping (HCMM) platform

5 Data Format for Sharing Analog Map-Based Storytelling Content

For describing, storing, and distributing map-based storytelling content via georeferences, a suitable data format is required. Apart from the descriptions of the geographic features, which can be the same as the existing GIS data standards, the data format should also include definitions of the graphic features in the analog map images, the georeferences, and the multimedia resources linked to the maps for storytelling. To match the context of geospatial data infrastructures and existing GIS tools and services, this research proposes the ManpoJSON format, which is based on an extension of GeoJSON (Butler et al. 2016). Manpo (漫歩), our original software, is a smartphone application for creating and experiencing location-based walking tours. Figure 5 shows the basic structure of a ManpoJSON object.

- **Features**: The geometric description of a feature in a map image for map-based storytelling consists of two corresponding components: a geographic description and a graphic description. As GeoJSON has already defined the format of geographic features, like points, lines, and polygons, ManpoJSON inherited the GeoJSON format for the geographic description. At the same time, ManpoJSON extends the format for the graphic description by adding definitions of the corresponding graphic coordinates of the features in a map image. In corresponding to the key geometry for providing a geographic definition of a feature in GeoJSON, ManpoJSON adds a key reference to define the feature in the map image. A reference needs to contain the following keys and values:
  - **type**: This key is usually the same as the type defined in the geometry, which is typically Point, LineString or Polygon.
  - **coordinates**: The value contains an array of graphic coordinates that describe the shape of the feature in the analog map image.
- **Georeferences**: Although the features in a map image can act as georeferences as they have corresponding geographic and graphic definitions, the map often needs additional georeferences to refine the results of mapping. ManpoJSON adds a key georeference, which contains keys and values:
  - **type:** As the georeference contains multiple points and lines, its type should be FeatureCollection.
  - **features**: The georeference usually contains one or two features, namely control points and/or polylines. Each feature should have the following keys and values:
    - *type*: The type should be Feature.
    - *geometry*: The value for type should be MultiPoints or MultiLineString; the value for coordinates is the array of geographic coordinates of the control points or polylines, using the same GeoJSON format.

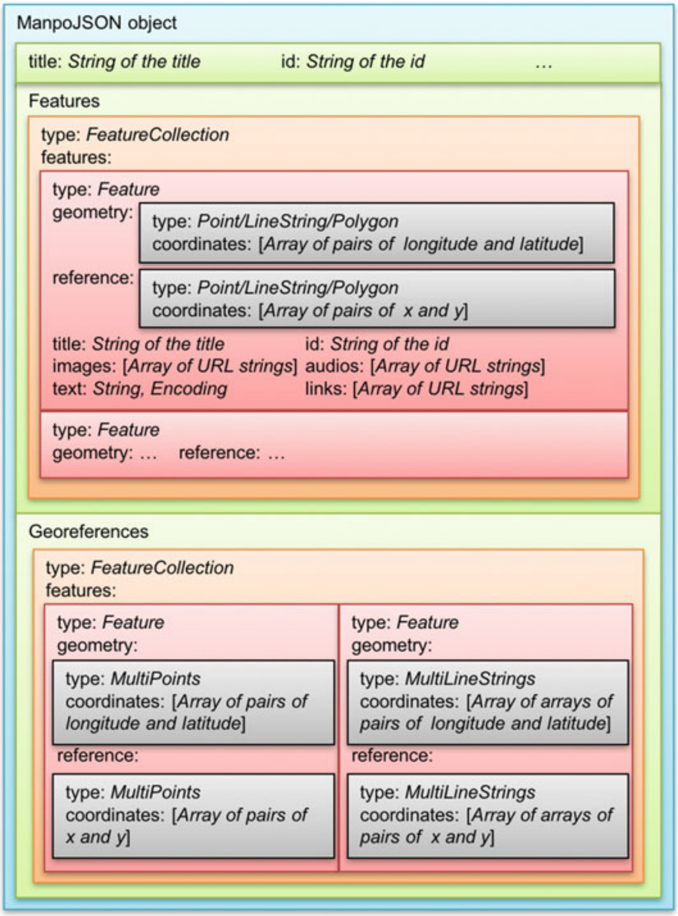

Fig. 5 Structure of a ManpoJSON object

– *reference*: This is defined by ManpoJSON. The value for type should be MultiPoints or MultiLineString, the same as in the geometry. The value for coordinates is the array of image coordinates of the control points or polylines, which should be in the same order, i.e., correspond to, the array in geometry.

- **Foreign Members for Storytelling**: As GeoJSON mainly defines the geospatial data, foreign members are needed to describe the multimedia resources linked to the features on the map images for storytelling.

  - **title**: This key can be a member of a feature or feature collection that has a string value of the title for the feature or feature collection.

- **id**: This key can be a member of a feature or feature collection with a value of the number. The id can be used for setting the order of features for storytelling.
- **images**: It can be a member of a feature, which contains an array of images, which have the key image, which contains a necessary member URL, whose value is a web URL or a file path.
- **audios**: It can be a member of a feature, which contains an array of audio resources, which have the key audio, which contains a necessary member URL, whose value is a web URL or a file path.
- **text**: It can be a member of a feature, which contains the following members:
  - *type*: The value can be a string or URL.
  - *value*: The value can be a string for the URL of the text file, or a string as the content.
  - *encoding*: The value can be a string that indicates the encoding of the text, such as ASCII and UTF8.
- **links**: It can be a member of a feature or feature collection, which contains an array of strings, which are web URLs.

6 Prototype Development

To realize the proposed approach of analog map-based storytelling with local and dynamic georeferencing, prototypes were developed, including editing tools for creating storytelling content and mobile applications for appreciating the content in real places. This research succeeded in developing and applying the following prototype for the purpose of evaluating the method in different application scenarios.

Manpo is an iOS application originally designed for location-based digital guides of walking tours with multimedia storytelling based on analog maps. Manpo makes use of analog walking-tour maps, such as the paper tourist maps provided by local tourism organizations and hand-drawn maps created by designers, in the digital mobile environment by enhancing the maps with georeferencing and multimedia interactions (Lu and Arikawa 2014). Figure 6 shows the main interface for viewing the georeferenced and multimedia-enhanced analog maps. When using the application in the places covered by the map, users can view their current locations on the analog map image. Their moving trajectories are recorded when they are moving, which will be shown on the map image as well. The users can view the content embedded on the maps by interacting with their content. For example, by clicking the POIs on the map image, a view with detailed information, including photos, text, and audio, will be shown to the users, as shown in Fig. 7. Lines with arrows show the recommended walking routes, in which audio guidance or narrations are embedded to be listened to along the way. The storytelling content can interact with the user's location. For example, when the user is nearing a POI or the start point of a line with audio, its icon will begin blinking. The recorded user trajectories and actions can be played back as a memorial of the trip.

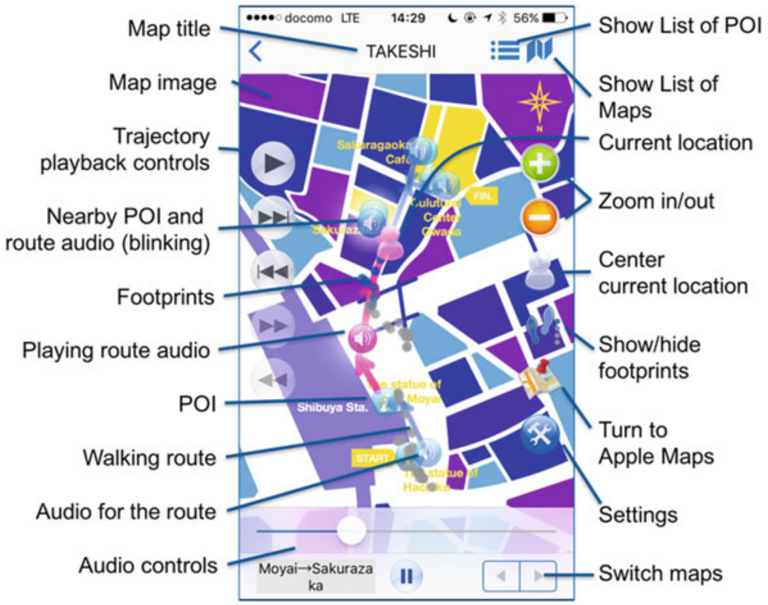

Fig. 6 User interface of *Manpo* for viewing georeferenced and multimedia-enhanced analog maps

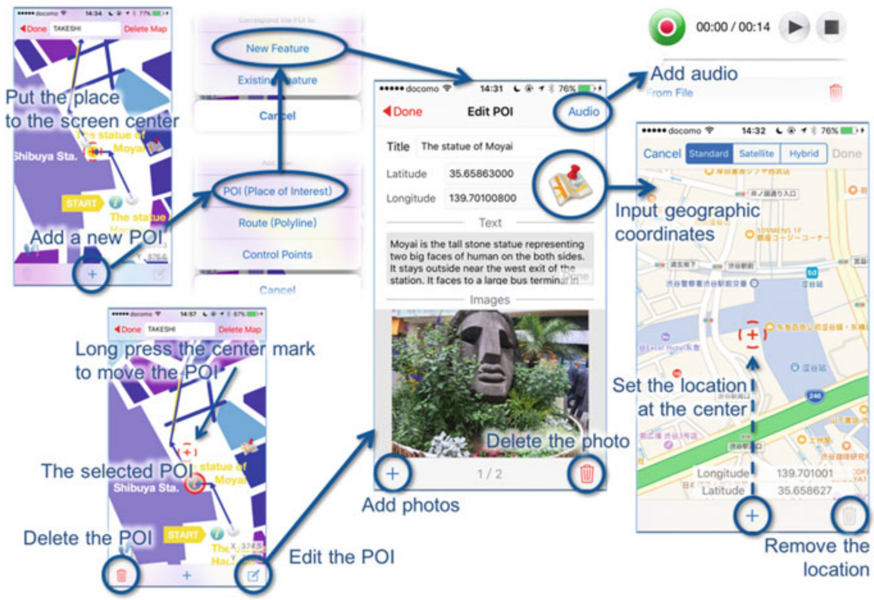

Fig. 7 User interfaces and procedures for creating a POI on the analog map image with text information, photos, and an audio clip using Manpo

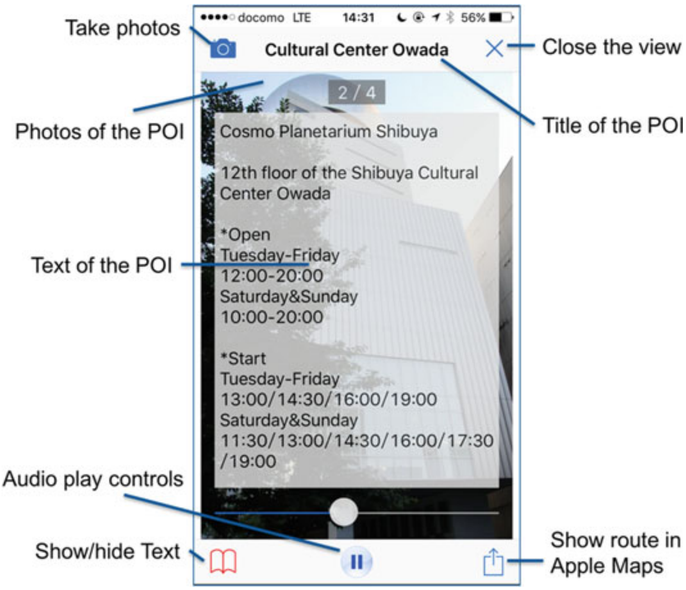

Fig. 8 The user interface for viewing the text, photos and playing the audio of a POI in Manpo

Manpo includes a tool for importing map images onto mobile devices and for inputting POIs, route lines, and control points onto the images. Storytelling content, such as images, text, and audio, can be bound to the points and routes. Figure 8 shows the user interfaces and procedures for creating a POI with text information, photos, and an audio clip. The way in which graphic coordinates are inputted is by simply pinning the correct position of the image on the center of the device screen. For inputting the geographic coordinates, Manpo provides an interface to pin the point on commercial web mapping (Apple Maps is used in Fig. 8). Manpo mainly applies *point-based georeferencing*. An interface of two split views showing the analog map image and the web mapping at the same time was developed for inputting the control points, as shown in Fig. 9. The user only needs to pan and zoom the maps, pin the corresponding points at the center of both views, and then tap the add button, after which the coordinates will be picked up and recorded by the application.

Manpo has been used by university students to create hand-drawn maps of areas near their campus in order to introduce others to local POIs and stories (Lu and Arikawa 2015). The students recorded audio guides about and took photos of the POIs and then organized them on their hand-drawn maps. Their outstanding work was then incorporated into an iOS application and published in the App Store. The Manpo approach is also used to develop mobile applications for university campuses and local tourism organizations, as explained in detail in the next section.

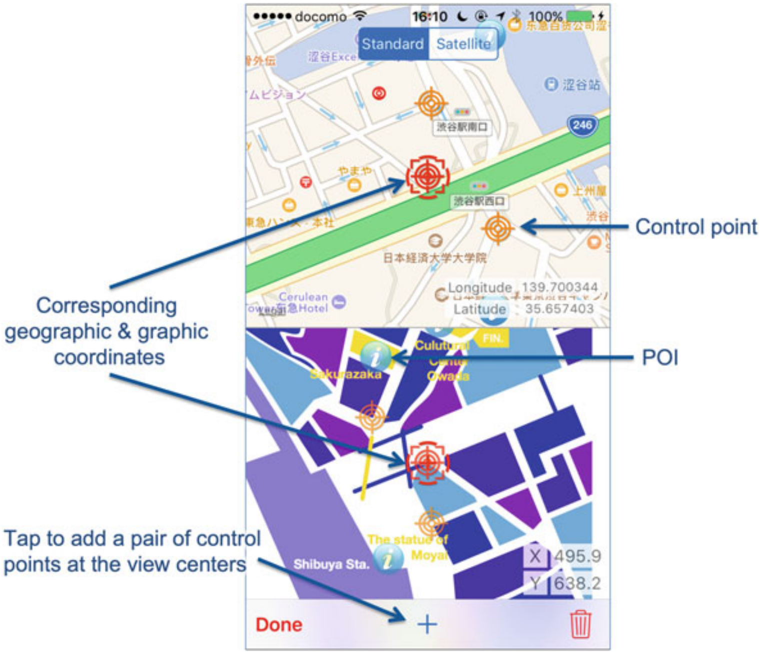

Fig. 9 User interface of Manpo for inputting the geographic coordinates and graphic coordinates of a control point from the maps

7 Experimental Applications

In cooperation with college students, university campuses, and local tourism organizations, experimental applications were developed to test the functionality and usability of the proposed mobile mapping application, as well as the feasibility of the proposed local tourist map ecosystem (Lu et al. 2018). Some of these applications have already been published for ordinary users. Two of the published applications are briefly introduced here.

7.1 Applications for Open Campus Events

Every October, from 2012 to 2017, an iOS application was introduced at a university's open campus events. The targeted users were participants at the open campus events, usually local residents and young students. The application was designed for the participants to freely move about the whole campus, visiting all of the institutes that were holding events or exhibitions, and being provided with brief introductions to the institutes and information about their events. The interfaces of this application are shown in Fig. 10.

(a) List of the stamps (POIs), showing their status and distances

(b) Displaying current location and trajectory on the campus map, with a POI invoked

(c) Main icons and buttons of the map view

(d) A checkpoint (POI) invoked by the current location, with a stamp to be obtained

(e) Event information of the POI during the open campus

Fig. 10 Application interfaces and instructions for open campus events: **a** list of the stamps (POIs), showing their status and distances; **b** display of current location and trajectory on the campus map, with a POI invoked; **c** main icons and buttons of the map view; **d** a checkpoint (POI) invoked by the current location, with a stamp to be obtained; **e** event information on the POIs during the open campus events. *Source* The maps and other image resources were provided by Kashiwa Campus, University of Tokyo

The application uses the official illustrated campus map, which was originally printed in leaflets and distributed to the participants. The institutes introduced in the leaflets were converted into POIs in the application. These POIs were also designed as checkpoints for a stamp rally activity. When the participants were close to a checkpoint (POI), they would be alerted by a blinking button in the map view, which would guide them to information about the POI, and a stamp could then be obtained by tapping the screen. When the participants viewed the map and its content, their location (longitude and latitude data from the smartphone) was recorded every 10 s; and when they obtained a stamp or took a photo, an additional location was recorded. Participants were encouraged to donate their trajectory data for research after finishing the stamp rally.

Analyses were conducted on the donated data, the results of which are shown in Figs. 11 and 12. In these figures, the official campus map is the one used in the mobile application, although it was processed to a much lower contrast in order to display the analysis results. In Fig. 11, which shows all of the donated movement trajectories in 2015 and 2016, we can see that the users tended to visit the western part of the campus (left part of the map) first, and then the eastern part. It seems that some users tended to follow the order of the POI numbers, but this is likely because the bus stop and general information center for the open campus events were closer to the western part. From these trajectories, heat maps presenting popular places on the campus, as shown in Fig. 12, were generated by setting a buffer range (20 m) to each location of a trajectory and then counting the number of different users in each pixel of the map. In the heat maps, the row of buildings at the center of the campus map was visited by most of the users, while buildings in the northern part, as well as gardens with woods and ponds in the southern part, were less visited.

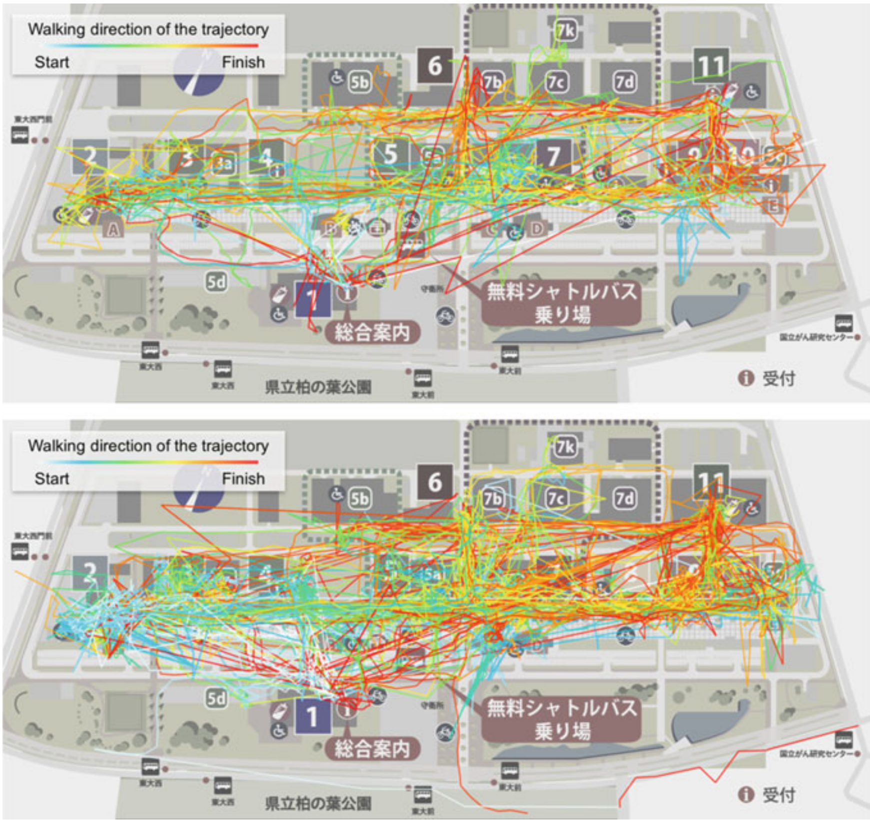

Fig. 11 Movement trajectories donated by the users of the application in the open campus events of 2015 (top) and 2016 (bottom). *Source* The map was provided by Kashiwa Campus, University of Tokyo

7.2 Applications for a Local Tourism Association

In 2015, the authors proposed solutions for utilizing existing paper-based tourist maps for mobile tourism applications to a tourism association in a district of Tokyo, Japan, and has been collaborating with this association ever since. The district includes many famous sightseeing spots, like gardens and temples. However, these spots are mostly known only to locals, with foreign visitors being rare. Therefore, there has been strong demand to improve awareness about these sightseeing spots, as well as knowledge about other places that tourists might be interested in. There have also been calls to improve the district's services and facilities. Toward this end, the district has already created free map leaflets, comprising base maps and data sources for the mobile application, in different foreign languages.

Via joint research, an iOS application was developed and published in Apple Inc.'s App Store. The application contains the English versions of three tourist maps: one

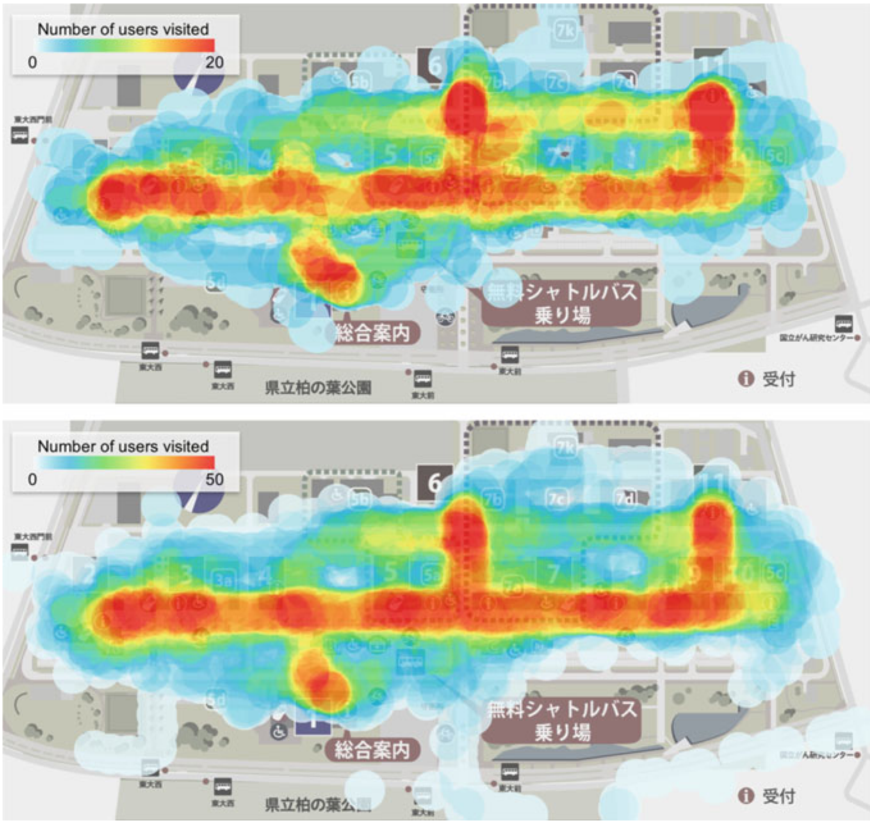

Fig. 12 Heat maps of popular places during the open campus events of 2015 (top) and 2016 (bottom), generated from the data in Fig. 11. *Source* The map was provided by Kashiwa Campus, University of Tokyo

tourist map of the whole district, and two maps of two famous gardens in the district. All three maps, which were originally printed on free leaflets, were georeferenced and attached with POI information originally printed on the leaflets. Apart from the functions of browsing the maps and obtaining POI information with positioning functions, comments, personal memos, and feedback with photos were also incorporated into the maps. Users can donate their comments, feedback, photos, and movement trajectories to the tourism association via a simple questionnaire accessible in the application.

Experiments involving the application were conducted in Tokyo with 12 international students, who were asked to take a walking tour independently with the application and to make comments with photos at any place and time they preferred. The movement trajectories and comment bubbles created by the participants are shown in Fig. 13. The results cannot be considered comprehensive because of the small number of users, and they may additionally have been biased as all of the

Fig. 13 Interfaces of the application for a local tourism association with user-generated comments and trajectories displayed (three on the top) and examples of user comments with photos (two on the bottom). *Source* The map was provided by the Bunkyo City Tourism Association, Tokyo, Japan

participants were young college students. However, the results have already made positive contributions—for example, the comments show that some historical places were interesting to foreigners but lacked information in foreign languages. In other example, the trajectory of one participant, who was near a garden, shows that he/she had been confused and took additional time to enter the garden, as the entrances were not clearly indicated on the map. Based on this feedback, the tourism association resolved the issue in the latest version of the map (2016–2018).

8 Conclusions

Map-based storytelling requires base maps with related backgrounds and context. Although current web mapping has the great advantages of ubiquity and convenience, the latest map data and multipurpose map representations are not always suitable for the topics and backgrounds of the stories. By introducing local and dynamic georeferencing, conventional paper-based maps can be utilized in location-aware mobile environments. Novel editing tools with a data format extended from a popular GIS data standard make it possible for mapmakers, designers, and even ordinary users to easily create storytelling content by attaching multimedia resources to georeferenced map images. Prototypes developed in this research have been tested and applied in cooperation with local communities, governments, and university students, and the map-based storytelling content created by them has been published as smartphone applications. These results have thus demonstrated the feasibility of the proposed approach.

In future work, the proposed georeferencing methods will be compared and refined to achieve better accuracy and stability. The characteristics of different georeferencing methods must be analyzed in order to determine the suitable map types of the different methods. On the other hand, input from the control points gathered by the prototype applications also introduced errors into the final georeferencing results. Therefore, better user interfaces and workflows for inputting georeferences must be designed. Furthermore, automatic or semi-automatic detection of suitable georeferences from analog maps using technologies such as image recognition and machine learning must be considered for longer-term development.

Currently, this research has focused on methodologies and prototypes for analog map-based content creation; thus, tools and applications were developed mainly for standalone use. In the next stage, this research will focus on constructing a platform for sharing the map-based storytelling content, one in which the effectiveness of the proposed data exchange format, ManpoJSON, will be tested and refined. This platform will be used for sharing created content, resources, and knowledge for creating the content, which may include maps, georeference data, georeferencing techniques, user data and feedback, and all kinds of multimedia resources. Finally, this research aims to establish a new mapmaking ecosystem and enhance local knowledge sharing, involving both ordinary users and specialists of different areas.

Acknowledgements We are very grateful to Bunkyo City Tourism Association in Tokyo, Japan; Okabe Lab at Aoyama Gakuin University, Tokyo, Japan; Kashiwa Campus of the University of Tokyo; and all other collaborators for their maps, documents, and cooperation in the development of the prototypes.

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Developing and Evaluating *Virtual Heiankyō AR*

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Abstract GIS and geographic information science (GISc) have advanced at breakneck speed in the past 20 years evidenced by the growing popularity of 3D GIS maps. There is also growing interest in the construction of 3D urban models that can be integrated with virtual reality (VR) and augmented reality (AR) technologies and applied in many sectors, including tourism. Using *Virtual Heiankyō* as a basis, an app we previously developed as part of the Virtual Kyoto project, we developed a new and unique VR and AR-driven smartphone app called *Virtual Heiankyō AR*. This app recreates the historic cityscape of Heian-kyō. We explore the app's potential and user sentiment towards *Virtual Heian-kyo AR* by analysing app performance metrics, online articles, and social media commentary. We consider how the app differs from existing maps, the new value it potentially offers, and the issues to be addressed. The results suggest that the app could serve as a tool for VR and AR maps and a new type of mapping technology with novel application of VR and AR. This technology could be applied to evaluate maps or generate cartographic, geospatial data. We consider that this combination of mapping technologies could be applied to many industries, such as tourism and urban planning.

Keywords Geographical information systems (GIS) · Virtual reality (VR) · Augmented reality (AR) · Kyoto

1 Introduction

Since the revolution in geographic information systems (GIS) that occurred in the late 1980s, GIS and geographic information science (GISc) have advanced at breakneck speed, making it easier to construct 3D GIS maps. There is now growing interest in the construction of 3D urban models that represent buildings and other urban

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objects on a 3D scale (Yano and Yoshitomi 2020). Three-dimensional urban models are popular tools used in many sectors and, in a number of cases, they are integrated with virtual reality (VR) and augmented reality (AR) technologies. For example, in the urban design sector, VR and AR technologies depict urban landscapes (Steinitz 2012) while, in the tourism sector, AR has been used to show how historic urban landscapes appeared at a certain point in time (Kurata 2016).

In 2002, the Art Research Centre of Ritsumeikan University launched Virtual Kyoto, a project to develop a 3D model of the historical urban landscape of Kyoto (Yano 2011). For this project, we constructed a 3D model showing how Kyoto would have appeared during the Heian period (794 to 1185), Edo (Tokugawa) period (1603 to 1867), and other historic periods, and provided this data under a software-as-a-service model to recreate historic cityscapes in 3D GIS maps. The model was created using *MapCube* (Takase et al. 2004). *MapCube* draws from residential map data and a digital surface model (DSM). The DSM uses light detection and ranging (LIDAR) techniques to represent the earth's surface, all buildings and all objects. The Virtual Kyoto project led to the development of *Virtual Heiankyō*, a 1:1000 scale 3D diorama of Heian-kyō, the name of Kyoto, when the city served as the imperial capital during the Heian period (Kawasumi 2011; Kinda 2011).

In the present study, we use *Virtual Heiankyō* as a basis for developing a VR and AR-driven app that recreates Heian-kyō's historic cityscape. We then analyse user sentiment towards this app.

2 Developing *Virtual Heiankyō AR*

In this study, we develop *Virtual Heiankyō AR*, a smartphone app (Android, iOS) that uses VR and AR technologies to recreate the historic cityscape of Heian-kyō. The app builds upon *Virtual Heiankyō*, which we had previously developed as part of the Virtual Kyoto project and which developed spatiotemporal data for the purpose of recreating Kyoto's present and historic cityscapes (Fig. 1). In developing *Virtual Heiankyō AR*, we used the same 3D urban modelling technology that underlies the

Fig. 1 Virtual Heiankyō

Fig. 2 Dai Dairi AR

Virtual Kyoto project and used a global positioning system (GPS). The app has three main components.

Dai Dairi AR Dai Dairi AR is a smartphone-based AR system that recreates the historic structures of the Greater Palace (*Dai Dairi*). Measuring 1.4 km north–south by 1.2 km east–west, the Greater Palace was a section of the city where the Emperor resided. When users visit the site where the Greater Palace once stood, they can hold up their smartphone, and the AR system overlays the historic buildings in the relevant places. We used GPS data to pinpoint the location of the Greater Palace and used AR technology to superimpose the models of the buildings and mountainous backdrops as they would have appeared at the time (Fig. 2). The Greater Palace data is composed of 704 3D models, 1,830,000 polygons, and 1,185 textures. Because the polygon count was high, we reduced and baked the textures.

Suzaku Oji VR Suzaku Oji VR provides 360-degree panoramas of historic views at eight points along Suzaku Avenue (Suzaku Ōji). Measuring 82 m in width, Suzaku Avenue was the central north–south road in Heian-kyō's grid-patterned layout. It extended approximately 4 km from Rajōmon, the main gate at the southern edge of the city grid, to Suzakumon, the main gate of the Imperial Palace. The app renders *Virtual Heiankyō* with 3D models of mountainous backdrops (Fig. 3).

Rajōmon VR Rajōmon provides a 360-degree panorama of Heian-kyō, as seen from Rajōmon. The display is triggered by an AR marker on a plaque attached to a 1:10 scale model of Rajōmon, which stands outside the Karasuma exit of JR Kyoto Station. To create the panorama, we displayed a VR-compatible version of the 3D cityscape model developed as part of the Virtual Kyoto project, extracted a 360-degree panorama from Rajōmon facing northwards along Suzaku Avenue, and then rendered the 3D view by setting the resolution and lighting. Without reducing the textures, we modelled the mountainous backdrop. Specifically, we modelled Kitayama, Nishiyama, and Higashiyama—the three mountains that surround the Kyoto (or Yamashiro) Basin on its northern, western, and eastern sides (Fig. 4).

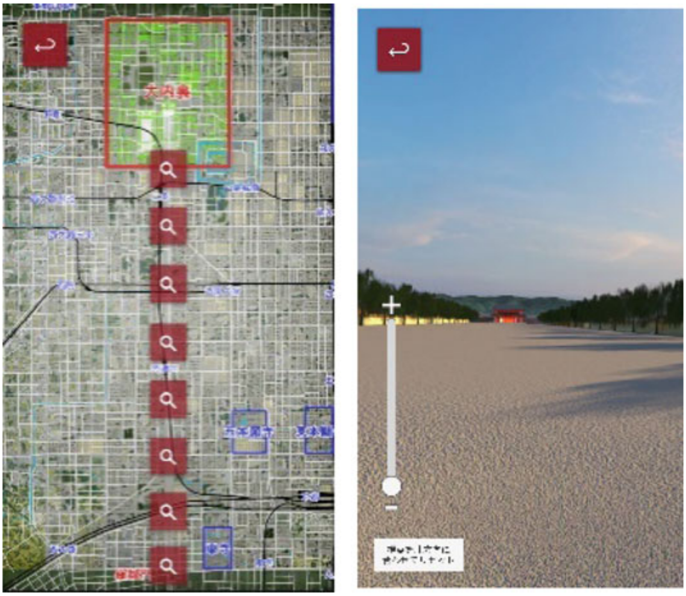

Fig. 3 Suzaku Oji VR

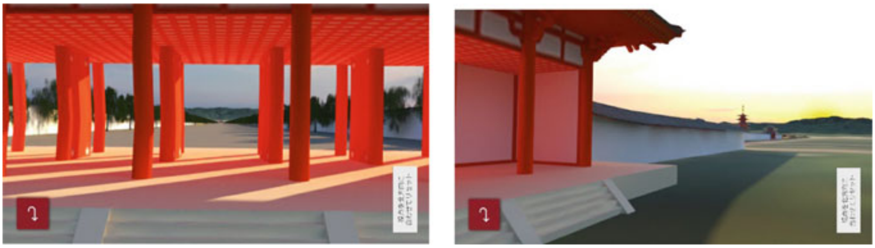

Fig. 4 Rajōmon VR

3 App Performance Metrics

We analysed user interactions with *Virtual Heiankyō AR* quantitatively and qualitatively. For the quantitative analysis, we measured the number of app downloads and installs to identify the level of user interactions and the app's social media impact. For the qualitative analysis, we collected online articles about the app as well as the social media commentary accompanying these articles. We used this content to analyse user sentiment towards the app. From the results, we surmised that the app could serve as a tool for VR and AR maps. On this assumption and based on the results of the analyses, we considered how the app differs from existing maps, the new value that the app potentially offers, and the issues that need to be addressed.

An Android version of *Virtual Heiankyō AR* was released in June 2018, and an iOS version was released in August of the same year. Using Google Play for the Android version and Apple Console for the iOS, we tracked downloads and user interactions for both versions on the developer's account. In this section, we present the results of our data analysis.

3.1 Downloads and Installs

Table 1 shows the app downloads and installs (the number of people who installed the app and did not uninstall it) for both versions between the release date and the end of January 2019. The app (either version) was downloaded a total of 1,280 times. In almost 60% of cases, the app was uninstalled, leaving 531 cases where the app was retained throughout the evaluation period. The iOS version was downloaded more frequently. During the evaluation period, the iOS version was downloaded an average of 3.8 times per day, whereas the Android version was downloaded an average of 2.4 times per day.

Figure 5 shows the download trends from the release date to the end of January 2019. We plotted the downloads for both versions on the same graph, which revealed that the daily download rates, rather than rising evenly and continuously, spiked on certain days. As these spikes in the graph indicate, the Android version attracted an immediate surge in downloads following its release on 4 June 2018. In contrast, downloads for the iOS version barely changed in the days following the 1 August 2018 release date.

The spikes in downloads overlap the dates of media coverage and press releases, as shown in Table 2. This finding underscores the effectiveness of the public relations (PR) campaigns for the app, which focused on print media and television broadcasts.

Table 1 Downloads and installs

	Downloads	Installs		Uninstalls		Period
Android	584	242	41.4%	342	58.6%	8 months
iOS	696	289	41.5%	407	58.5%	6 months
Total	1,280	531	41.5%	749	58.5%	

Because Google Play and Apple Console use different nomenclature, the metrics in Table 1 were defined as follows:
For the Android version, 'downloads' indicates the number of installs while 'installs' indicates the number of downloads less the number of uninstalls. For the iOS version, 'downloads' corresponds to 'app units' (as defined in subsection 3.2.1), and 'uninstalls' indicates the number of downloads less the number of 'installs'.

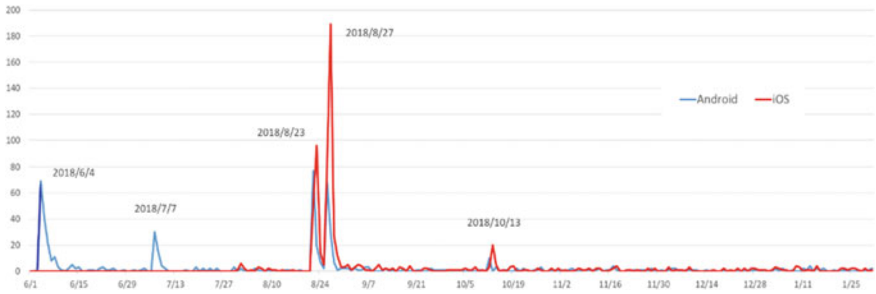

Fig. 5 Download trends (Android in blue, iOS in red)

3.2 Additional App Performance Metrics

For the iOS version, we tracked additional metrics other than downloads and installs. These other metrics were available on Apple's App Analytics (if the app had been payable, we could also have tracked metrics such as in-app purchases, paying users, and sales). These additional metrics were unavailable on the Google Play Console, so the analytics described below pertain to the iOS version only.

3.2.1 Metrics for User Interaction

Impressions Apple defines this metric as follows: 'The number of times your app was viewed in the App Store for more than one second. This includes search results, Featured, Explore, Top Charts, and App Product Page views' (https://developer.apple.com/app-store/measuring-app-performance/). An 'impression' occurs every time a user views the app, including when a user clicks on the app page in App Store, which is also called product page views (described next). During the evaluation period, there were 9,406 impressions at an average rate of 40 per day. Regarding impressions over time, impressions surged whenever there was media coverage. Even in periods with no media coverage, impressions trended upwards, either because the app was gaining popularity or because awareness of the app was steadily increasing.

Product Page Views 'Product page views' refers simply to the number of times the app was viewed in App Store. Apple defines this metric as follows: 'The number of times your app's App Store page has been viewed on a device using iOS 8 and tvOS 9 or later'. During the evaluation period, the app had 807 product page views at an average rate of three per day. As time elapsed from the release date, the number of product page views decreased. This trend mirrors that of impressions, but the absolute number of product page views suggests that few people viewed the app by linking to the product page.

App Units Apple defines this metric as follows: 'The number of first-time app purchases…made on the App Store using iOS 8 and tvOS 9 or later'. In this study,

Table 2 Media coverage and press release dates

Media coverage or press release date	App release	Media	
		Internet	Print media
4 June 2018	Android version*		
4 June 2018		IT media	
4 June 2018		Ritsumeikan Keitai Watch	
5 June 2018		MoguraVR Vsmedia SocialGameInfo	
6 June 2018		Newssalt	
9 June 2018		University journal online	
23 June 2018		XR-Hub	
6 July 2018		Dot Apps	
8 July 2018			Yomiuri Shimbun (Kurashi IT)
1 August 2018	iOS version		
23 August 2018			Kyoto Shimbun (front page of morning edition)
26 August, 2018		Kyoto Shimbun	
7 September 2018		Techable	
11 September 2018		Hotondo 0-yen Daigaku	
30 September 2018		XR-Hub (new version)	

* On this release date (4 June 2018), staff at Ritsumeikan University handed out promotional flyers for the 1:10 scale model of Rajōmon outside the Kyoto Station
For the Android version, there was significant media interest, primarily from the digital versions of newspapers and from prominent online news sites such as ITmedia, Keitai Watch, and Mogura VR. This media interest was generated in large part by a press release delivered by senior staff at Ritsumeikan University at the time of the app's release. In contrast, when the iOS version was released, Ritsumeikan University gave no official press release, and there was little media interest, which might explain the lack of an immediate surge in downloads

the metric is considered synonymous with the number of downloads. We did not count the downloads of updates or redownloads on the same Apple ID. During the evaluation period, there were 696 app units, which matches the number of downloads for the iOS version indicated in Table 1 and the download trends for the same version indicated in Fig. 5 (in red line).

App Installations Apple defines this metric as follows: 'The total number of times your app has been installed on an iOS device with iOS 8 and tvOS 9 or later. Redownloads on the same device, downloads to multiple devices sharing the same Apple ID, and family sharing installations are included'. In this study, the metric is considered synonymous with the number of active users, which is the number of downloads less the number of uninstalls. During the evaluation period, there were 289 app installations. The trend over time was similar to that of other metrics.

Sessions This is one metric that measures how frequently users interact with the app. Apple defines the metric as follows: 'The number of times the app has been used for at least two seconds'. During the evaluation period, there were 1,161 sessions. The trend over time differed slightly from that of impressions and downloads. Sessions clearly spiked in November and December, denoting that users who had already installed the app opened the app again during this period. Users may have done so because they were attending workshops or other events that used the app or because media coverage inspired them to do so. Although users can only access the app's AR content if they are physically present on the site that triggers such content, the app also includes a VR mode that has no such requirement. Thus, it is likely that the users used the VR mode repeatedly wherever they were.

Active Device Apple defines this metric as follows: '[Devices] with at least one session during a given period.' During the evaluation period, there were 629 active devices with an average of three sessions per day. Like sessions, active devices measure user interaction with the app. However, because this metric counts the number of devices rather than sessions, the trend over time was slightly different from that of sessions.

3.2.2 App Analytics By Source Type

In addition to offering the above app performance metrics, App Analytics breaks down this data by source type to identify the sources that result in downloads, impressions, product page views, and so on. Table 3 shows the breakdown by source for

Table 3 Metrics by source type

		App store search (%)	App referrers (%)	Web referrers (%)	App store browse (%)
Impressions	9,275	90.5	7.5	1.5	0.5
Product page views	800	68.8	17.6	8.0	5.6
App units	696	81.9	13.9	3.0	1.1
Installations	288	82.3	13.5	2.4	1.7
Sessions	1,158	86.4	8.6	2.4	2.6

the five performance metrics introduced in subsection 3.2.3. There are four types of sources:

App store search	Identifies how many downloads came from users who tapped App Store search for the first time
App referrers	Identifies how many product page views came from users who tapped links within other apps
Web Referrers	Identifies how many product page views came from users who tapped links within websites
App store browse	Identifies how many downloads came from users who tapped for the first time while browsing the App Store (such as its Featured or Top Charts sections)

Tables 3, 4, 5 and 6 show the source-specific results for impressions, product page views, app units, app installations, and sessions. We are particularly interested in app units and app installations as these represent downloads. Table 3 shows the results for the source type. Over 80% of downloads came from App Store searches, whereas few came from App Store browses. This finding implies that many downloads resulted from the person discovering the app on media other than the App Store and then searching for the app on the App Store. As Table 4 shows, of the downloads that came from App Store searches, most were from searches on the store's iPhone section. The clear majority of these downloads, over 80%, were performed on iPhones.

While users were most likely to have downloaded the app by searching App Store directly, the next most common source of downloads was app referrers—cases where the user accessed the app's product page on App Store from a link within another

Table 4 App store search: breakdown by section

		iPhone (%)	iPad (%)	iPod (%)	Apple TV (%)
Impressions	9,191	86.2	13.8	0.0	0.0
Product page views	795	94.0	6.0	0.0	0.0
App units	693	95.2	4.8	0.0	0.0
Installations	288	86.5	13.5	0.0	0.0
Sessions	1,139	86.5	13.5	0.0	0.0

Table 5 Apps referrers: breakdown by type of app

		QR code scanner for iPhone	Google	Barcode scanner (Iconit)	Line
Impressions	9,406	25	19	12	11
Product page views	807	25	19	12	11
App units	696	15	13	10	6
Installations	289	6	5	4	3
Sessions	1,161	16	11	11	7

Table 6 Web referrers: breakdown by website

		Google.co.jp	Cadcenter.co.jp
Impressions	9,406	17	12
Product page views	807	17	12
App units	696	9	8
Installations	289	3	2
Sessions	1,161	14	10

app. There were four types of apps from which the product page was accessed. Table 5 shows the breakdown of app referrer results by app type. Many users accessed the product page through Google, Chrome, or another web browser app, but a significant proportion accessed the page using a QR code scanner app or barcode scanner app. We published a QR code that linked to the download page for *Virtual Heiankyō AR* and displayed the QR code on location (by the scale model of Rajōmon outside Kyoto Station) and in promotional flyers. The results in Table 5 suggest that many people scanned this QR code.

Table 6 shows the breakdown of the web referrers. Both websites led to only a small number of downloads (app units or installations), suggesting that the website was either not mobile compatible or did not contain the link.

4 *Virtual Heiankyō AR*: User Feedback, Content Analysis

In this section, we discuss our analysis of the user feedback. To gauge user sentiment and the app's social media impact, we collected online articles, reviews, and social posts about the app, analysed the number of times the content was shared on social media, and then analysed the content qualitatively using text mining.

4.1 Search Method, Search Results

We collected relevant online articles and social posts from 15 to 31 January 2019. To automate the data collection as much as possible, we initially used BuzzSumo, a buzz marketing platform for analysing how articles and websites are trending on social media. However, we ultimately stopped using this platform to analyse primary news sources due to its restrictions. BuzzSumo could not analyse all articles and could not provide links to individual social posts (although, as discussed later, BuzzSumo's Backlink feature allowed us to identify how often each primary news source had been shared).

Noting that Google's search engine ranks the search results by the number of social shares or importance, we decided that these top-ranking news articles would prove useful sources for retrieving the desired data—as many key social posts as possible. Accordingly, we ultimately resorted to manual Google searches to obtain the URLs for all relevant primary news sources. After obtaining these URLs, we searched for the key social posts related to these articles on Facebook and Twitter's search engines.

For search terms, rather than entering three or more search terms, such as *bācharu* [virtual] + *heiankyō* + *AR* (the words forming the app's title, *Virtual Heiankyō AR*), we decided to use pairs of terms, such as *bācharu* + *heiankyō*, on the assumption that using all three terms would return too many results unrelated to the app. Since different pairs of search terms would affect the way Google ranked the results, we experimented with a number of search term pairs. Eventually, we settled on two pairs: (1) *bācharu* [virtual] + *heiankyō* and (2) *daidairi* [Greater Palace] + *apuri* [app]. Using these search terms, we managed to retrieve data that exhaustively covered the relevant primary news sources. The search results were composed of 121 articles and sets of social posts. Since we wanted articles that were both important and original, we differentiated between primary[1] and secondary sources (shared primary news sources; hereafter, 'shared' sources). There were 13 primary sources (all 13 of which were effective) and 108 shared sources (96 of which were effective).

We defined 'primary news sources' as (1) those that a media organisation published immediately after (and as a consequence of) Ritsumeikan University's press release for the app and (2) later articles that were based on the above articles while still being original news articles in themselves. Three criteria were used to determine whether articles met the definition: (1) The articles must have been written by humans (i.e. they must not be products of automated journalism) and published by a media organisation; (2) they must have had hits on BuzzSumo (denoting that the article is trending on social media); and (3) they must not contain any links to other news sites.

For shared sources, we used Twitter and Facebook's search engines to retrieve the articles together with the accompanying social posts. Additionally, we retrieved key social posts from Yahoo News. This site's articles failed the criteria for primary news sources, but the site served as a useful resource for shared sources in that its articles were shared extensively on social media.

4.2 Social Media Impact

For the 13 primary news sources, we determined the social media impact of each source by measuring the number of times the article was shared on key social media platforms. We used BuzzSumo's Backlink's feature to obtain the number of links for each source (Table 7).

[1] The primary sources were from 13 news sites: ITmedia, MoguraVR, Keitai Watch, Techable, University Journal Online, Ritsumei University, Dot Apps, Hotondo 0-yen Daigaku, Vsmedia, SocialGameInfo, Newssalt, XR-Hub, and Kyoto Shimbun.

Table 7 Social media shares by key social media platforms

Primary news source	Shares on Facebook	Shares on Twitter	Shares on Pinterest	Shares on Reddit	Total shares	Links
ITmedia	637	213	0	0	850	5
MoguraVR	107	172	1	0	280	1
Keitai Watch	57	63	1	15	136	1
Techable	58	14	0	0	72	2
University journal online	91	19	0	0	110	0
Ritsumeikan University	76	12	0	0	88	9
Hotondo 0-yen Daigaku	9	1	0	0	0	0
Vsmedia	1	1	0	0	2	0
Social Game Info	1	6	0	0	7	0
Newssalt	2	6	0	0	8	0
XR-Hub	0	0	0	0	0	0
Kyoto Shimbun	4	72	0	0	76	2
Total	1,039	507	2	15	1,553	18

Although omitted in the table, Line is the largest social media platform in Japan in terms of the monthly number of active domestic users. The reason for this omission is that we were unable to determine the number of shares on Line because the platform does not support BuzzSumo's application programming interface (API) for counting social shares. The monthly numbers of active domestic users for the key platforms are ranked as follows (the data are as announced on each platform as of February): (1) Line: 78 million; (2) Twitter: 45 million; (3) Instagram: 29 million; (4) Facebook: 28 million; (5) Pinterest: 4 million; and (6) LinkedIn: 2 million

The total number of key social shares of primary sources was 1,553. Of these shares, 66.9% were on Facebook and 32.6% on Twitter. The majority (54.7%) of the shared content was from ITmedia followed by MoguraVR (18.0%), Keitai Watch (8.8%), University Journal Online (7.1%), Ritsumeikan University (5.7%), Kyoto Shimbun (4.9%), and Techable (4.6%). ITmedia, MoguraVR, and the other organisations we surveyed have a high social media impact. Thus, when ITmedia, followed by other news sites published news on the release of the Android version, the news content was shared on social media. This sharing likely precipitated the surge in downloads and impressions that immediately followed the release. The results also revealed the extent of the articles' social media impact in this case: all 13 articles were shared at least 100 times.

4.3 Text Mining with KH Coder

Using text mining, we analysed the online news content and accompanying social posts to gauge sentiment towards the app. Text mining is a technique for quantifying textual information and is often used to analyse descriptive survey responses or social media commentary. As such, we decided that it would prove effective for analysing the free, decontextualised social posts that we had retrieved. Using the text mining tool KH Coder, we segmented and extracted text on a word level,[2] using an external morphological analysis engine[3] *5 included in the software and then subjected the results to various analytical operations.

4.3.1 Procedure

Before the actual analysis, we cleaned the input data and removed inconvenient elements (see the next paragraph for details). We then inputted the effective sources (all 13 of the primary news sources and 96 of the 108 secondary sources) and configured the KH Coder settings.

We cleaned the input data using MS Excel. In the cleaning process, we removed all kaomoji smileys and other ASCII emoticons, removed all shares that lacked any accompanying social posts, and standardised the vocabulary to some extent. Next, we configured KH Coder's settings: Using the [Check the Target File] command, we executed automatic correction of the target file (based on a morphological analysis) to delete garbled characters; using the [Run Pre-Processing] command, we segmented the text into words; using the [use TermExtract] command, we opened the [Word Clusters] window to display the compound words (or 'word clusters') among the text; in the [Select Words to Analyse] window, we selected [force pick up] to ensure that these compound words would be treated as a single word (rather than being segmented into multiple words). Finally, we executed the [Run Pre-Processing] command again to make the above changes take effect.

4.3.2 Results of KH Coder's Analysis

KH Coder's morphological analysis of the pre-processed (segmented) input data revealed that the target text contained 9,087 words in total (of which we kept 3882 for analysis), 1,306 types of words (of which we kept 1043 for analysis), 444 sentences, 326 paragraphs, and 111 articles (social posts).

To gauge sentiment towards the app, we extracted the words with the highest 'term frequency' (TF), meaning those that appeared frequently among the target text data

[2] For a quantitative analysis, Japanese sentences must be segmented at a word level so that matching words are counted.

[3] For quantitative analysis, we divided the Japanese sentences into word units so that they can be aggregated as the same word.

Table 8 Words ranked by term frequency

No	Extracted word	TF	No	Extracted word	TF	No	Extracted word	TF
1	*Heiankyō*	85	10	*Miru* [See]	21	19	*Kabushiki-gaisha Kyado Sentā* [CAD Center]	24
2	*Apuri* [App]	67	11	*Genzai* [Now/present]	21	20	*Suzaku Ōji* [Suzaku Avenue]	24
3	*Rajōmon*	56	12	*Ritsumeikan*	31	21	*Heian Jidai* [Heian period]	24
4	*Kyōto*	53	13	*Hyōji* [Display]	28	22	*Suzakumon*	23
5	AR	52	14	*Yano Keiji Sensei* [Dr. Keiji Yano]	27	23	*Kaihatsu* [Development]	22
6	*Bācharu Heiankyō AR* [Virtual Heiankyō AR]	48	15	*Daigaku* [University]	26	24	*Tsukau* [Use]	22
7	*Keikan* [Landscape]	46	16	*Taiken* [Experience]	26	25	*Omou* [Think]	22
8	*Sumātofon* [Smartphone]	43	17	*Bācharu Heiankyō* [Virtual Heiankyō]	25	26	*Fūkei* [Scenery]	21
9	*Daidairi* [Greater Palace]	42	18	*Mokei* [Model]	24	27	*Saigen* [Recreation]	21

(the articles and social posts). These high-ranking words are shown in Table 8. The top two words in the list feature in the app's title: *Heiankyō* and *Apuri* [app]. The third and fourth placed words are the names of places related to the app: *Kyōto* and *Rajōtmon.* In fifth place is the abbreviation 'AR'.

Although omitted from Table 8, which only shows words with a term frequency of 20 or higher, there were a number of descriptive words representing sentiment towards the app. The sentiments expressed were generally favourable. The descriptive words included adjectival nouns (*keiyō-dōshi* or *na*-adjectives), adjectival verbs (*keiyōshi* or *i*-adjectives), and adverbials. In order of term frequency (term frequency is shown in parentheses), the adjectival nouns were *Kanō* [possible] (8); *Riaru* [real], *Hitsuyō* [necessary], *Samazama* [various], *Kirei* [beautiful] (3), *Genki* [hearty], *Juyō* [important], *Mijika* [familiar], and *Dōyō* [similar]. The adjectival verbs were *Omoshiroi* [interesting] (6), *Tanoshii* [fun] (5), *Utsukushii (*beautiful) (4), *Furui* [old], *Sugoi* [amazing], and *Yoi* [good] (3); and *Chikai* [close], *Atarashii* [new], *Tadashii* [correct], and *Subarashii* [excellent].

Next, we visualised the data to make it easier to interpret. For this process, we used four of KH Coder's features to analyse the relationships between words. These were hierarchical cluster analysis, correspondence analysis, co-occurrence network, and multidimensional scaling. For each of these analyses, we selected only those words with a term frequency of 12 or higher (the top-50 words in Table 8). We did so because given the small size of the data input, running the analyses on words with a lower term frequency would subdivide the data to an extent where it would be difficult to summarise the results.

Hierarchical Cluster Analysis

The purpose of a hierarchical cluster analysis is to identify clusters of words with similar appearance patterns. KH Coder presents the results in a dendrogram, as shown in Fig. 6. We found seven clusters. The following is an outline of the word combinations in each cluster.

Cluster 1	Words related to users' experience with the app (both the AR and VR modes)
Cluster 2	Words related to the AR technology
Cluster 3	Words related to the app's features (modes) and developer
Cluster 4	Words related to how the app integrates geospatial information
Cluster 5	*Heiankyo Alien*
Cluster 6	Words related to the app in general
Cluster 7	Words related to the locale's landscape (as seen through the app)

Heiankyo Alien is a video game released in 1979 by the University of Tokyo's Theoretical Science Group (TSG). The game takes place in historic Heian-kyō, represented in the game by a Pacman-style maze. The player controls a Heian-period police officer (kebiishi) who must run around the maze and capture space aliens by digging holes and then filling them when an alien falls inside. Many of the social posts related to the app's *Heian-kyō AR* featured the word *Heiankyo Alien.*

Some of these clusters are difficult to interpret because they are nonspecific. Cluster 6, for instance, describes the app *in general*. This lack of distinction may be related to the fact that the input text contained both primary news sources and social posts accompanying the shared sources. The former sources were mostly composed of general descriptions of the app while the latter tended to express sentiment towards it. Given this, analysing the two separately may have yielded more distinct clusters.

Compared to clusters 6 and 7, the other clusters (1, 2, 4, and 5) are more distinct[4]; they suggest that the app created a strong impression by its AR and VR modes, its technology, its integration of geospatial information, and its perceived resemblance to *Heiankyo Alien.* Cluster 5 stands out because it contains only two words: *Heiankyō Eirian* [*Heiankyo Alien*] and VR.

[4] While we omitted the details from this paper, we did attempt multiple cluster analyses, each with a different configuration. For example, we attempted an analysis on only those words with a term frequency of no less than 15 (the top-40 words in Table 8), an analysis in which we specified the number of clusters as five, and one in which we specified the number of clusters as eight. In each case, the resulting clusters were generally similar to clusters 1, 2, 3, 4, and 5.

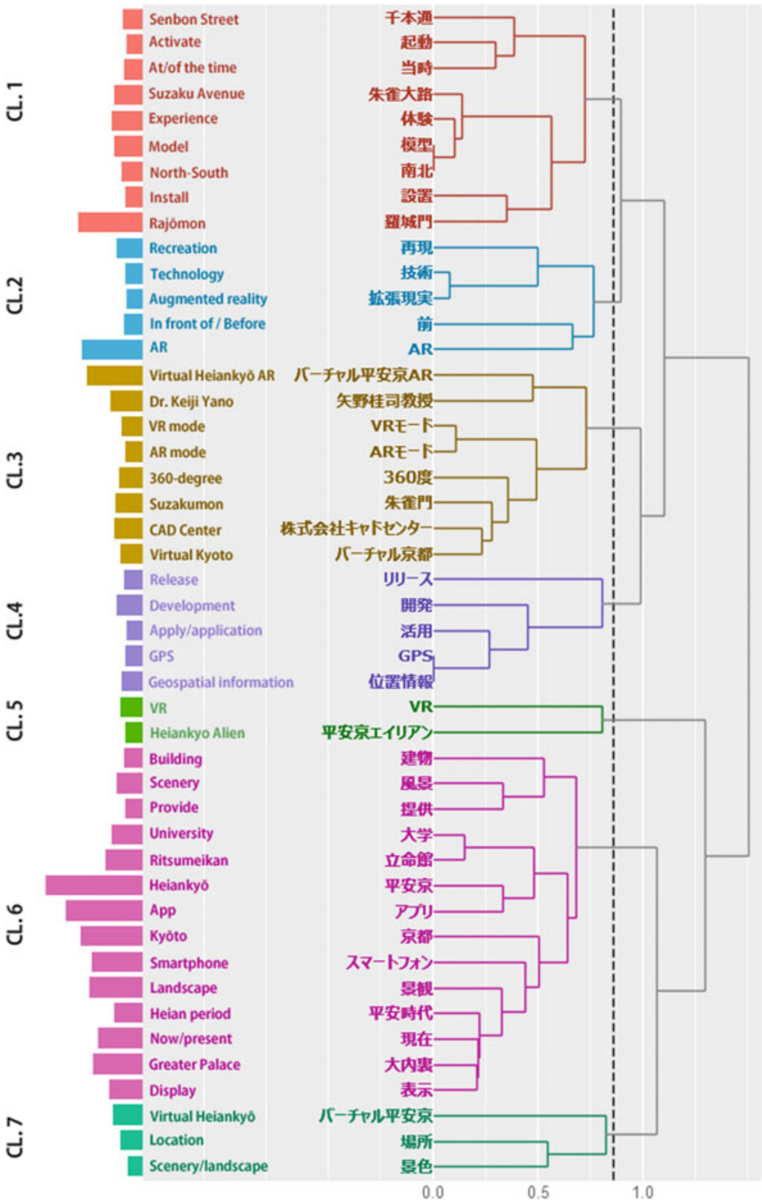

Fig. 6 [Hierarchical Cluster Analysis]: Performed on all words with a term frequency of 12 or higher (the top-50 words in Table 8); number of clusters (CL.): 7, 5, and 8

Fig. 7 [Correspondence Analysis]: Performed on all words with a term frequency of 12 or higher (the top-50 words in Table 6)

Correspondence Analysis

KH Coder's [Correspondence Analysis] feature plots the results on a scatter diagram to help the reader visualise the relationships between different groups of words (Fig. 7). The results in our case revealed two clusters, one in quadrant 2 and the other in quadrant 4. The first cluster contained words related to VR experiences with the model of Rajōmon, such as *Secchi* [install], *Mokei* [model], and *Rajōmon*. The second cluster contained words describing the app in general.

Sparsely distributed in quadrant 1 were the words *Bācharu Heiankyō* [*Virtual Heiankyō*], AR, and VR. This sparse distribution probably reflects the fact that these words featured extensively in social posts. Quadrant 4 contained only one word, *Heiankyō Eirian* [*Heiankyo Alien*]. As we alluded to earlier, of all the words featuring in the social posts, *Heiankyo Alien* was the most distinctive proper noun, which explains why it had such limited correspondence with the other words.

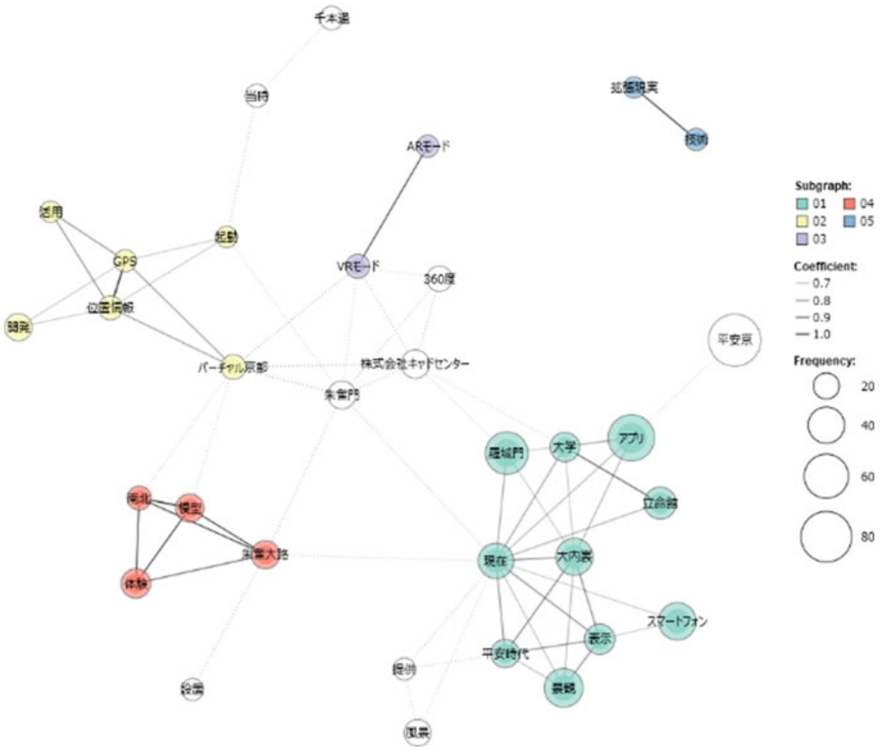

Fig. 8 [Co-occurrence Network] Performed on all words with a term frequency of 12 or higher (the top-50 words in Table 6)

Co-Occurrence Network

KH Coder's [Co-occurrence Network] feature plots the results in a network diagram to help the reader visualise the words that tend to co-occur (collocate) with each other and to show whether these collocations are significant. The diagram contains a number of subgraphs representing communities of co-occurring words. In our case, KH Coder found five such communities, represented in Fig. 8 as subgraphs 1 to 5. The five subgraphs and their corresponding cluster numbers are listed below in the hierarchical cluster analysis.

1: Cluster 6 Words related to the app in general
2: Cluster 4 Words related to how the app integrates geospatial information
3: Cluster 3 Words related to the app's features (modes) and developer
4: Cluster 1 Words related to users' experience with the app (both the AR and VR modes)
5: Cluster 2 Words related to the AR technology

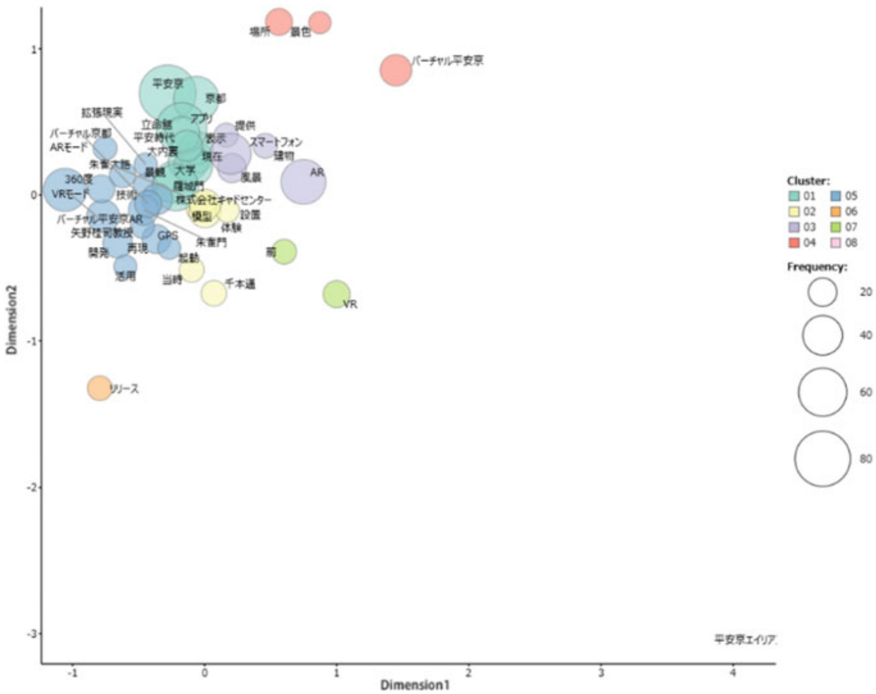

Fig. 9 [Multidimensional Scaling] Performed on all words with a term frequency of 12 or higher (the top-50 words in Table 6)

Multidimensional Scaling

Similar to the [Co-occurrence Network], we used the [Multidimensional Scaling] command to plot the results, grouping words with similar appearance patterns. The command yielded eight clusters. In view of how these clusters appeared in the diagram (as shown in Fig. 9), we identified five groupings. The five groups and their corresponding cluster numbers are listed in Table 9 in the hierarchical cluster analysis.

4.4 Summary of Data, Discussion

4.4.1 Summary of Commentary

Text mining allowed us to identify how frequently words in the target text appeared and how the words collocated and correlated with each other. However, since the target data included free, diffuse, online commentary, text mining was unable to provide a complete descriptive summary of the content of these social posts. The

Table 9 Relationship between MDS groups and the clusters

Group 1		
1:	Cluster 6	Words related to the app in general
2:	Cluster 1	Words related to users' experience with the app (both the AR and VR modes)
3:	Cluster 3	Words related to the app's features (modes) and developer
5:	Cluster 2	Words related to the AR technology
Group 2		
4:	Cluster 7	Words related to the locale's landscape (as seen through the app)
Group 3		
6:	Cluster 4	Words related to how the app integrates geospatial information
Group 4		
7:	None	[Corresponds to none of the clusters]
Group 5		
8:	Cluster 5	*Heiankyo Alien*

analysis focused on term frequency and collocation, not on the content itself or on the explicit or implicit meanings embedded in this content. Accordingly, of the posts that were effective (105 out of the 111 retrieved) in that their meaning was reasonably clear on the first read through, we extracted those where the poster used emphatic language to describe their sentiment or opinion regarding the app and its outlook. These posts are summarised in Table 10.

Once we filtered out the posts that only expressed sentiments such as 'fun', 'interesting', 'amazing', 'just what I wanted', and so on, the majority of the remaining posts contained constructive feedback. Such feedback included posts where the user said they would prefer a different time period or place, a larger area of coverage, or more variety—including higher resolutions (or more granular data). Given the small total number of social posts, such feedback could not be quantified as 'numerous'. At this point, we were more concerned with the internal, descriptive content of the posts rather than quantitative data from a number of posts. We consolidated this feedback into two categories: (1) feedback in which the posters praised the app saying that by integrating AR and VR technologies with tourism software, it increases motivation to physically visit the sites and (2) constructive feedback in which the posters highlight issues with or discuss the potential of the AR and VR technologies and their applicability.

4.4.2 The App's Significance and Potential as a Map Tool

We noted earlier that of the seven clusters identified in the hierarchical cluster analysis, four contained distinct groups of words: clusters 1, 2, 4, and 5. If we remove cluster 5 (*Heiankyo Alien*), which has little to do with the app itself, the remaining three clusters can be interpreted as expressing sentiment towards the app: Cluster

Table 10 Description of posters

Descriptions		Number of posts
1	Poster mentions *Heiankyo Alien*	25
2	Poster would prefer the app to recreate a different place or time period	12
3	Poster would like to use the app on location (while sightseeing or attending a walking tour)	7
4	Poster expresses opinion from within the industry	6
5	Poster discusses possibilities for VR and AR-driven recreation and the approach for AR visualisation	5
6	Poster highlights limitations of the app's features (would like to be able to use the app even if not on location; development of iOS version)	4
7	Poster alludes to three-dimensionality	3
8	Poster alludes to a similar app	3
9	Poster mentions that the 3D experience is immersive/realistic	3
10	Poster says that app is cutting-edge	3
11	Poster says that app provides a new sightseeing (or walking tour) experience	2
12	Poster suggests that the app has potential application in other fields	2
13	Poster says that the app blends the old with the new	2
14	Poster discusses the quality of the graphics	1
15	Poster says that the app feels incomplete	1

1 describes how good posters thought the experience was, cluster 2 describes how good they thought the AR effects were, and cluster 3 describes how well they thought the app integrated geospatial information (Table 11).

In addition to these three types of feedback, in subsection 4.4.1, we previously identified a number of posts highlighting locality and space: '7. Poster alludes to three-dimensionality', '9. Poster discusses immersiveness of the 3D experience,' and '11. Poster says that the app provides a new sightseeing (or walking-tour) experience'. Thus, some users were interested in how the app allowed them to see and

Table 11 Interpritations of clusters

Interpritations		Interpreted as:
Cluster 1	Words related to users' experience with the app (both the AR and VR modes)	How good the experience was
Cluster 2	Words related to the AR technology	How good the AR effects were
Cluster 4	Words related to how the app integrates geospatial information	How well the app integrates geospatial information

experience an actual, specific space and built environment. In emphasising real-world interactions as these posters suggest, the app evidently has a map-like feel and, as such, could serve as a tool for VR and AR maps. Based on this assumption, we considered how the app differs from existing maps, what new possibilities and issues there were, and the roles that VR and AR maps could potentially serve.

4.4.3 How the App Differs from Existing Maps

When discussing the app's cartographic elements, it is important to distinguish between maps that present static, non-real-time geospatial information, and those that use GPS to present real-time geospatial information (such as those used on mobile devices).

Comparted to AR technology, VR corresponds to a non-real-time map; a VR map displays graphical elements, such as symbols and icons, to enhance immersion in the virtual environment, including the sense of space, three-dimensionality, and physical presence. AR, on the other hand, corresponds to a real-time map; it uses geospatial data from the user's real-world location to add, in real-time, the type of cartographic information that features in a tourist guidebook. *Sekai Camera* was an early example of AR for geospatial information. This applied technology then evolved following the addition of a gaming aspect, with apps such as *Pokémon Go*. Our own app potentially marks another stage in this evolutionary process: a shift from the paradigm of triggering AR content at certain pinpointed geolocations towards a paradigm of seamlessly and continuously providing 3D vistas as the user moves around.

Regarding the ways in which the app differs from existing maps, the first point to note is that differentiating the app from existing maps would add a unique selling point. Second, the app stands out as one of the few examples of 3D AR solutions.[5] Among the social commentary on the app's 3D experience, there were posters who highlighted the 'immersiveness of the 3D experience'. Thus, our app differs markedly from existing maps in that, as the user moves around a real-world environment, it

[5] There are some AR-driven apps that provide 3D immersion to some extent, but they are few. Examples of such apps include *Himeji-jō Daihakken AR Apuri* (Himeji City, CAD Center), *Bācharu Asuka-kyō* (Asuka-mura, University of Tokyo, Asukarabo), *Edo-jō Tenshukaku to Nihonbashi Fukugen 3D Tsuā* (Kinki Nippon Tourist), *Teku-Teku-Teku* (Dwango), *Horogurafikku Manshon Byūā* (Nomura Holdings, Prime X, Nextscape), and, more recently, a viewer app for HoloLens. As these apps illustrate, when developing an app that provides 3D content with reasonable geospatial coverage and resolution, it is typical to use a combination of AR and VR. Generally, AR is used for buildings and VR for the terrestrial surface and backgrounds. Because AR uses 3D models, the extent of AR's geospatial coverage will depend on how well the app can process the 3D data. In addition to the examples listed above, there are many AR-driven apps that feature only a single 3D object depicting a historic castle or other historic structure, so that visitors to the sites can experience the structure as it once stood. Examples include *Go! Go! Shidami Kofun-gun* (Nagoya City, Xeen), *AR Nagaoka-kyū* (Muko City, Xeen), and *AR Naniwa-kyū* (Naniwa Kasseika Jikkō Iinkai, Sunwell).

updates the virtual space in real time, giving the user a more expansive and immersive virtual space.

While the social posters praise the app for providing a virtual experience that they can explore as they physically move around, users can only access this experience by being physically present in the actual location. In this respect, the app ultimately serves as a tourist guidebook. Moreover, insofar as the app serves as a tourist guidebook, it raises the question as to whether people really want to immerse themselves in a real-scale virtual tourist guidebook.

4.4.4 New Possibilities, Issues

A number of posters highlighted the potential of the app and the AR and VR technologies underlying it. However, we limit the discussion to the way the app integrates AR and VR with geospatial information.

To achieve the shift from pinpointed AR content to a seamless and continuous 3D experience, apps must incorporate new content more effectively. Even as a simple AR-powered guidebook, our app can provide extensive 3D content, giving users a volume-realistic, immersive, and impactful experience. The app could potentially be used to visualise a wide range of subject matter that requires effective transmission of AR and VR content. For example, the app could be used to visualise how locales or buildings would look if they were actually developed or reconstructed, the app could be used in locations where such development or visualisation is not possible, and it could be used to visualise the interiors of buildings. Additionally, the app could be used to add 3D volume-realism and upward-looking effects.

While unrelated to the contexts in which the app could potentially be used, there were a number of posts that highlighted the significance of recreating historic environments virtually in such a way that the virtual recreations exceed (or at least substitute for) physical recreations. Examples include the following posts: 'People should stop developing the surroundings of historic sites in the name of tourism and instead use this tech as a substitute'. 'Because you can't physically restore historic landscapes in built-up areas, an effective solution would be to recreate them virtually'. As AR and VR devices become more familiar, they are also advancing and becoming more diverse, as Google Glass and HoloLens illustrate. If this trend continues, then AR and VR applications that handle large volumes of data will increasingly operate on wearable devices. Given this possibility, it is necessary to reconsider the significance and innovativeness of AR-driven visualisations and representations.

A number of technical and other issues need to be addressed to realise these possibilities. The most urgent technical issue concerns graphics performance; we must improve the rendering time for data-rich 3D environments. If the app is to include more expansive 3D content and provide a more realistic, immersive experience, the resolution/granularity of objects and textures must improve. However, this will cause the volume of data to balloon. The key challenge, therefore, is how to achieve more data-rich AR content without overburdening the processing units. We can envisage only two realistic options: (1) minimise the data load or streamline the graphics or (2) rely on the device's processing capacity or the app's code base.

Another issue that must be addressed concerns the use of the app to access real-time, GPS-linked cartographic, and tourist information. We must improve the precision and accuracy of the information displayed and enhance the app's geo-tracking. There are also non-technical issues. To ensure user safety, the app must avoid showing AR objects that would completely block the user's field of vision. Therefore, as AR and VR applications evolve, there must be rules, best practices, and guidelines concerning how AR and VR-powered apps should operate.

4.4.5 Appraisal of Technical Aspects

None of the social posts mentioned any technological breakthrough. Getting the app to work on smartphones is a high hurdle because of the use of expansive 3D models. Compared to 2D models, these models involve large amounts of data; the more detailed and realistic the graphics (for example, the more polygons that are used and the higher the texture resolution), the longer the graphics take to load and the more burdened the processing units become.

Our initial task in developing this app was to find the optimum way to obtain the target vistas with a combination of AR-powered 3D models and VR-powered 360-degree rendering. In searching for the optimum method, we ultimately focused mostly on the key issue with the extensive, data-rich 3D models—specifically, how to reduce the data burden and speed up the data loading time to render a faster AR experience.

When developing *Virtual Heiankyō*, the original app on which *Virtual Heiankyō AR* is based, we similarly encountered the issue of a vast volume of textures. Accordingly, when we converted the data format from OBJ to MAX for the pre-rendered map, we baked the data to reduce the burden on the processing units. By reducing the number of nodes (such as models, materials, and textures), we were able to use fewer draw calls. Although this strategy increased the volume of data slightly, we accepted this as a trade-off in our efforts to achieve the optimum balance between data volume and rendering efficiency. Needless to say, the most important benefit of VR and AR graphics is that they create a virtual space and integrate it with the real world, thus creating an immersive, impactful, and realistic experience.

Applying this value proposition to maps brings both benefits and problems. The benefit is that we can enrich the map's content (including more cartographic information, more realism/immersion, and more gaming elements). The problem is that with all this extra content, it becomes questionable as to whether the data is sufficient to ensure the level of precision and accuracy a map requires. A map needs to be both accurate and clear. Crucially, the data is unable to accommodate all the 3D spatial information in a flexible manner. Moreover, the information is transmitted in a way that results, to some extent, in information overload. Given this issue, VR and AR-driven cartographic content can only be practically feasible insofar as the content is generated with the aid of an existing map.

If the above is true when the app is used as a map, what, then, of cases where it is used as a tourist guidebook? The app can add value to tourist content by using VR-driven vistas and worldviews to provide immersion and fun and using AR content to provide a virtual space that is integrated with the real world. Thus, the app has a wide range of possibilities.

5 Conclusion

In this study, we explored the potential of and sentiment towards *Virtual Heian-kyo AR* by analysing app performance metrics, online articles, and social media commentary. The results suggested that the app could serve as a tool for VR and AR maps. We considered, based on the results of the analyses, how the app differs from existing maps, the new value it potentially offers, and the issues that need to be addressed. We evaluated whether the app, as a new type of mapping technology, could potentially serve as a novel application of VR and AR to evaluate maps or generate cartographic, geospatial data.

AR and VR technologies are undeniably growing more sophisticated, and this trend is driven to some extent by progress in wearable devices such as head-mounted displays. Additionally, AR and VR software that incorporates geospatial information now features in a wider range of applications, including gaming, as heralded by the release of *Pokémon Go*. We expect the range of applications, including business applications, to become even more diverse in the future.

Finally, regarding the realistic outlook for the app, in view of the social posts that expressed constructive criticism and highlighted issues, we hope to address the issues and enhance the app's content. Most importantly, we hope to address the criticism that the AR content is only accessible at the right real-world location. Ideally, we would like the app to be capable of providing the content (real-scale 3D graphics in the location with real-time feedback in response to the user's geolocation, like a living tourist guidebook), even when the GPS mode is deactivated. This feat is already performed by a stationary device installed by Suzakumon; the device provides AR-generated 3D data for the Greater Palace despite being installed outside the real-world location where the Greater Palace once stood. Additionally, the app currently displays cartographic symbols for VR visuals, and it also has a tour guide feature that informs the user of their geolocation when AR content is triggered. Still, we will need to explore more ways of integrating the app with online maps and find ways to differentiate it from other apps. Therefore, we will continue working on solutions to make the app a success.

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Role of Maps and Public Street Signs in Wayfinding Behavior by Foreign Visitors

Bochra Bettaieb and Yoshiki Wakabayashi

Abstract In wayfinding behavior, individuals occasionally use public street signs to confirm their current position on the map and find their way. Foreign visitors, in particular, tend to rely on public signs in unfamiliar environments to ensure their position and location. However, few studies in cartography have dealt with the role of signs in wayfinding behavior of tourists and their relationship to maps. This study examined the current status of public street signs, maps, and related issues in wayfinding behavior by foreign visitors. We obtained data on public signs from our fieldwork in Shinjuku District, Tokyo. For the current study, information displayed on 187 signs was recorded, and locations of these signs were geocoded. Data analysis revealed that 65.7% of the signs included a map. In Shinjuku, public signs were unevenly distributed, and many signs were seen in the new urban area situated on the western side of the district. According to the typology of public signs, signs with maps were classified as guiding signs that are used to identify one's current location and find one's way. To prepare for the increase in the number of foreign visitors, most of the signs in Shinjuku displayed pictograms and multilingual annotations. The maps on the signs were aligned with the direction of the viewer to avoid problems caused by the alignment effect. Thus, the direction sign can be regarded as an environmental cue connecting the map and real-world space.

Keywords Public signs · Wayfinding · Guide maps · Foreign visitors · Ubiquitous mapping

1 Introduction

In wayfinding behavior, maps are usually used for planning routes prior to spatial movement. After starting the navigation, travelers must rely on sequentially organized knowledge of landmarks. If they carry a map, they can check whether they are on a planned route or not by identifying landmarks on the map. In the absence of

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maps, they can identify their current position by monitoring self-movement based on velocity or angle of turn. In an urban environment, public signs may help travelers confirm their current position on the route and find the way to their destination.

Cities in advanced countries have a number of signs, both public and private. In a sense, it is a notable feature of the Japanese (or Asian) cityscape due to the lax regulations concerning billboards. These signs may play a role in enhancing the legibility of a city's pathways (Lynch 1960). In this way, public signs can complement maps in wayfinding behavior by showing the current location and giving direction. Foreign visitors, in particular, tend to rely on signs in unfamiliar environments.

Previous studies on signs have been conducted in the fields of environmental/experienced graphic design, architecture, and transport planning (e.g., Gibson 2009; Calori and Vanden-Eynden 2015). Some psychologists are interested in the role of you-are-here maps in spatial cognition (e.g., Levine 1982).

However, few studies in cartography and Geographic Information Science (GIScience) have dealt with the role of signs in wayfinding behavior and their relationship to maps; an exception is Nestel's (2019) study, which examined the design and function of maps in the environment by analyzing maps and signage at an archeological site. In the context of ubiquitous mapping research, how modern technologies complement or alternate existing maps and signs in the environment has become an important research topic. The aim of this study is to examine the current status of public street signs, maps, and issues related to them in wayfinding behavior by foreign visitors.

2 Data and Method

The data used in this research were derived using two methods—fieldwork and questionnaire survey. For fieldwork, we obtained data on public signs from our fieldwork in Shinjuku District (within 1 km of Shinjuku Station), which is one of the most popular tourist sites in Tokyo. The information displayed on 187 signs was recorded as a geotagged photograph using a smartphone. Thereafter, the locational information of these signs was input as geocoded point data into the GIS.

We employed a questionnaire survey to examine the role of sings in wayfinding behavior. We administered the survey to 200 foreign visitors on the street of Shinjuku in 2017: 100 visitors to the Tokyo Metropolitan Government Office located in west Shinjuku and 100 to Shinjuku Gyoen located in east Shinjuku.

Previous studies on environmental graphic design (e.g., Calori and Vanden-Eynden 2015; Gibson 2009) and cartography (Nestel 2019) have listed several types of signs. Based on these studies, we classified public signs into four types—guiding signs, directional signs, identification signs, and regulation signs (Fig. 1).

- *Guiding signs* are used to identify one's current location and determine one's way. This type of sign generally contains maps.
- *Directional signs* always display arrows to point out a specific path to destinations.

Fig. 1 Typology of public signs

- *Identification signs* are located at a destination to identify the place in an environment.
- *Regulation signs* are intended to regulate people's behavior or prohibit certain activities within an environment.

According to the classification of spatial knowledge by Siegel and White (1975), these signs provide visitors with various kinds of spatial knowledge. Guiding signs provide survey knowledge, directional signs provide route knowledge, and identification signs provide landmark knowledge. Hence, public signs can be used to provide visitors with a variety of spatial information.

3 Distribution of Public Signs

Data analysis revealed that 65.7% of the signs included a map (classified as the guiding sign, shown as a red circle on the map below). Figure 2 illustrates the distribution of signs by type, demonstrating that public signs were unevenly distributed within 1 km of Shinjuku Station. Many signs are seen in the new urban area on the west side of the district, characterized by the development of new streets and buildings after the 1970s. Hence, signs are systematically located in that area.

It was observed that guiding signs are dominant on both sides of Shinjuku. Direction signs are located at street corners to provide route knowledge to visitors. In contrast, there are few identification signs in Shinjuku and only a handful of digital signages equipped with information and communications technology (ICT) on the western side of the district.

The contrast between east and west Shinjuku can be attributed to the differences in the development process and spatial structure. Since west Shinjuku was built following a new development plan, this area has regular broad streets and skyscrapers. Therefore, public signs were systematically placed there. In contrast, east Shinjuku is characterized by disorganized development, irregular narrow streets, and high-density built-up districts.

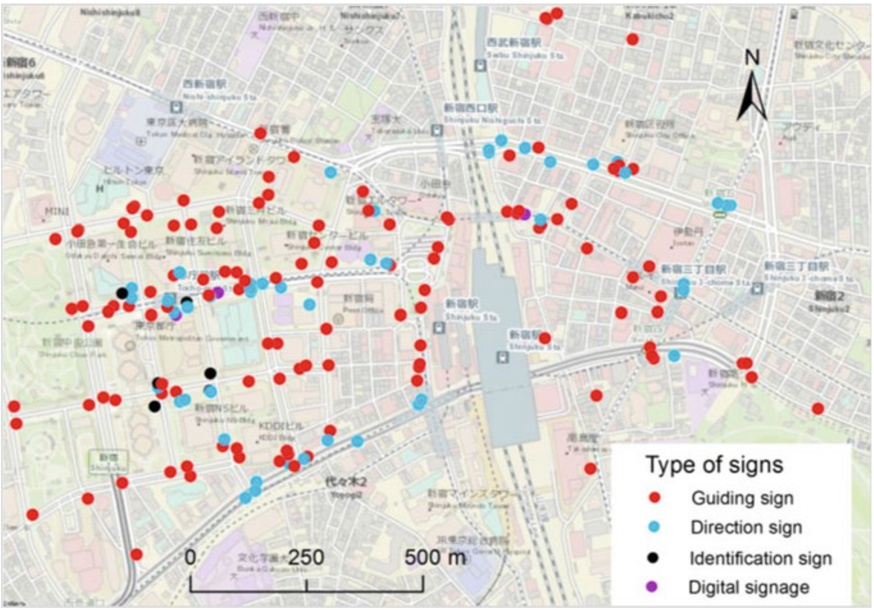

Fig. 2 Distribution of signs in Shinjuku district

4 Expression of Public Signs

Regarding the expression of signs, most of the signs that we observed in Shinjuku displayed multilingual expressions. To prepare for the 2020 Olympic Games, the Tokyo metropolitan government has been promoting the widespread use of multilingual signs for foreign visitors. Moreover, maps of public signs featured pictograms that were comprehensible to foreign visitors. Usually, a guide map is combined with a wide-area map, as shown in Fig. 3, which enables us to ascertain the current location in a city.

A notable feature of the map on a sign is fixed direction, which implies that map readers cannot change the direction of the map. Since most of the maps on signs in Shinjuku were aligned to the direction of the viewer, problems caused by the "alignment effect" described in previous psychology studies can possibly be avoided. In fact, guidelines for public signs set by the municipalities in Tokyo recommend aligning the map with the terrain (Fig. 4).

Fig. 3 Example of the map on signs based on a guideline for public signs by the Tokyo metropolitan government

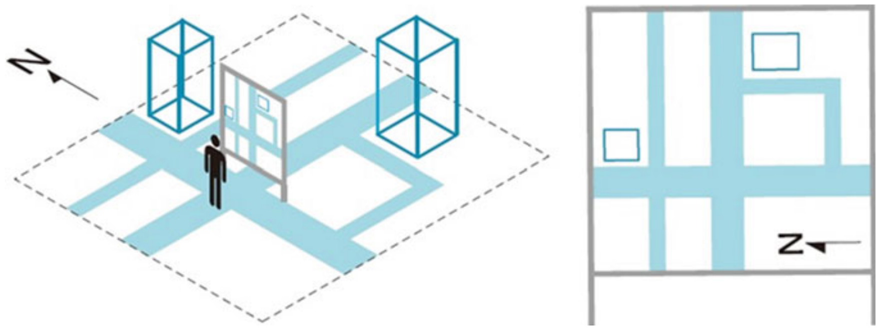

Fig. 4 Guideline of the direction of maps on public signs. *Source* Guideline of public signs in Koto city

In a psychological study on you-are-here maps, Levine (1982) recommended designing you-are-here maps to align the map with the terrain so as to avoid alignment problems. The study provided the following points:

(1) Provide salient, coordinate labels in both, the terrain and the map.
(2) Place the map near an asymmetrical part of the terrain.
(3) Design the you-are-here symbol to indicate the map-terrain correspondence.
(4) Align the map with the terrain (to avoid the alignment effect).
(5) Be redundant: that is, use as many of these supplements as possible.

Most of the maps on signs in Shinjuku match these recommendations, particularly the fourth point.

5 Problems of Public Signs

However, there are some problems with public signs in central Tokyo. The first concerns the cultural differences that might arise. Although maps on public signs featured pictograms and multilingual annotations (Fig. 5), we found that the use of pictograms was not uniform and that some expressions might confuse the foreigners. Visitors are thus forced to rely on landmarks because most of the streets have no name, which is inconvenient for those from Western countries.

The second problem is the inconsistency of design and content between facilities or municipalities, which may confuse foreign visitors. Signs within stations or buildings are managed by owners (e.g., railroad companies and prefectures) (Fig. 6), whereas road signs are specified by road authorities. Therefore, addressing the imbalance in the distribution of signs is needed.

Figure 7 presents the variation in you-are-here maps mentioned on public signs. We observe variations in the contents and expressions of maps employed by different cartographers. These maps are made by different divisions of the Tokyo Metropolitan Government, and each division's rules for designing maps is distinct.

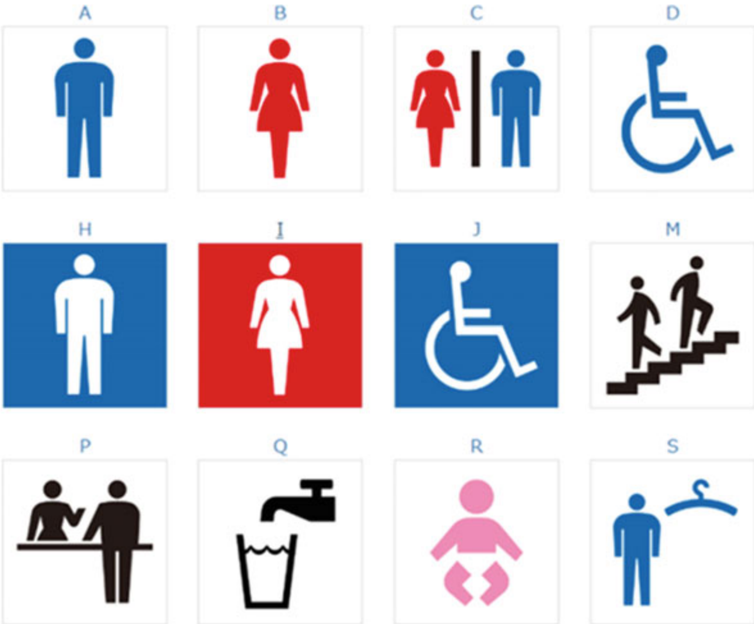

Fig. 5 Pictograms specified by Japan industrial standards (JIS)

Fig. 6 An example of direction sign inside a station

Fig. 7 You-are-here maps on public signs

Guidelines for public signs by municipalities recommend maintaining a ledger of signs. Nevertheless, old and current information were observed to coexist in the same map on the sign. Hence, regular inspection and revision should be performed to keep the signs relevant and comprehensible to all (Fig. 8).

To evaluate the role of public signs for foreign visitors, we conducted a questionnaire survey in Shinjuku in 2017. Participants included 200 foreign visitors visiting the eastern and the western sides of the district. The majority of the respondents were from France (34), followed by USA (22), Germany (18), Australia (16), and the UK (11). Answers to the item on tools for wayfinding were analyzed by dividing the sample into east and west Shinjuku.

As shown in Fig. 9, foreign visitors commonly use GPS/smartphones to find their way. In west Shinjuku, public signs are used as much as GPS/smartphones. Nevertheless, a smaller number of respondents use public signs in east Shinjuku because there are few signs there. This indicates the importance of public signs for foreign visitors in finding their way.

Fig. 8 Identification of pubic sign with ledger. *Source* Itabashi city sign design guideline

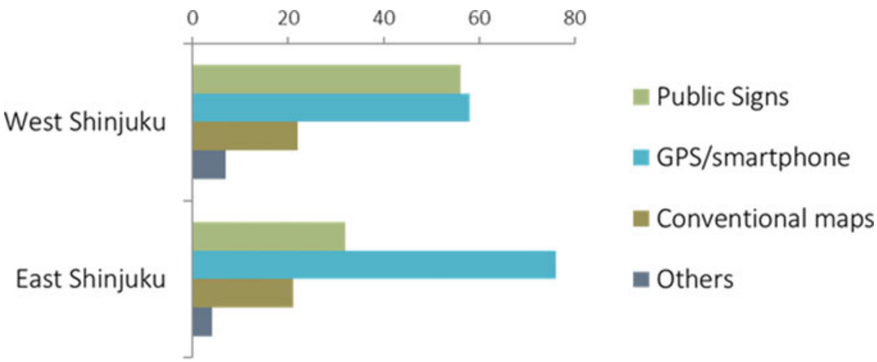

Fig. 9 Tools for wayfinding by foreign visitors (multiple answer)

6 Discussion and Conclusions

Although public signs and maps present on the streets of downtown Tokyo occasionally create problems for foreign visitors' wayfinding, they have often undoubtedly helped to provide accurate directions through characters and pictograms. Recommendations to mitigate the problems of signs found in this study are as follows.

First, cultural differences can be solved by adjusting the style and content of the map on sign to the style and customs of foreign visitors.

(a) Digital signage (b) A sign with QR code

Fig. 10 Examples of application of the ICTs to public signs

Second, problems of inconsistency can be solved by coordination among the administrators of the signs based on specific guidelines.

Third, maintenance problems can be solved by regular inspections and revisions by the administrator of the signs.

The results of the questionnaire survey suggest the possibility of a combination of ICTs and public signs. A viable way to combine public signs with ICTs is to adopt digital signage (Fig. 10a). However, the role of digital signage, which is promoted by the Tokyo metropolitan government, may be limited owing to its limited number, cost–benefit weakness, and issues arising from map making.

Another way is to connect signs with cyberspace by using the quick response (QR) code or radio frequency identification (RFID) (Fig. 10b).

Dickmann (2015) pointed out that the cartographic integration of QR codes is particularly advantageous for digital information transfer, called “cross-media mapping,” due to the easy creation of QR codes.

As an implication for the study of ubiquitous mapping, we can point out two roles of signs in wayfinding. Klippel et al. (2010) mentioned that you-are-here maps are the original form, the grandmother of all location-based services (LBS). The finding from this study of public signs can be applied to indoor navigation, where guiding signs play the role of ubiquitous mapping in a real-world space by showing the current location and direction. Thus, in this manner, the direction sign becomes an environmental cue connecting the map and real-world space. In other words, public signs can be regarded as an annotation of actual size maps in a real-world urban space. In the near future, public signs can be replaced by LBS.

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Part II
Human Aspects

Use of Smartphones as Navigation Aids and its Effects on Acquisition of Spatial Knowledge

Noriko Shingaki

Abstract The purpose of this study was to identify the characteristics of cognitive maps envisaged by people who use smartphones to access rail-route planning information or web-based maps. The study consisted of two experiments. In Experiment 1, the accuracy of cognitive maps of Tokyo envisaged by university students was compared with the accuracy of those envisaged by older adults. Experiment 2 compared the accuracy of students' cognitive maps at different cartographic scales. The results revealed that students exhibited inaccurate spatial knowledge at a cartographic scale that encompasses Tokyo's rail network because of their reliance on smartphones to access geospatial information.

Keywords Cognitive maps · Google effect · Mobile device · Spatial knowledge

1 Introduction

It has been clear for decades that people rely not only on their inner cognitive resources but also on cognitive information in the external environment, as if the latter were an extension of the former (Norman 1991; Hutchins 1995). An example of this practice is the use of memory aids such as sticky notes. Hutchins (1995) argued that such external memory can, in addition to aiding memory, help simplify complex tasks or problems. External memory is often contained in human-made cognitive artifacts, but it can also be contained in other people's memories; Wegner et al. (1985) called the latter "transactive memory."

In today's digitally connected world, we can access the Internet whenever and wherever we desire. With this powerful external memory available to us, we tend to rely on online information to a greater extent than we do upon our inner resources or those of our friends. Sparrow et al. (2011) named this trend the "Google effect."

The purpose of this study was to determine whether cognitive mapping is subject to the Google effect. When navigating an unfamiliar area, we rely on maps or other

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types of travel information, such as rail-route planning guides. In recent years, we have increasingly obtained geospatial information from digital devices (PCs or smartphones) rather than from printed maps. Unlike traditional printed maps, digital maps allow users to adjust the cartographic scale to suit the dimensions of the screen or window. This action affects the geospatial content that the user sees; i.e., by zooming further in, the user will see a smaller portion of the map.

Does a preference for viewing geospatial data on digital devices affect one's ability to acquire the spatial knowledge underlying a cognitive map? A cognitive map is an internal representation of the outer environment, including spatial relationships (Kitchen 1994). A number of studies have examined whether cognitive maps vary depending on the type of cartographic display that people use. For example, Dillemuth (2009) compared the cognitive maps of participants who viewed a map through a large window on a computer screen, which is similar to viewing a paper map, with those of participants who viewed a map through a small window on a computer screen, which is similar to using a smartphone to view a map. The study found that participants who used the smartphone display gave less accurate answers regarding spatial distances and relative positions. Similarly, Dickmann (2012) compared a map-based car navigation system (which automatically plots one's route to their destination) with a printed city map for orientation in traffic; participants who used the navigation system were less accurate than their counterparts in recalling spatial information (such as landmarks and key points) and spatial relationships. This body of research suggests that using a digital device to view a map of an unfamiliar area contributes negligibly to the development of a cognitive map of that area.

What, then, of *familiar* areas? How is the cognitive mapping of a familiar locale affected by the routine use of a smartphone to access, wherever and whenever desired and to the extent desired, a map of a geospatial area or a rail-route planning service (a service showing the best route from the user's present location to the intended destination)?

1.1 Cognitive Maps of Tokyo

Central Tokyo is complex in form, but its rail network provides a useful reference that can present one with an idea of the city's overall layout. This way, the rail network may serve as an anchor point for developing a cognitive map of central Tokyo (Canter and Tagg 1975). Previous studies on the cognitive mapping of central Tokyo have focused on people's perceptions of the layout of stations along the Yamanote Line, a loop line that runs around central Tokyo. Participants of two studies (Canter and Tagg 1975; Wakabayashi 1990) aligned the line's stations in a circle, when in reality the stations were aligned in an oval oriented vertically (north–south). The participants had accurately aligned the stations along the north–south portions of the line, but had overestimated the space for the stations along the east–west portions. Another similar study examined the effects of automotive navigation systems on taxi drivers' cognitive mapping (Wakabayashi et al. 2011).

Accordingly, the present study focused on cognitive maps of the Yamanote area of Tokyo in order to examine whether the routine use of smartphones affects the accuracy of smartphone users' internal knowledge underlying a cognitive map of that area.

2 Experiment 1

2.1 Purpose

The purpose of Experiment 1 was to identify the differences between young people's and older adults' spatial knowledge of central and suburban Tokyo.

2.2 Method

Participants The sample representing young people consisted of 37 university students aged 18–23 (mean ± standard deviation: 20.8 ± 1.21) who were attending a university in Setagaya-ku, Tokyo. The sample representing middle-aged people consisted of 29 individuals aged 34–64 (52.8 ± 5.25) who were relatives of the university students. All participants resided primarily in Tokyo or in neighboring Kanagawa. All but two of the participants were included in the analysis; the two exceptions were a male university student and a female middle-aged participant, both of whom had answered none of the questions on spatial information.

Study Period The study was conducted from November 11 to November 30, 2016.

Materials The participants were set a task that measured their knowledge of the spatial relationships between eight spatial points in Tokyo. They also completed a questionnaire about their ownership and use of digital devices and the navigational tools they use when traveling.

Spatial Perception Test Participants were provided with a sheet of A4 paper on which they were required to indicate what they reckoned to be the correct locations of eight landmarks in and around Tokyo, including Yamanote Line stations. The eight landmarks were Tokyo Tower, Haneda Airport, Machida Station, Ueno Station, Ikebukuro Station, Senso-ji (Asakusa), Shibuya Station, and Tokyo Station. The sheet contained pre-prepared cues: It displayed the direction of north and showed the correct relative positions of two additional landmarks: Shinjuku Station and Mount Takao.

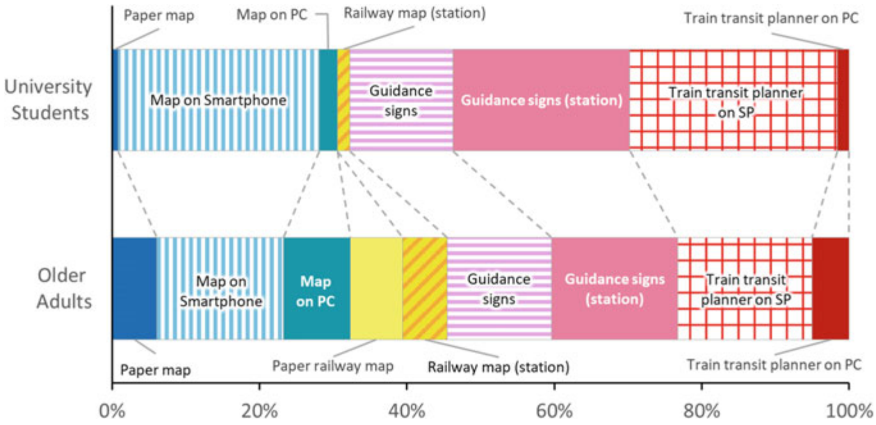


Fig. 1 Differences between university students and older adults in terms of preferences for navigational tools during travel

2.3 Results

2.3.1 Navigational Tools Used by University Students and Older Adults

Figure 1 shows the navigational tools university students and older adults stated that they use when traveling to a new location by train. When asked what tools they would use as a general map (as opposed to a rail network map), university students mostly responded that they would use a navigational app on their smartphone; older adults mostly responded that they would examine a printed map or view a digital map on a PC. When asked about rail navigation, many of the older adults answered that they would view a handheld rail map or a rail network map displayed by the ticket area, while few university students gave such answers. When asked about the device on which they would access rail-route information, the older adults tended to answer that they would obtain this information on a PC, while the university students tended to answer that they would use a smartphone to access this information. In summary, older adults tended to prefer a printed map and printed rail network map, while the university students tended to prefer a smartphone-based app as a map and rail-route planner.

2.3.2 Knowledge of Spatial Relationship of Key Landmarks and Stations

How accurately did the university students and older adults envisage the spatial relationships between the eight landmarks and stations? In Fig. 2, the upper subfigure shows the distribution of the spatial points plotted by the university students, while

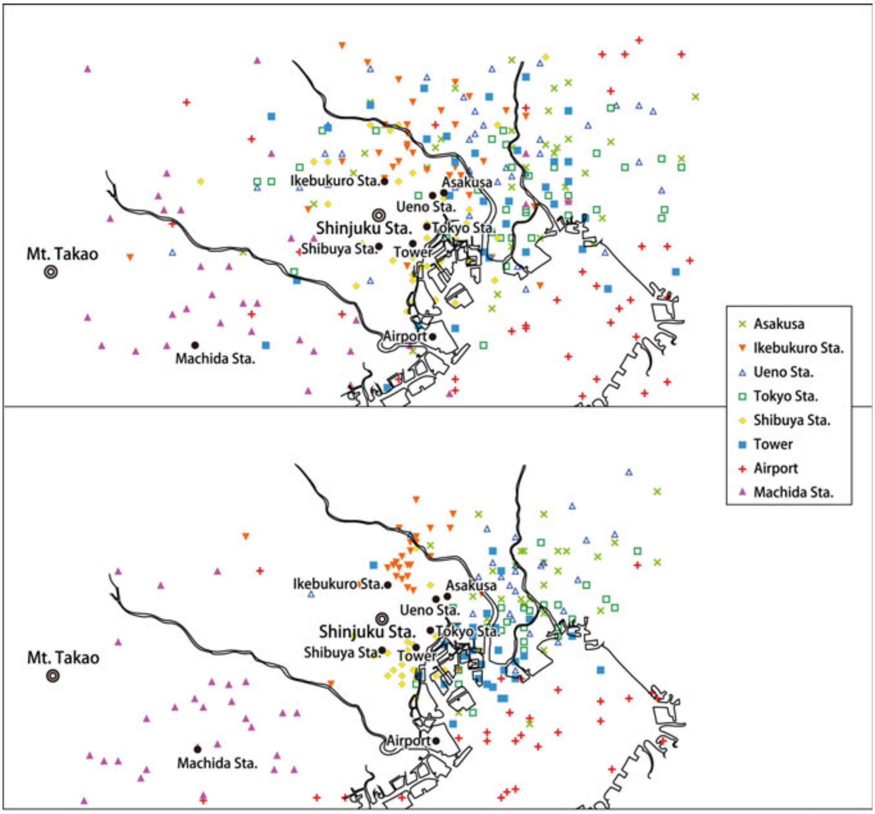


Fig. 2 Participants' plots of landmarks in the zone through which they commute to campus (upper subfigure: university students; lower subfigure: older adults)

the lower subfigure shows the distribution for the older adults. These distributions represent the cognitive maps for their respective groups.

The double circle dots indicating the locations of Shinjuku Station and Mount Takao are the two pre-prepared cues provided to the participants. The results revealed intergroup differences. Taking Shibuya Station as an example (indicated by a purple mark), the points plotted by the older adults were clustered southeast of the actual location of the station, while the points plotted by the university students were distributed sparsely around the actual location in all cardinal directions. The students tended to plot the point further from the actual location than did the older adults.

The plotted locations represent the cognitive maps of the two groups. The locations plotted by university students were more sparsely distributed than those plotted by older adults.

To clarify the differences between the two cognitive maps, the points plotted by the university students and those plotted by the older adults were compared with the actual cartographic locations of the landmarks by seeking, for both groups, the two-dimensional correlation coefficients.

Two-dimensional correlation is used to compare the similarity between two distributions of spatial points. When comparing the two distributions, each point in one distribution is paired with a point in the other distribution to estimate the similarity between the two distributions. This method is typically used to measure the degree to which a cognitive map is inaccurate. Tobler (1994) demonstrated that the similarity between two distributions can be determined by deeming one distribution as a function of the other. Thus, for the present study, the following approach was adopted: The two coefficients are sought in the following formula:

$$u = f(x, y)$$

$$v = g(x, y)$$

where (u_j, v_j) represent the coordinates of the distributions of spatial points plotted by the participants and (x, y) represent the coordinates of the actual locations. These functions are used to transform the coordinates. The closer the result for the distribution of actual locations to the result for the distribution of points plotted by the participants, the more the two distributions would be deemed to resemble each other. However, a Euclidean bidimensional regression is employed when purely linear functions are used to determine the resemblance and correlation between the two planar distributions (plotted points vs. actual cartographic locations). If linear functions are used to estimate the distributions of participants' spatial knowledge, then we would choose functions that would minimize errors by least squares; we would use $(\hat{u}_j, \hat{v}_j)$ to represent the coordinates of the theoretical spatial knowledge inferred from the actual cartographic spatial-point distribution. The two-dimensional correlation for the coordinates of a given participant's perceived distribution versus the coordinates of the actual locations can be represented by the formula below, where $(\overline{u}, \overline{v})$ is the centroid of (u_j, v_j) (Sugiura 1991; Wakabayashi 1994; Nakaya 1997).

$$r = \sqrt{1 - \frac{\sum \left(u_j - \hat{u}_j\right)^2 + \sum \left(v_j - \hat{v}_j\right)^2}{\sum \left(u_j - \overline{u}\right)^2 + \sum \left(v_j - \overline{v}\right)^2}}$$

The two-dimensional correlation coefficient (r) is $0 \leq r^2 \leq 1$. As such, the closer it is to 1, the more the participant's spatial-point distribution resembles the actual cartographic distribution. Compared to other approaches used to measure the distortion of a cognitive map, the two-dimensional correlation approach is relatively effective for measuring the goodness-of-fit of spatial-point distributions (Wakabayashi 1990). As such, it is widely used (Wakabayashi 1990, 1994; Kitchin and Fotheringham 1997; Wakabayashi et al. 2011).

Table 1 Difference of bidimensional correlation between university students and older adults

	University students	Older adults
n	36	28
0–0.7	10	0
0.7–0.8	5	1
0.8–0.9	8	6
0.9–1	13	21
*Mean**	0.768	0.928
SD	0.192	0.061

* Difference in mean
t (39.08) = 4.64, *** $p < 0.001 r = 0.59$

Since the purpose of the study was to identify the extent to which university students and older adults' knowledge of the spatial relationships between landmarks differs from the actual spatial relationships, and to identify whether this differs between university students and older participants, two-dimensional correlation coefficients were used to measure the similarity between each participant's plotted distribution and the actual distribution of the landmarks. Where there were missing values (where a participant gave no response as to the position of a landmark), we assigned the group's average coordinate for that landmark. We assumed that if a participant had missing values, it might imply that the participant had limited spatial knowledge regarding other landmark locations (landmarks for which the participant gave a response); hence, we assigned the average value for the missing responses rather than removing the entirety of the participant's responses from the analysis.

For both groups, Table 1 shows the bidimensional correlation coefficient between the eight landmarks in Tokyo as plotted by the participants and the actual locations of the landmarks (result of two spatial cued response tests). The coefficient for older adults was significantly higher than that for the university students [t (39.08) = 4.64, $p < 0.001$, $r = 0.59$].

2.4 Discussion

The purpose of Experiment 1 was to identify whether young people's spatial knowledge was affected by their increased use of digital devices, rather than conventional printed maps, for navigation.

2.4.1 Intergroup Differences Regarding Geospatial Information

The results revealed the following intergroup (university student vs. older adults) differences in navigational tool preferences during rail travel to an unfamiliar destination: Older adults were more likely than university students to favor the options of viewing a printed map, using a PC to view geospatial information, or using a PC to plan a rail route. The university students tended to favor the option of using a smartphone to view a map or plan a rail route. These results imply that the university students, when traveling, use a smartphone to access spatial information regarding railway stations and other landmarks. The finding that older adults favored the use of printed maps and PC-based maps implies that this group, when traveling, rarely uses a smartphone to access spatial information. It also implies that this group, prior to traveling, will access information about a landmark's spatial relationships by viewing an expansive map—one that covers (on the printed page or on the PC screen) a wide expanse of the area of interest, as opposed to showing a discrete section.

Experiment 1 was conducted in 2016. Since then, smartphone use may have increased among older adults. However, the above results imply that older adults are more likely than young people to obtain their spatial information from a printed map or PC software.

2.4.2 Differences in Acquired Spatial Knowledge

Our results offer evidence that university students, compared to older adults, possess less accurate spatial knowledge. We sought the bidimensional coefficients to represent how participants' knowledge of the spatial layout of the landmarks in the commuting zone (the area across which the students regularly commute to campus) correlated with the actual spatial layout. The coefficients were significantly higher among older adults. There are two likely reasons why older adults exhibited better accuracy. The first reason is that older adults have more experience using maps. As the questionnaire results suggested, these participants were more likely than the university students to access the spatial layout of the commuting zone from a printed or PC-based map. Before the advent of the Internet and the proliferation of smartphones, these adults would have learned how to obtain the relative spatial positions of landmarks (stations) from printed maps and rail network maps. In contrast, university students rely predominantly on smartphones to obtain this information, while in transit, university students would typically view a map showing only a discrete section of the area of interest (as the smartphone's display area is small compared to a printed map or PC monitor) or view a rail-route planner app, which displays topological information. Another factor is the use of smart cards for rail travel in the Greater Tokyo Area following the phased rollout of a prepaid travel card in 1991, and a smart card (Suica) in 2001, across the rail networks in this area. Previously, rail passengers would need to buy a ticket to their destination prior to boarding. Moreover, prior to passing through the ticket gate, they would need to check the price for their destination by viewing a rail network map displayed at the station. The use of smart cards means that these steps are no longer necessary. University students, who started using trains well after the proliferation of smart cards, would have few occasions to check the rail network map. Thus, the types of maps that people use in their daily life significantly shape the kind of spatial knowledge they acquire.

3 Experiment 2

In Experiment 2, we sought to identify the geographic scale(s) at which young people exhibit insufficient spatial knowledge. In Experiment 1, we examined how university students differ from older adults in terms of the accuracy of spatial knowledge (their knowledge regarding the relative positions of landmarks in their commuting zone). However, Experiment 1 did not reveal whether young people's (university students) spatial knowledge is insufficient across a range of spatial scales or whether it is only, or particularly, insufficient at a spatial scale encompassing the commuting zone. We were interested in this particular scale because it features in rail network maps, which have become increasingly redundant with the prevalence of smartphones.

Before the spread of smartphones, rail passengers would use general maps and rail network maps that display geospatial information on a two-dimensional plane. Following the advent of the Internet and the spread of smartphones, people increasingly use rail-route planning apps, which display not two-dimensional information but topological data that indicate the rail connections from the station closest to the user's present location to the user's intended destination (i.e., data that shows the user which station to change at and which rail line to connect to). If it is the case that people today lack spatial knowledge of rail networks, for which they no longer routinely use two-dimensional maps due to the spread of smartphones, then such interfaces may be the cause.

Following the March 2011 Tohoku earthquake and tsunami, people in the Greater Tokyo Area became stranded after train services stopped running. News stations reported scenes in which people had to return home from their school or workplace on foot, walking many miles and for many hours along national roads. As this incident illustrates, disasters are often accompanied by power outages, which can render digital devices inoperable. Accordingly, it is important to possess a cognitive map of the spatial layout of the commuting zone for use in emergencies.

In Experiment 2, we examined whether university students' cartographic knowledge is stable across multiple cartographic scales or whether it differs between the commuting zone scale and other scales.

3.1 Purpose

The purpose of Experiment 2 was to identify how university students' spatial knowledge (cognitive map) differs between geospatial scales.

3.2 Method

Participants The participants were 166 university students aged 20–26 who were attending a university in Setagaya-ku, Tokyo. Included in the analysis were the responses of 153 of these participants (38 men, 108 women; mean age, 20.56 ± 0.80). Excluded from the analysis were participants who gave no response with regard to 10 or more spatial points. The participants were in the third or fourth year of their university course, the majority being in their third.

Study Period The study was conducted on the university's campus from November 6, 2018, to June 12, 2019.

Question Sheets Participants were given sheets of A4 paper representing different geospatial scales. Each sheet contained pre-prepared cues: It displayed the direction of the north and showed the correct relative positions of two spatial points.

Four scales were used: a scale encompassing every prefectural capital in Japan (1:1,500,000), a scale encompassing every prefectural capital in the Kanto region (1:1,000,000), a scale encompassing the commuting zone (1:100,000), and a scale encompassing the environs of the campus and its nearest station (1:1700). The participants would have likely acquired spatial knowledge regarding the four scales as follows. For the first scale (all of Japan), they would have learned the relative positions of prefectural capitals during geography classes in elementary school. They would also have had ample opportunities to see a map of Japan. The same is true for the second scale (prefectural capitals in Kanto), since this scale forms part of the map of Japan. Additionally, insofar as the students resided in Kanto, they would also have regularly seen maps of the region on TV news reports or weather reports. The students would have gained knowledge of the third scale (stations in the commuting zone/Yamanote area) primarily from their experience of traveling in the commuting zone. They would have used this knowledge during their regular commutes to and from campus or when, for weekend social trips, they would plot the best route from their residence to the destination. As for the fourth scale (campus and environs), the students would have had few occasions to view maps for this zone; they would most likely have formed the knowledge as they walked to campus from the nearest station and vice versa.

Table 2 shows the locations the participants were required to plot. For each scale, there were seven locations to plot and two locations provided as reference points. The participants would have been familiar with each of these locations, including the reference points.

Procedure The question sheets were distributed to the participants during a university class. The participants then returned the completed sheets.

Analysis As in the analytical procedure for Experiment 1, the spatial points plotted by the participants were compared with the actual locations for that scale using a bidimensional correlation analysis.

Table 2 Plotted places for these experiments and scale of questionnaire sheet

Plotted places for the 2nd experiment	Reference points	Scale of questionnaire sheet
University neighborhood: Auditorium on campus, pond on campus, library on campus, Bldg #8 on campus, post office, bank, KFC restaurant	Gate of the university Gate of the station	1:1700
Landmarks and train stations around Yamanote Line: Ikebukuro Station, Ueno Station, Shibuya Station, Seijo Station, Shinagawa Station, Disney Tokyo Airport	Tokyo Station Shinjuku Station	1:100,000
Capital cities of the prefectures in Kanto region: Utsunomiya, Mito, Maebashi, Saitama, Yokohama, Kofu, Shizuoka	Tokyo, Chiba	1:1,000,000
Capital cities of the prefectures in all Japan: Sapporo, Akita, Sendai, Toyama, Nagoya, Kochi, Fukuoka	Tokyo, Osaka	1:1,500,000

3.3 Results

To determine the scale at which young people exhibit deficient spatial knowledge, the bidimensional correlation coefficients (for the seven points plotted by the participants versus the actual locations) were averaged for each scale, as shown in Table 3, where there were missing values (where a participant gave no response as to the position of a location), we assigned the group's average coefficient. The results are presented in Table 3.

To determine the scale at which the participants' plotted distributions resembled the actual distribution for that scale, the mean coefficients for each scale were subjected to an analysis of variance (ANOVA) with one within-participants factor (four levels, within-participants). The ANOVA indicated significant differences between scales [F (2.66, 152) = 73.27, $p < 0.001$, $\eta_p{}^2 = 0.325$]. The mean coefficients for the scales were then subjected to multiple comparisons using the Bonferroni correction. For the largest scale (all of Japan), the mean coefficient (d) was significantly higher than that for other scales. For the second-largest scale (Kanto), the mean coefficient (c) was significantly higher than the mean for the commuting zone (Yamanote) scale (b) and the mean for the campus environs scale (a). Additionally, (a) was significantly higher than that in (b). The scale with the lowest mean coefficient was the commuting zone scale (the nodes for which include stations and sites in and around the Yamanote Line area).

Figure 3 shows the distribution of points plotted by the participants in each of the four scales. In the commuter zone scale, the distribution of the stations and sites in and around the Yamanote Line area is more disorganized compared to the distributions in the other scales.

Table 3 Differences in bidimensional correlations between four geometric scales

	University neighborhood (a)	Around Yamanote Line (b)	Kanto region (c)	All of Japan (d)	+ANOVA
0–0.6	13	19	7	1	$F(2.66, 152) = 73.27$
0.6–0.7	27	20	4	0	$***p < 0.001$
0.7–0.8	25	42	20	2	$\eta_p{}^2 = 0.325$
0.8–0.9	32	48	43	9	++
0.9–1	56	24	79	141	a, b, c < d $***p < 0.001$
					a, b < c $***p < 0.001$
n	153	153	153	153	b < a $**p < 0.01$
Mean	0.805	0.764	0.862	0.954	
SD	0.148	0.152	0.130	0.050	

+Adjusted by Huynh–Feldt-Lecoutre's epsilon
++Shaffer's modified sequentially rejective Bonferroni procedure

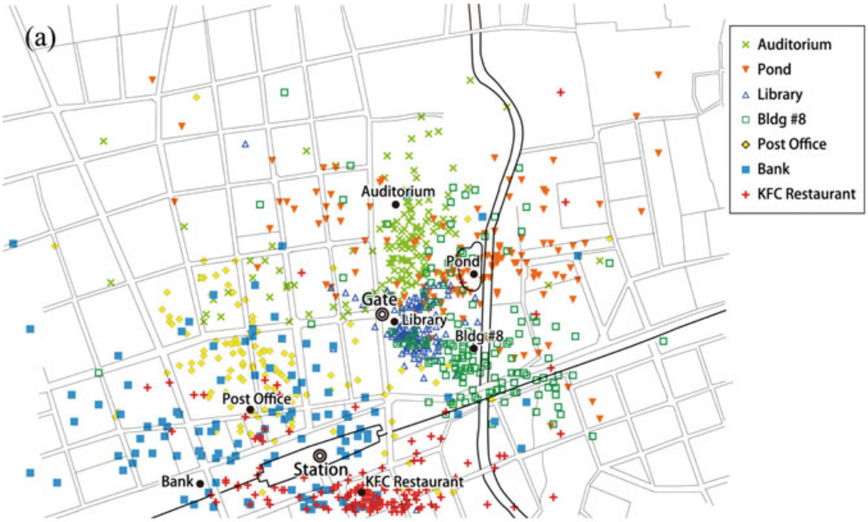
3.4 Discussion

We compared the spatial knowledge of key (and thus familiar) locations between four different cartographic scales. The participants' spatial knowledge was particularly limited with respect to the commuter zone/Yamanote scale (b). Although the participants exhibited reasonably accurate spatial knowledge with respect to prefectural capitals at the Kanto area scale (c) and the university neighborhood layout in the campus environs scale (a), their knowledge of the spatial layout of the commuting zone was less accurate. This observation suggests that young people's knowledge of spatial relationships is particularly poor for a rail travel network.

We asked a separate set of students (separate from the sample in Experiment 2) to draw a map of the Yamanote area in whatever style they desired. The maps they drew are shown in Fig. 4.

The first map indicates that the student who drew it understands the position of key locations and understands the sequential positions of stations along the line. However, if north is supposed to be at the top of the map, then the map depicts the stations in a mirror image of the actual layout. The map shows the topological relationship between stations, thus indicating the correct sequence of stations a passenger would ride through; however, the layout is inverted insofar as the map's top and bottom are north and south, and its left and right are west and east.

The second map displays the sequence of the Yamanote stations incorrectly. In an east–west inversion, Tokyo Disneyland is where Haneda Airport should be and vice versa.



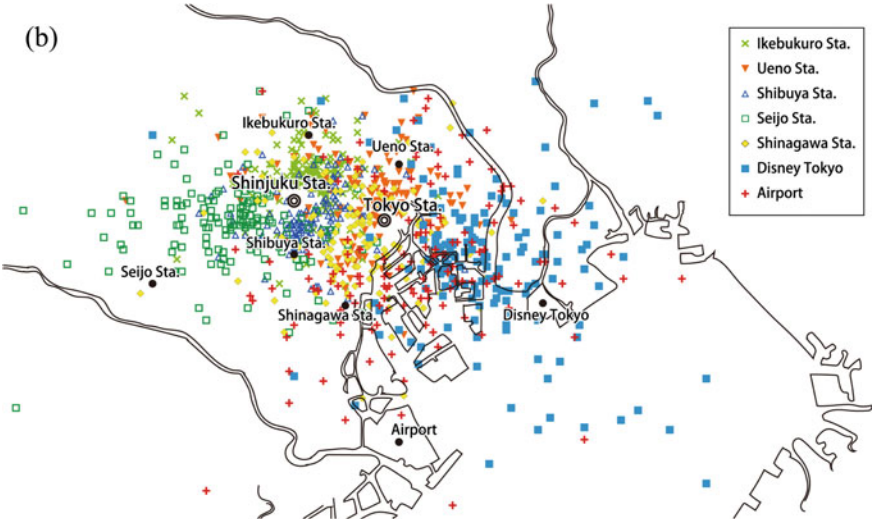


Fig. 3 Spatial plots: **a** university neighborhood, **b** around Yamanote Line. Spatial plots: **c** Kanto region, **d** all of Japan

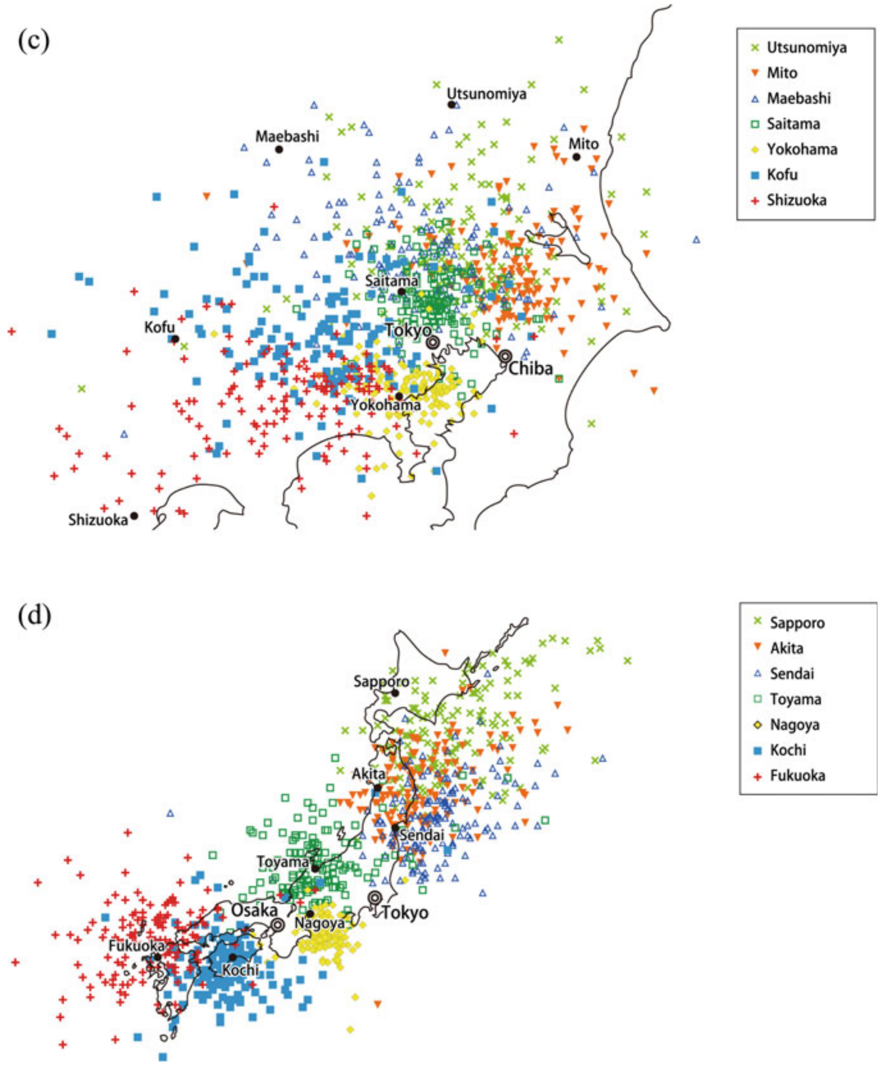


Fig. 3 (continued)

The third map exhibits the student's knowledge of the spatial relationships between a station that serves as a key transport hub and the lines to which passengers can transfer from that station. Although the student knows that the station serves as a terminus for a number of lines, they have failed to grasp the inter-station distances or the ways in which the stations connect.

These freely drawn maps imply that the way young people envisage a rail network differs from the two-dimensional spatial layout seen in typical top-down, planar visualizations. Specifically, young people envisage a topological network, as displayed

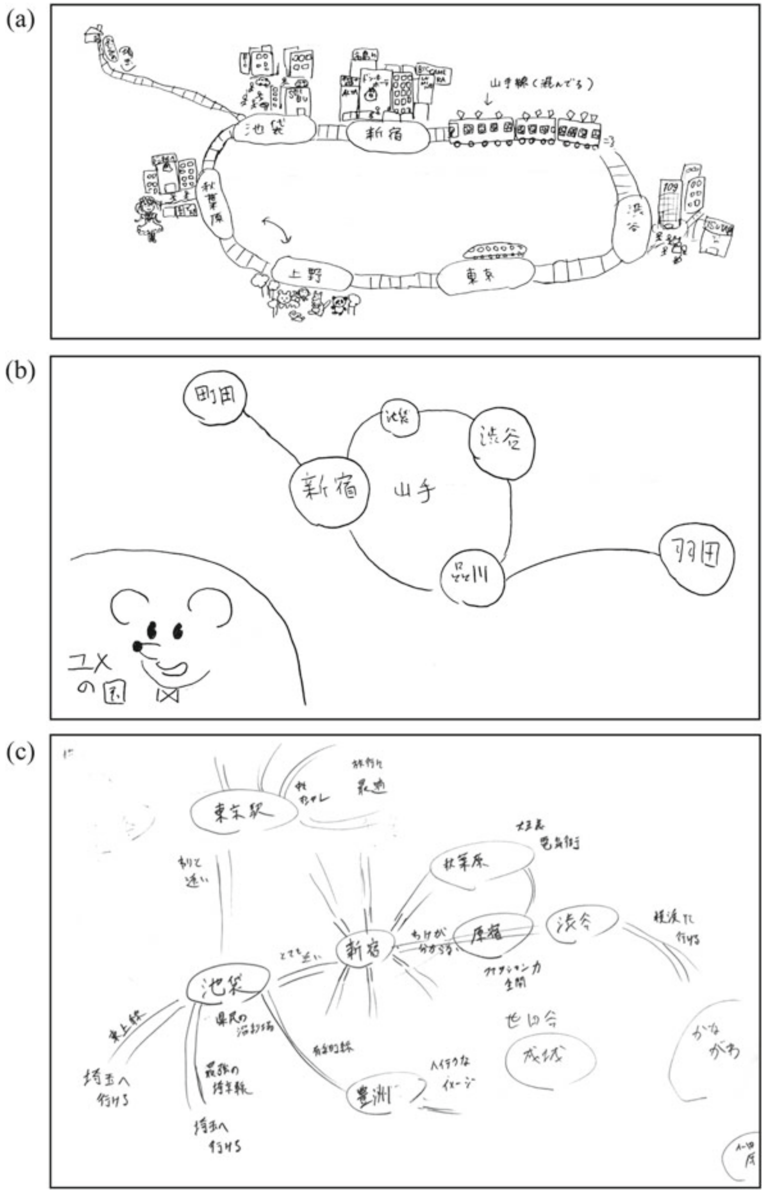


Fig. 4 Maps of the Yamanote area freely drawn by students. **a** The Yamanote Line layout is inverted, but the sequential relationship of the stations is accurate. **b** Tokyo Disneyland appears at the west when it should be at the east of the Yamanote Line. **c** The map shows the transfer station and the lines to which it is linked, but the relationship between the rail links is obscure

in a route planning tool, or in some cases, they envisage a vaguer layout that gives no idea of the internode (inter-station) connections.

In 2018, a singer who was due to a live music event missed the event because she traveled to the wrong station. Despite having intended to travel to a station in the Tokyo Bay area, she arrived at a station 50 km away in the foothills of Mount Okutama. The singer had confused the two stations because the names were orthographically similar: The intended station was Aomi (青海), and the station she traveled to was Ome (青梅). This incident illustrates a pitfall of route planning apps: If the name of a destination station is orthographically similar to that of another station, the user may inadvertently enter the wrong station into the search engine, resulting in the app displaying an incorrect route. If the user then trusts this information and follows the route as indicated, they may arrive in a rural locale even 50 km away from the intended urban destination. However, if the user has reasonable geospatial knowledge, they will notice the mistake and avoid such an eventuality. This shows that spatial knowledge is important not only during emergencies but also in normal times.

4 General Discussion

The results of Experiment 1 imply that the prevalence of smartphones, with their geolocation and route-planning apps, has significantly impeded university students' spatial knowledge of the area through which they routinely travel by rail. The older adults that participated in this study were experienced in using printed maps, having done so since pre-Internet times (when people, unlike today, could not access geospatial information whenever and wherever desired); hence, their cognitive maps of the Yamanote area were more accurate than those of the students, who relied predominantly on their smartphones to access geospatial information. In Experiment 2, we found that students' cognitive maps were particularly inaccurate, compared to other scales, at the commuting zone (Yamanote) scale, an area navigated using rail-route planning aids. This result implies that the students were dependent on the Internet; their preference for using smartphones to access route information prevented them from forming a mental image of the rail network's spatial layout. Thus, geospatial information is subject to the Google effect.

Although the Internet provides convenience, people still require cognitive maps for use in disasters as well as in normal times. Digital devices may provide little use if rail services stop running and power is cut. Accordingly, it is necessary to provide people with cartographic tools that encourage them to form cognitive maps of the areas they routinely navigate.

The COVID-19 pandemic has made geospatial information even more relevant; maps now show the areas traveled by virus carriers. Thus, people now have more occasions to view planar maps at a prefecture or municipal scale. This trend may help people develop spatial knowledge. However, these maps rarely display rail-commuting zones. Thus, it remains necessary to examine the types of cartographic visualizations that would help people mentally map the areas through which they routinely travel.

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Intergenerational Differences in the Use of Maps: Results from an Online Survey

Yoshiki Wakabayashi

Abstract Since the end of the twentieth century, the widespread availability of information and communications technology (ICT) has led to an increased use of web-based maps that has altered the utilization of geospatial information. In particular, intergenerational differences in the use of digital maps have increased due to the generation gap in the skills required to use ICT devices. This study examined variations in map usage by focusing on the characteristics of digital natives. The data used in this study were derived from an online survey of 624 people in 2018. A questionnaire was designed to gather data about the participants' current state of map use, their usage of ICT devices, their degree of geospatial awareness, and demographic attributes. Differences in map usage patterns between generational groups were examined using statistical methods. The results revealed that most people use web maps and that conventional paper maps are still widely used by middle-aged and older adults. Whereas middle-aged and older groups tended to use maps with PCs, most web map users of young generation browsed the map using a smartphone. Young people's dependence on web maps may reduce their interest in maps and geography, but they are given more benefits from new types of web maps.

Keywords Web map · Map use · Geospatial information · Digital natives

1 Introduction

The dissemination of digital maps and the Internet have promoted the use of maps on the web (web maps), including Google Maps and Yahoo! Maps. Particularly, the widespread availability of information and communications technology (ICT) has led to an increased use of web maps, which has changed the usage of geospatial information since the end of the twentieth century. These web maps have drawn the attention of cartographers. For example, a commission on maps and the Internet was established by the International Cartographic Association (ICA), and several books

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(Peterson 2005, 2008) and special issues (e.g., Cartographica Vol. 41 (1), 2006) on web maps have been published.

However, previous studies have primarily focused on the conceptual or technical aspects of web maps (Kraak and Brown 2001). A few empirical studies have been conducted on how ordinary people use maps on the web, focusing on map usability (Poplin 2015; Gottwald et al. 2016). This study focuses on the role of web maps in map use.

In previous studies on map use in Japan, Wakabayashi (2003) administered a questionnaire among university students concerning the use of various maps, spatial abilities, and personal attributes. Based on the pattern of map use, maps were classified into three types: guide maps, digital maps, and multipurpose maps. Then, factors affecting map use were examined, and personal computer (PC) use, gender, and sense of direction were found to have significant effects on map use patterns. This study was further examined by Takeuchi (2003), whose findings were consistent with those presented here.

However, several concerns, such as the evaluation of the effects of web maps, persisted. Because these studies were conducted before the advent of Google Maps in 2005, the role of web maps in the modern world was not anticipated. Murakoshi (2006) partially analyzed the role of online maps. He conducted a survey on the use of maps, including web maps, among university students. A major finding of this study was that web maps were easier to use than paper maps according to the survey respondents. Furthermore, several studies (e.g., Nivala et al. 2008) have evaluated the usability of web maps.

An additional concern is the limitation of the study samples. Because most of the previous studies only queried university students, the generalizability capacity of the findings to include the general public is unclear. In particular, intergenerational differences in the use of digital maps have apparently expanded owing to the generation gap in the skills required to use ICT devices. Hence, further investigation is required to examine the intergenerational differences in map use.

A few empirical studies have been conducted to examine the variation in the manner in which a variety of users employ web maps. To overcome these limitations, Wakabayashi (2015) examined the variation in map usage among ordinary people by making three improvements. First, data regarding how people use maps, including web maps, were collected. Second, questionnaires were administered to various people using the online survey method. Third, the patterns of map use and their influencing factors considering spatial abilities and concern about maps were analyzed. This study aims to examine the variation in map usage among ordinary people by focusing on intergenerational differences with respect to map use.

2 Intergenerational Differences in Usage of Information Technologies

Several researchers have mentioned the need for an intergenerational comparison of spatial information. Downs (2014) noted that the experiences of Generation M are qualitatively different from those of preceding cohorts due to the geospatial revolution. Additionally, Sparrow et al. (2011) referred to the tendency to forget information obtained through online searches as "Google effects."

Vrenko and Petrovic (2015) examined the challenges experienced by the elderly population when using web maps. In particular, user-friendly web mapping is required to promote public participation geographic information systems (PPGIS) (Newman et al. 2010; Poplin 2015). Gottwald et al. (2016) explored the usability of PPGIS and demonstrated that using older adults as a test group for PPGIS usability could inform the improvement of the greater public's user experience.

In the Japanese context, differences in the technological environment according to generation are summarized in Table 1, which was derived from the study by Hashimoto (2011), who administered a longitudinal survey of information behavior

Table 1 Differences among technological environments according to generations in Japan

Year	Major event in the ICT development in Japan	Generation (year of birth)			
		Digital immigrant (before 1976)	PC digital native (1976–1985)	Mobile phone digital native (1986–1995)	Neo-digital native (after 1995)
1982	NEC PC9801 was released	×	×		
1984	Apple launched Macintosh	×	×		
1987	Mobile phone service was launched	×	×	×	
1995	Windows 95 was released	×	×	×	
2001	Wikipedia was launched	×	×	×	×
2005	YouTube and Google Maps were launched	×	×	×	×
2006	Twitter service started	×	×	×	×
2008	iPhone 3G was released	×	×	×	×
2010	iPad was released	×	×	×	×

Created by the author based on Hashimoto's (2011) study among the Japanese. According to the difference in the ICT environment surrounding each age group, four generations can be distinguished.

Digital immigrants born before 1976 started using digital technologies in their adulthood; that is, they did not grow up using them. The other three generations are classified as digital natives (Prensky 2001; Tapscott 2008), which refers to the generation that grew up with digital technologies and the Internet as part of their daily lives. Specifically, *PC digital natives* born between 1976 and 1985 learned to use a PC or game player before adulthood. *Mobile phone digital natives* born between 1968 and 1995 used the Internet on mobile phones during their youth. *Neo-digital natives* born after 1995, corresponding to the so-called Generation Z or millennial generation, grew up using a variety of Internet services, including movies and social networking services (SNS).

According to the Communications Usage Trend Survey 2019 conducted by the Ministry of Public Management, Home Affairs, Posts, and Telecommunications in Japan, ICT devices for Internet connection differ according to age group, as shown in Fig. 1. This difference can affect the variations in map use among generations. Considering these conditions, this study examines the intergenerational differences in map use by focusing on digital natives.

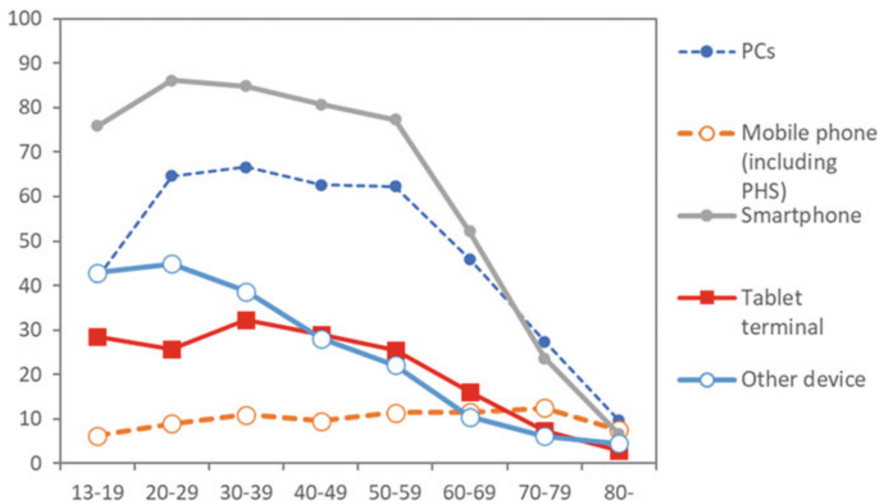


Fig. 1 Percentage of users of ICT devices for Internet connection by age group in Japan. *Source* Communications usage trend survey 2019 (Ministry of Public Management, Home Affairs, Posts, and Telecommunications)

3 Data and Methods

Data were collected through a web questionnaire survey conducted in March 2018. I outsourced sampling and data collection to an Internet-based marketing company (Macromill Co. Ltd.), which has more than two million monitors in Japan. Respondents comprised residents of fifteen years and over in the Tokyo metropolitan area and featured equal distribution among age groups and genders. I analyzed 624 valid samples.

The questionnaire covered the actual state of map use and focused on the web map evaluated according to a four-grade scale; respondents were required to choose among "frequent use," "occasional use," "rare use," and "no use." During the calculation of the number of map users, respondents that chose "frequent use" or "occasional use" were regarded as map users.

I also collected information on the usage of ICT devices, degree of interest in maps/geography, spatial abilities, changes after using web maps, and demographics (gender, age, educational background) to examine the factors affecting map use patterns and the effects of web map use.

4 Role of Web Maps in Map Use by the Average User

In this study, maps were classified into three groups: general web maps that were used for a variety of purposes, thematic web maps that portrayed the geographic pattern of a particular subject matter, and conventional maps other than web maps.

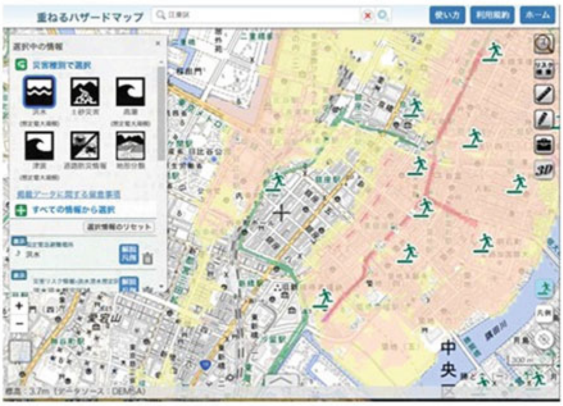
Fig. 2 Examples of the general web map

General web maps are incorporated into major search engines. Figure 2 shows typical examples of web maps: Google Maps and Yahoo! Maps. A close examination of these maps reveals a slight difference between their scheme and style. Google Maps is the most popular web map and represents the universal map scheme; that is, streets on this map are somewhat more amplified than those in Yahoo! Maps. Certain Japanese people prefer Yahoo! Maps, wherein the map style is adjusted to the conventional maps in Japan, in which the areal unit and its boundary are emphasized.

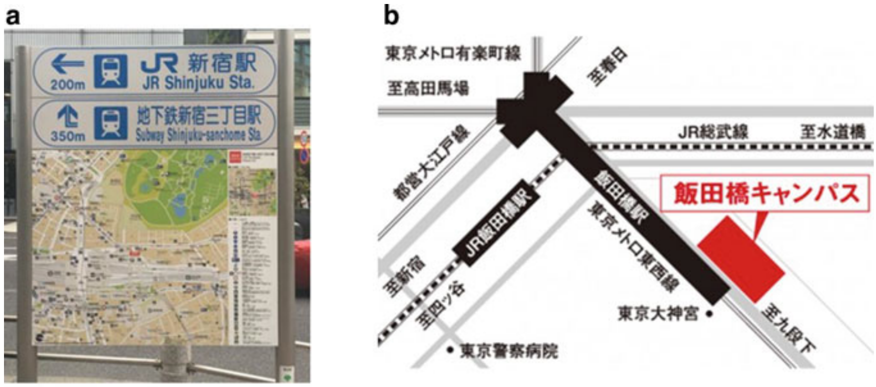
Figure 3 shows examples of the thematic web maps. For example, tourist maps are usually provided by the tourism bureau of municipalities. Recently, tourist maps have tended to use Google Maps as a base map. Hazard maps were also published by municipalities in Japan after the 1990s. This type of map shows the areas that are affected by or are vulnerable to natural hazards as well as the location of refugees from the hazard.

Fig. 3 Examples of thematic web maps

Tourist Map (https://www.gotokyo.org/jp/index.html)



Hazard Map (https://disaportal.gsi.go.jp/)



"You are here" map at the street corner

Guide map of a university campus

Fig. 4 Examples of conventional maps

Figure 4 shows examples of the conventional maps in Japan. Several "You are here" maps can be found on signboards at the street corners. Additionally, many facilities and shops provide visitors with a guide map drawn on paper. These maps are common in Japan, likely due to the difficulty of navigation in Japanese cities. Certain Western scholars (Rudofsky 1965; Barthes 1970) mentioned that Japanese people are good at using hand-drawn maps to find their way in the absence of street names.

The usage of each type of map is presented in Table 2. The results show that a considerable portion of the respondents still use conventional maps, such as guide maps and road maps. Among general web maps, Google Maps and Yahoo! Maps are used by most people. A variety of thematic maps are available on Japanese websites; however, only a few of them, except for tourist maps, are used by the general public.

Table 2 Number of users for each type of maps

General web maps	*N*	Thematic web maps	*N*	Conventional maps	*N*
Google Maps	466	Tourist maps	227	Tourist maps	320
Yahoo! Maps	299	Hazard maps	72	Guide maps on signboard	297
Mapion	106	Medical/welfare maps	53	Vehicle navigation system	263
iOS Map	97	Radiation dosage maps	37	Road maps	230
MapFan	47	GSI maps	34	Guide maps in magazines	215
Bing Maps	17	Crime maps	23	Housing map	107
Others	12	Childcare/childrearing maps	17	Topographic map of GSI	43

Source Questionnaire survey by the author

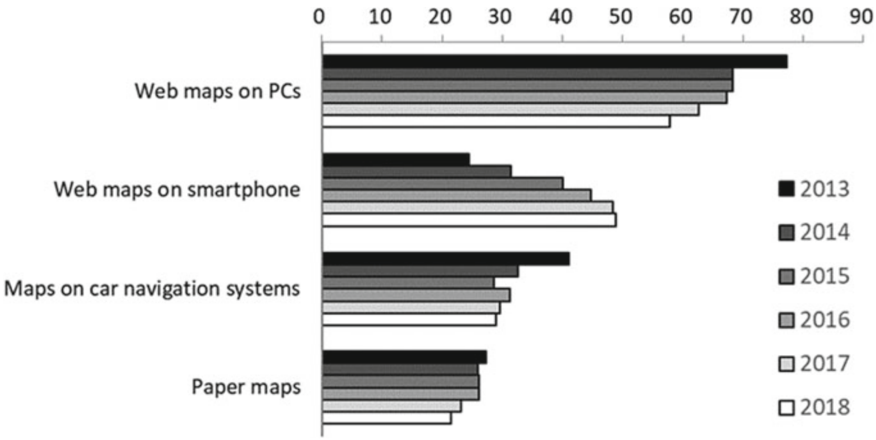


Fig. 5 Trend of the percentage of users for major types of maps. *Source* Research on map use by Zenrin Corporation (2013–2018)

A considerable number of respondents still use conventional maps, such as guide maps and road maps.

These facts are confirmed by a research report on map use conducted by the Zenrin Corporation. This report summarizes the trend of map use based on an online survey of approximately 20,000 Internet users in Japan between 2013 and 2018. Figure 5 shows a section of this report by selecting four major types of maps. This figure indicates a sharp decline in the number of map users on PCs and car navigation systems. Conversely, a marked increase in the number of smartphone users was observed. Nevertheless, some people continue to use paper maps classified as conventional maps.

5 Intergenerational Differences in Map Use: Analysis and Discussions

5.1 Use of General Web Maps

Table 3 shows the percentage of users of general web maps according to age group. Google Maps is used by more than 80% of the respondents; younger people use it a little more than the elderly population. In contrast, Yahoo! Maps, which is designed according to a conventional style of Japanese maps, is principally used by the middle-aged and elderly populations. However, the iOS Map is preferred by young people, probably because Apple's computers and devices are popular with young people.

Table 3 Percentage of users of general web maps by age group

General web maps	Age group						Total	
	10 s	20 s	30 s	40 s	50 s	60–	$N = 544$	
Google Maps	82.7	91.3	88.5	74.0	76.9	72.1	80.9	**
Yahoo! Maps	18.3	26.9	40.4	48.1	56.7	52.9	40.5	**
Bing Map	2.9	2.9	1.9	1.0	1.9	3.8	2.4	
iOS Map	34.6	23.1	20.2	18.3	17.3	3.8	19.6	**
Mapion	1.9	1.9	9.6	8.7	15.4	12.5	8.3	**
MapFan Web	4.8	1.9	2.9	3.8	5.8	1.0	3.4	

Percent of answers "frequent use" or "occasional use"
Result of the chi-square test: *$p < 0.05$, **$p < 0.01$

Table 4 Percentage of devises for using web maps according to age group

Device for using web maps	Age group						Total	
	10 s	20 s	30 s	40 s	50 s	60–	$N = 600$	
Desktop PC	21.2	26.0	40.4	43.3	43.3	49.0	37.2	*:
Laptop PC	43.3	47.1	51.9	50.0	62.5	63.5	53.0	*
Tablet PC	24.0	21.2	23.1	21.2	23.1	23.1	22.6	
Smartphone	96.2	94.2	87.5	84.6	74.0	36.5	78.8	**
Mobile phone	7.7	1.9	2.9	1.0	1.9	7.7	3.8	*

Percent of answers "frequent use" or "occasional use"
Result of the chi-square test: *$p < 0.05$, **$p < 0.01$

5.2 *Device for Using Web Maps*

Intergenerational differences regarding web map use are related to the device used to access them (Table 4). The middle-aged and elderly populations tend to use laptops and desktop PCs. In contrast, young people prefer to use mobile devices, such as smartphones equipped with satellite navigation systems (e.g., GPS), to access web maps. This can be reflected in young people's use of web maps for the on-site checking of locations. Hence, young people tend to use web maps for navigation and route finding, while middle-aged and elderly populations use them for navigation and other purposes.

5.3 *Use of Conventional Maps*

According to Table 5, which shows the percentage of users of conventional maps according to age group, conventional maps including vehicle navigation systems are mainly used by the middle-aged and elderly populations. In contrast, young people

Table 5 Percentage of users of conventional maps by age group

Conventional maps	Age group						Total	
	10 s	20 s	30 s	40 s	50 s	60–	$N = 474$	
Road maps	16.3	17.3	22.1	26.0	30.8	45.2	26.3	**
Tourist maps	41.3	43.3	58.7	47.1	51.0	67.3	51.4	**
Guide maps in magazines	26.9	25.0	39.4	32.7	39.4	34.6	33.0	
Guide maps on outdoor signboard	50.0	38.5	57.7	47.1	51.9	45.2	48.4	
Vehicle navigation system	30.8	46.2	62.5	60.6	51.9	46.2	49.7	**
Housing map	8.7	11.5	12.5	19.2	17.3	33.7	17.1	**
Topographic map of GSI	4.8	4.8	3.8	6.7	6.7	17.3	7.4	**

Percent of answers “frequent use” or “occasional use”
Result of the chi-square test: *$p < 0.05$, **$p < 0.01$

use fewer conventional or paper maps, which characterizes the digital natives. Road maps and vehicle navigation systems are less frequently used by young people, which implies that young people either drive less or are satisfied with navigation systems built into their smartphones. Among the conventional maps, guide maps in magazines or outdoor signboards are commonly used by all age groups.

5.4 Map Literacy

To evaluate the effects of intergenerational differences in map use on people’s map literacy, the percentage of answers to the items of map literacy by age group were compared. The map literacy items were listed based on Hayashi’s (2016) study. As shown in Table 6, only a small percentage of younger respondents could draw a rough map, which implies that young people have rarely drawn maps in the past.

Table 6 Percentage of answers to the items of map literacy according to age group

Map use literacy	Age group						Total	
	10 s	20 s	30 s	40 s	50 s	60–	$N = 599$	
Be able to draw a rough map	76.0	69.2	81.7	78.8	82.7	86.5	79.2	*
Prefer maps aligned with direction	71.2	67.3	70.2	79.8	78.8	78.8	74.4	
Get lost even using maps	56.7	60.6	54.8	54.8	53.8	49.0	55.0	
Easy to find shortest path	41.3	36.5	46.2	44.2	46.2	51.0	44.2	
Easy to estimate movement time	30.8	27.9	35.6	36.5	37.5	42.3	35.1	
Prefer digital map than paper map	16.3	14.4	30.8	42.3	42.3	55.8	33.7	**
Ask someone in unfamiliar place	20.2	32.7	32.7	29.8	37.5	55.8	34.8	**

Result of the chi-square test: *$p < 0.05$, **$p < 0.01$

Table 7 Percentage of answers to the items of geospatial awareness by age group

Interest in maps/geography and spatial abilities	Age group						Total	
	10 s	20 s	30 s	40 s	50 s	60–	$N = 520$	
Map lover	44.2	47.1	51.9	55.8	63.5	63.5	54.3	*
Interested in geography	39.4	42.3	42.3	44.2	52.9	56.7	46.3	
Good at science subjects	38.5	37.5	36.5	33.7	36.5	36.5	36.5	
Good at using ICT apparatus	45.2	42.3	44.2	42.3	39.4	29.8	40.5	
Good sense of direction	35.6	31.7	43.3	43.3	41.3	40.4	39.3	
Frequently drive a car	16.3	33.7	47.1	40.4	40.4	40.4	36.4	**
Good at model building, paper folding	42.3	28.8	42.3	35.6	36.5	35.6	36.9	

Result of the chi-square test: $*p < 0.05$, $**p < 0.01$

The marked difference between age groups is statistically significant in the answer to the item of "prefer digital map over paper map." This means that only a few young people considered paper maps easier to use than web maps. Additionally, young people tend not to enquire about a route, which implies that they rely more on IT devices than other people.

5.5 Geospatial Awareness

Intergenerational differences in map use can also be affected by the degree of geospatial awareness, which is measured by interest in maps/geography and spatial thinking abilities. To examine this, I analyzed the answers to the questions on these matters.

Table 7 shows that young people appear to be less interested in maps and geography. This can be caused by young people's way of using web maps and supposedly affected by their superficial map reading, and limited view of mobile devices. Hence, young people's heavy dependence on web maps may reduce concerns for maps and geography.

5.6 Changes After Using Web Maps

The above-mentioned facts suggest that young people do not use maps, especially paper maps. Nevertheless, Table 8 shows that a large percentage of middle-aged and elderly respondents answered "less use of paper maps." This can be interpreted to mean that younger people considered to be digital natives do not use paper maps. However, young people are given more benefit from new types of web maps, which is verified by a large percentage of young respondents who answered "seldom lose one's way" or "expansion of activity range."

Table 8 Percentage of answers to the items of change after using web maps by age group

Changes after using web maps	Age group						Total	
	10 s	20 s	30 s	40 s	50 s	60–	$N = 614$	
Seldom lose one's way	73.1	69.2	68.3	72.1	58.7	38.5	63.3	**
Be able to behave efficiently	52.9	47.1	58.7	49.0	61.5	44.2	52.2	
Expansion of activity range	45.2	38.5	26.0	17.3	11.5	16.3	25.8	**
Expansion of region of interest	18.3	13.5	23.1	21.2	21.2	22.1	19.9	
Less use of paper maps	7.7	7.7	25.0	19.2	26.9	27.9	19.1	**
Increased interest in geography	15.4	9.6	10.6	14.4	6.7	12.5	11.5	

Result of the chi-square test: *$p < 0.05$, **$p < 0.01$

6 Discussion

These findings obtained are consistent with those of the research on map use by Zenrin Corporation in 2018. Table 9, which summarizes a section of the report, shows some intergenerational differences in the use of maps. Younger people tend

Table 9 Percentage of users of various maps according to generation and gender

Age group/gender	Number of samples	Map use within one year	Map use					Never used a map within one year
			Web map on PCs	Web maps on smartphone	LBS on smartphone	Car navigation system	Paper maps	
Total	20,000	84.1	57.8	48.8	26.9	29.0	21.4	15.9
Male								
18–19	297	83.2	36.4	60.9	27.3	11.1	12.5	16.8
20–29	1,533	80.1	50.2	53.0	27.9	20.2	14.7	19.9
30–39	1,913	83.4	60.8	53.7	26.4	29.1	18.2	16.6
40–49	2,255	87.8	68.9	54.5	26.2	36.0	20.7	12.2
50–59	1,871	89.5	77.4	50.2	25.0	42.1	23.4	10.5
60–69	2,140	90.6	80.2	40.1	22.1	46.7	28.6	9.4
Female								
18–19	285	88.1	32.6	62.8	45.3	10.5	19.6	11.9
20–29	1,474	85.0	34.5	65.2	40.2	20.4	20.3	15.0
30–39	1,875	82.3	36.1	59.6	34.0	24.7	18.7	17.7
40–49	2,218	81.5	46.5	49.1	28.0	22.2	19.5	18.5
50–59	1,883	80.6	58.5	39.4	24.3	24.9	23.4	19.4
60–69	2,256	79.3	61.9	27.8	17.3	23.9	25.9	20.7

Source Research on map use by Zenrin Corporation in 2018 to use maps via smartphones, while the middle-aged and older population prefer to access maps via PCs and paper maps. This table also indicates certain gender differences: maps on PCs and car navigation systems are used more by males than females. In contrast, young females tend to use web maps or location-based services (LBSs) via smartphones. Therefore, further examination is required to determine the confounding effects of sex and generation.

Considering the findings of previous studies, the accustomed use of navigation tools may have negative effects on people's geospatial awareness. For example, Ishikawa (2019) pointed out that frequent users of pedestrian navigation systems tended to have low sense of direction and mental navigation, while long-term users of maps tended to have high sense of direction and favored survey navigation strategies.

An analysis of the relationship between map use and map literacy (Table 6) and geospatial awareness (Table 7) revealed that younger respondents preferred digital maps to paper maps and tended not to ask for directions but relied on ICT tools to find their way. As some studies have pointed out that the accustomed use of navigation tools may have negative effects on people's geospatial awareness, young people's dependence on web maps may reduce their interest in maps and geography, which is characteristic of the millennial generation.

However, Table 8 indicates that young people are given more benefits from new types of web maps. Hence, the negative and positive effects of the usage of web maps should be evaluated. In fact, reliance on the Internet can be regarded as an extension of the "transactive memory system" (Wegner et al. 1985) to the cloud. As we no longer need to remember certain facts, we may be able to use our newly available mental resources for ambitious undertakings (Wegner and Ward 2013). Therefore, further examination should focus on the positive aspects of Internet usage.

7 Conclusions

In this study, I examined variations in map usage by analyzing intergenerational differences. The results revealed that most people were found to use web maps, while conventional paper maps continue to be extensively used by the middle-aged and elderly populations. While middle-aged and older groups tended to use maps via PCs or conventional maps, younger people used web maps mainly via smartphones. The young generation's considerable reliance on online maps may reduce their interest in maps and geography as well as geospatial awareness according to the Google effect. Conversely, young people benefit significantly from web maps integrated in the Internet. Hence, the negative and positive effects of the usage of web maps should be evaluated, as mentioned in the preceding section.

However, this study has several limitations with respect to the data and analytical method. Concerning the data, the sample should be expanded to represent non-Internet users. The availability of data from non-Internet users will allow the identification of wide diversities in map use between generations.

Methodologically, intergenerational differences should be further examined by distinguishing between age, period, and cohort effects. Age effects are variations linked to biological and social processes of aging specific to individuals (physiologic changes and accumulation of social experiences linked to aging). Period effects result from external factors that equally affect all age groups at a particular calendar time. They could arise from a range of environmental, social, and economic factors (e.g., war, famine, and economic crisis). Cohort effects are variations resulting from the unique experience/exposure of a group of subjects (cohort) as they move across time. The most commonly defined group in epidemiology is the birth cohort based on the year of birth. There is scope for further research on these issues.

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Development of OpenStreetMap Data in Japan

Toshikazu Seto

Abstract The development of volunteered geographic information (VGI) in Japan, especially the use of OpenStreetMap (OSM), became active after the Great East Japan Earthquake in March 2011. In addition, crisis mapping for disaster response and OSM activities have been under constant development in Japan since 2011. For the first time, the long-term evolution of OSM activities in the region and the number of contributors (mappers) was analyzed over the last 12 years. To clarify the regional differences, the coverage of some characteristic OSM features in each prefecture was clarified using OSM historical dump data and the ohsome API. The number of mappers increased significantly in response to several disaster events that occurred in Japan and has been increasing daily since 2016. Since 2016, OSM activities have been conducted outside major cities, and the development of residential road data has progressed. However, the creation of building data and the updating of road widths of major roads have not progressed significantly due to limited data maintenance.

Keywords Contributors (mappers) · OpenStreetMap (OSM) · Ohsome API · Volunteered geographic information (VGI)

1 Introduction

In addition to the conventional mapping methods where the government or public agencies survey the areas and create maps, open-source digital maps have been created mainly by the voluntary participation of individuals through the internet. This "volunteered geographic information (VGI)" has emerged since the late 2000s (Goodchild 2007). VGI includes information regarding stores and facilities shared via social media and basic geospatial information such as roads, buildings, and land use. In recent years, experts and citizens have been working together to conduct environmental monitoring and ecological surveys using smartphones and inexpensive sensor devices, and the results of these surveys have contributed to scientific

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knowledge in activities such as citizen science (Hecker et al. 2018). These activities have made it possible to use a variety of elements for research materials that were previously difficult to collect on a large scale by researchers alone.

This chapter focuses on OpenStreetMap (OSM), which is currently the most globally active participatory mapping platform (Arsanjani et al. 2015) and has been active in Japan since the Great East Japan Earthquake (GEJE) occurred in March 2011. The purpose of this contribution was to clarify the characteristic trends and status of the data creation method and the number of contributors (mappers) in Japan as a function of time and space via prefecture unit. The study that precedes this discussion, Seto and Nishimura (2016) analyzed the OSM activities in the form of crisis mapping after the GEJE. This chapter extends their analysis by investigating the trends in OSM data production over a longer period and over the entire country.

2 OSM as a VGI Infrastructure

Based on the concept of crowdsourcing, OSM was launched in the UK in 2004 as a project to create a global geospatial database that can be edited by anyone at any time and is intended for secondary use under a “free” license. As of December 2020, the number of mappers registered in OSM was more than 7.2 million, and a total of more than 6.5 billion points (nodes) of geospatial information have been entered in more than 180 countries and regions. OSM has four features, one of which is the recommendation of “on the ground” verification of information. A major turning point in the increase of data and users worldwide was the permission provided by Microsoft in November 2010 to trace data using Bing satellite imagery.

The data structure of OSM is composed of the original OSM XML format, which includes the location and geographic shapes (node/way/relation) of the geographic feature, along with the attributes and definitions of the geographic feature, the name of the user who edited the data, the edited version, and the timestamp. The data is updated in real-time on the server managed by the OpenStreetMap Foundation, a non-profit organization in the UK.

OSM can be used both as a background image on the website, and as the original data. Users who want to obtain the data can use various APIs or obtain data in the form of a dump file called Planet.osm, which is a single global data file, from several mirror sites with a daily or weekly update frequency. In the XML format, the total size of the database is approximately 1300 GB as of December 2020. One of the main features of OSM is that both the shape of the geographic features and its attributes can be freely extended based on certain rules, such as taginfo.openstreetmap.org, which lists Earth’s data attributes, including more than 80,000 types of geographic features (keys) and more than 110 million attribute values (values) (Fig. 1). The most common keys are building = * (type of building), source = * (name of the data source referred to by the user during data entry), and highway = * (type of road), in that order, indicating that these are the major data shared globally by OSM. The most common combination of key = value is building = yes, which indicates that

Fig. 1 Attribute (Key) data of OSM commonly used in Japan. (*Resource* http://taginfo.openstreetmap.jp/)

the object is a building, and approximately 430 million objects are registered in this way in the OSM database.

VGI is generally not guaranteed to be as accurate as GIS data provided by national or professional organizations. Because of the voluntary nature of the contributions, the quality of the data depends on the skills of the user, and the data quality is inconsistent. However, since OSM is geospatial information that can be used globally in the same format and under an open license, it has been highly valuable for research organizations and various business applications, including secondary use. Since the 2010s because of the global trend of open data policy (e.g., in Denmark, France, and Canada), the incorporation of surveyed land registry data and building data held by government agencies into OSM, or "data import," has been actively promoted. There has also been progress in research assessing the accuracy and completeness of OSM data (Brovelli and Zamboni 2018). Therefore, in recent years, OSM data has been used as the basic data for global geospatial analysis in many international journals, as well as papers in fields other than cartography (Ibisch et al. 2016; Fan et al. 2014; Haklay and Weber 2008).

3 Development of Related Technologies and Services for Data Enrichment of OSM

The development of the OSM platform was initially based on personal hobbies and leisure time, as is typical of voluntary activities. "Mapping parties" are a representative initiative of the OSM community, where mappers meet to create data and perform fieldwork for producing OSM maps. Such events have been held since the early days of OSM, and frequently occur around the world. These events provide opportunities for basic OSM lectures and consultations, especially for beginners, and serve as an opportunity to encourage newcomers to take up the activity. Similarly, in an effort to efficiently support basic mapping and disaster response in developing countries, a program called "Missing Maps (http://www.missingmaps.org/)" is being conducted to enrich data from satellite imagery and other sources outside the region, focusing on blank areas where OSM data has not yet been added. This project is also being undertaken by the American and British Red Cross, Médecins Sans Frontières, and the Humanitarian OpenStreetMap Team (HOT), and has become a training ground for beginners and students.

The efforts to adapt OSM for specific applications have been actively developed since the 2010s. One representative use is crisis mapping, which is a mapping activity that aims to help victims and first responders in a disaster situation and in disaster-prevention planning. Often, mapping of a disaster area using aerial photographs and satellite images taken before and after the disaster is performed. The maps developed during such projects have been shared through a platform called the HOT Tasking Manager (https://tasks.hotosm.org/). In addition, in recent years, major companies that use OSM for business purposes, such as automated driving and mobility, along with venture capital companies that develop services to support the OSM community, have been working on various initiatives to improve data quality and automatic mapping (Anderson et al. 2019). In Japan, OSM activities are mainly community based, and Japanese corporate mapping is not yet widespread, although it is attracting attention in East Asian countries, which have recently started OSM map development.

4 Spatio-Temporal Analysis of OSM Activities in Japan

To analyze the OSM data, the existing tool OSMstats (https://osmstats.neis-one.org/) was used to describe the trends and daily activities of mappers using the dashboard for each country. Because OSM is open-source data, dump files are distributed as archived data in various ways (e.g., classified by day, week, or country). Web-based data filtering services (e.g., https://overpass-turbo.eu/) are available, and advanced spatial analysis is possible using GIS software. However, if dump data from all over Japan were to be developed into GIS data for spatial analysis, it would be more than 10 GB in size. It is difficult to analyze the time-lapse of archived data because it is a snapshot of the current time. Therefore, this study analyzed the temporal and spatial progression of data using two approaches.

- The number of mappers in Japan was analyzed by developing a script for aggregation using “japan-internal.osh.pbf,” provided by Geofabrik. These data contain information such as mapper IDs, nicknames, and changesets, which can only be analyzed by OSM contributors. From these data, the monthly activity status of the mapper and the data when the mapper first edited the area were analyzed. The number of mappers in Japan was analyzed by developing a script for aggregation using "japan-internal.osh.pbf," provided by Geofabrik. These data contain information such as mapper IDs, nicknames, and changesets, which can only be analyzed by OSM contributors. From these data, the monthly activity status of the mapper and the data when the mapper first edited the area were analyzed.
- We also used the ohsome API provided by the Heidelberg Institute for Geoinformation Technology at Heidelberg University (HeiGIT) to aggregate the data creation status of each geographic feature and the number of anonymized users. The system uses an API metrics. In this system, count/length/area/user can be specified by the argument “–measure” and the date and time of aggregation (from October 8, 2007, to December 11, 2020) can also be specified. The spatial range can also be defined by the bploys function in the OSM Boundaries Map. In this paper, we present the results for each prefecture in Japan based on the upper limit of API requests.

4.1 Evolution of the Number of OSM Mappers in Japan

In this section, the evolution in the number of mappers who created OSM data in Japan from January 2008 to November 2020 is discussed. There is a setting on profiles in the OSM account, but the residence of each mapper is not clear. First, the monthly trends are presented, followed by the cumulative number of mappers, and finally, the date when the mapper, who edited Japan, first mapped the country.

Figure 2 shows the monthly number of mappers that compiled OSM data for Japan. The first major wave of OSM mapping in Japan was related to the GEJE, with 484 unique users in the month of March 2011. The average for the entire period was 545 users (black dotted line), and the first time it exceeded the average was in October 2012. This is thought to be related to the timing of the OSM international conference, State of the Map held for the first time in Asia, in Tokyo, in September 2012. The first time that the number of monthly unique users exceeded 1000 was four years later, in April 2016, likely predominantly due to the mapping activities during the Kumamoto earthquake. Since then, an average of 1000 users per month was recorded,

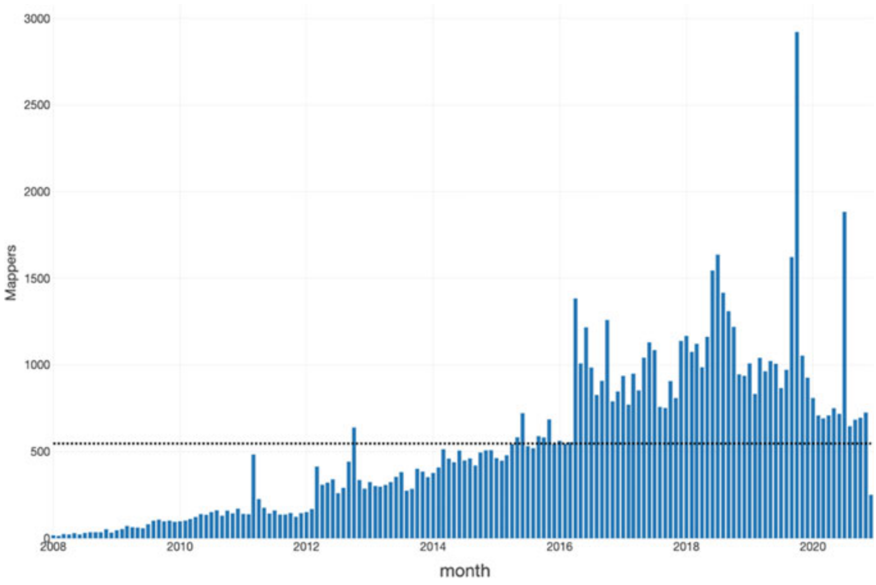

Fig. 2 Monthly number of mappers that compiled OSM data for Japan. The dotted line is the average value for the entire period

while in June–July 2018, it exceeded 1500 users. The largest number of unique users per month was 2922 in October 2019. Crisis mapping activities associated with two significant typhoons were underway in Japae, but the editing was not concentrated only within a specific region. Mapping parties and several community activities in various regions were active, and one of the factors may have been purely due to the nationwide increase in new OSM mappers. The number of unique mappers in Japan is approximately 100 per day (around 20th place globally). For comparison, this value is 690 mappers in Germany, which often ranks first worldwide, according to the results of OSMstats, which publishes various real-time OSM statistics.

In the monthly statistics, if a mapper with the same account edits every month, it is counted as a unique user every month, so the cumulative number of mappers involved in OSM editing in Japan is also shown in Fig. 3 by tallying the number of unique users from January 2008 to December 2020. The cumulative number of mappers who have edited in Japan exceeded 1,000 users for the first time in January 2011. The cumulative number of mappers who have edited in Japan exceeded 1,000 for the first time in January 2011, and then exceeded 10,000 in April 2016, indicating a faster increase in recent years. Furthermore, 2,000 additional mappers were added in September and October 2019, where the total cumulative number of mappers to date is approaching 35,000. However, as has been discussed in the OSM community for some time, there is also the issue of mapper motivation (persistence and continuity), and the number of mappers who have joined in recent years that are regularly active or have left the community. There is also a need for further analysis, such as aggregation,

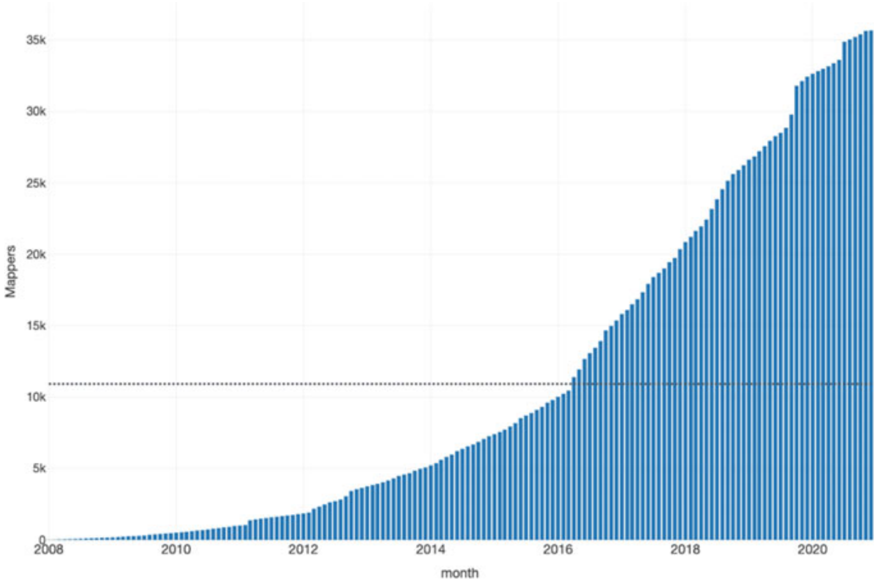

Fig. 3 Cumulative number of mappers. The dotted line is the average value for the entire period

of the extent to which mappers who have participated in recent years are regularly engaged in activities.

Next, we identified the month in which the mapper first edited Japan on the OSM, as shown in Fig. 4. Similar to the results shown earlier, there were large waves in March 2011, October 2012, April 2016, and October 2019. Although some of these mappers may have edited outside of Japan before this, these periods are major points of OSM participation in Japan. The overall average number of new mappers was 230 per month, but since April 2016, this number has frequently exceeded 500, which coincides with the time when mapping parties extended beyond the high populated Kyoto and Tokyo suburbs to a nationwide level. The number of participants has been slightly lower than the average since January 2020, probably due to restrictions on mapping parties during the COVID-19 pandemic. However, in July 2020, more than 1,200 new mappers were active again, coinciding with the launch of the HOT Tasking Manager after the river flooding caused by torrential rains in the Kyushu area in early July (Fig. 5).

4.2 Evolution of OSM Data Creation by Key Type and Region

In this section, the evolution of the number of mappers and the status of data creation classified by selected key types are presented. In addition, to understand the regional differences in the data, HeiGIT's ohsome API was used to obtain data

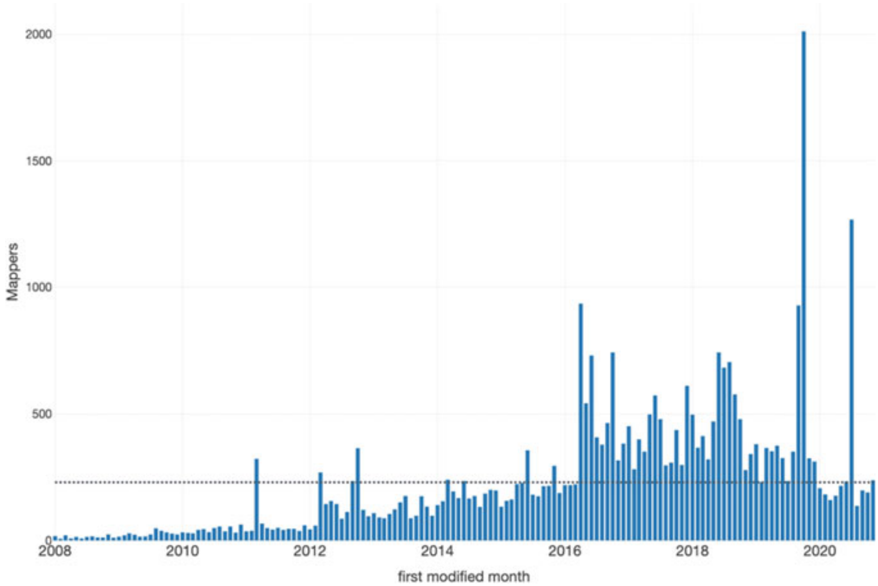

Fig. 4 Number of mappers per month who first edited data for Japan. The dotted line is the average value for the entire period

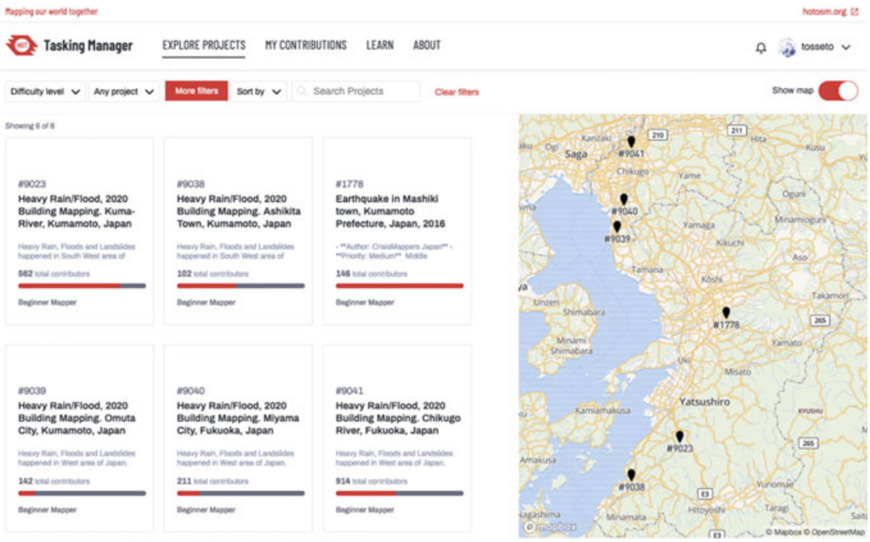

Fig. 5 Crisis mapping in response to the torrential rain in the Kyushu area in July 2020. (*Resource* https://tasks.hotosm.org/)

from January 2008 to the end of November 2020 (the same period as analyzed in the previous sections), categorized by three key types: amenity, building, and highway = residential. All of these map features are among the most input data in Japan.

4.2.1 Amenity Data

The amenity key describes important facilities and parking lots in a community, such as schools and hospitals. As shown in Fig. 6a, since the GEJE in 2011, open data has been gradually developed in Japan, and the number of mapped data features has gradually increased to more than 820,000 nationwide since September 2012. Figure 6b shows the number of amenities per 1000 people in each prefecture. In the Tohoku region, Miyagi and Yamagata tended to have the most mapped tourism site for example temples.

4.2.2 Building Data

The mapping of buildings accounts for a large proportion of the basic OSM data. According to the building statistics data of private companies; Zenrin Co., Ltd., the number of buildings in Japan is approximately 40 million as of February 2020 (https://resas.go.jp/building-usage-situation/). According to Fig. 7a, approximately 14 million buildings were mapped by OSM. In Japan, there is no large-scale open data on buildings at the national level, nor is it imported, so it is necessary to trace them from aerial photographs. In particular, the Kumamoto earthquake in April 2016 caused widespread damage, and large-scale crisis mapping using the "HOT Tasking Manager" was conducted by more than 1,300 mappers. Subsequently, many mappers participated in the same way in July 2018 and October 2019. Figure 7b compares the number of buildings mapped by OSM and the percentage of buildings mapped by each prefecture in the building statistics data shown above. In these prefectures, the mapping of buildings has progressed because of the sustained mapping parties and community activities.

4.2.3 Road of "Highway = Residential" Data

In addition to building data, highways, which indicate the centerline of a road, are typical elements of OSM data in Japan. However, such data differs greatly from the building data in that it can be used with road data for all of Japan provided by Yahoo! Japan. Because highways are a very large dataset, it is difficult to aggregate all values by prefecture because of the specification of the ohsome API. Therefore, we focused on residential roads, which tend to show regional differences among highways. As shown in Fig. 8a a sharp upward curve occurred between April 2011 and July 2013, indicating a large increase in the import of road data. Thereafter, although the number of mappers increased for crisis mapping, the increase in data

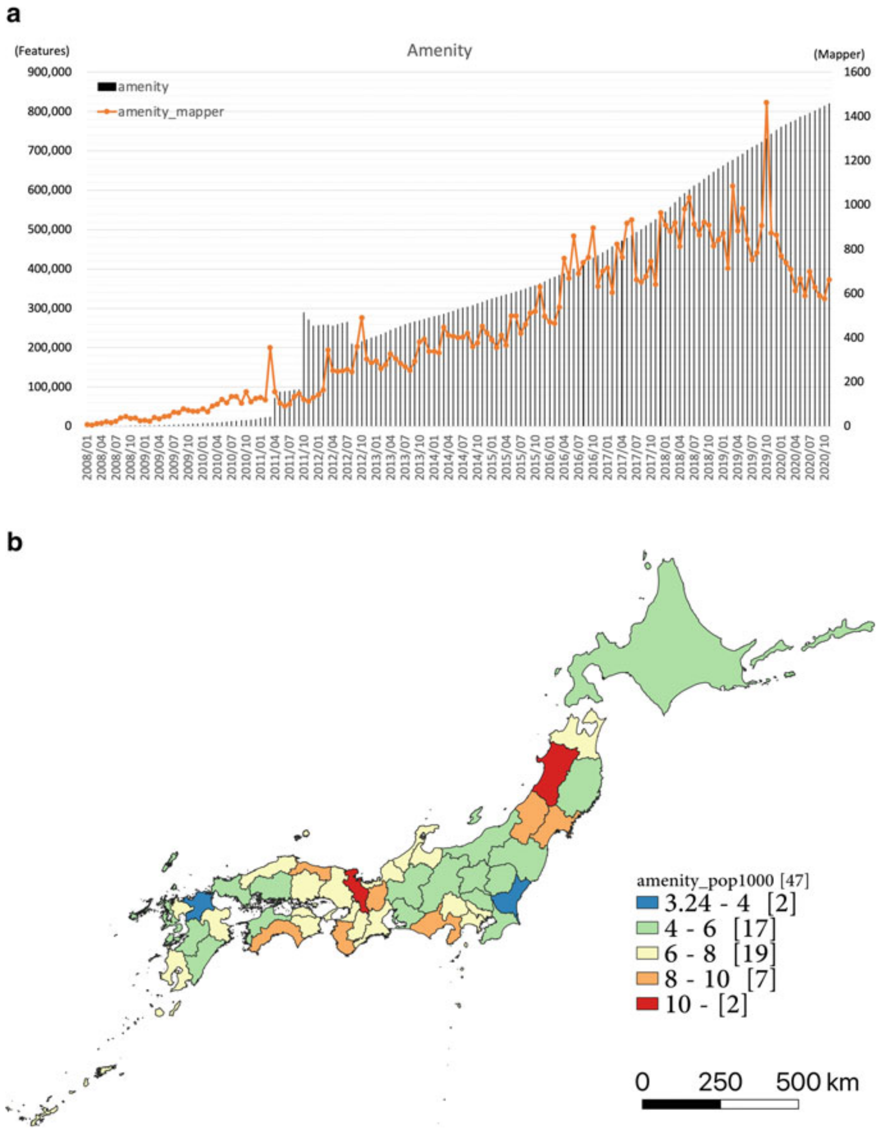

Fig. 6 Trends in the development of amenity data **a** Number of features and contributors by month. **b** Number of features per 1000 inhabitants in each prefecture

was only gradual compared to the building key period (Fig. 7a). Furthermore, the total length of imported road data decreased by approximately 10,000 km from October to November 2019 due to data consolidation. Figure 8b shows the total length of residential roads in each prefecture (based on 2019 statistical data from the Ministry of Land, Infrastructure, Transport, and Tourism) and the percentage of data generated

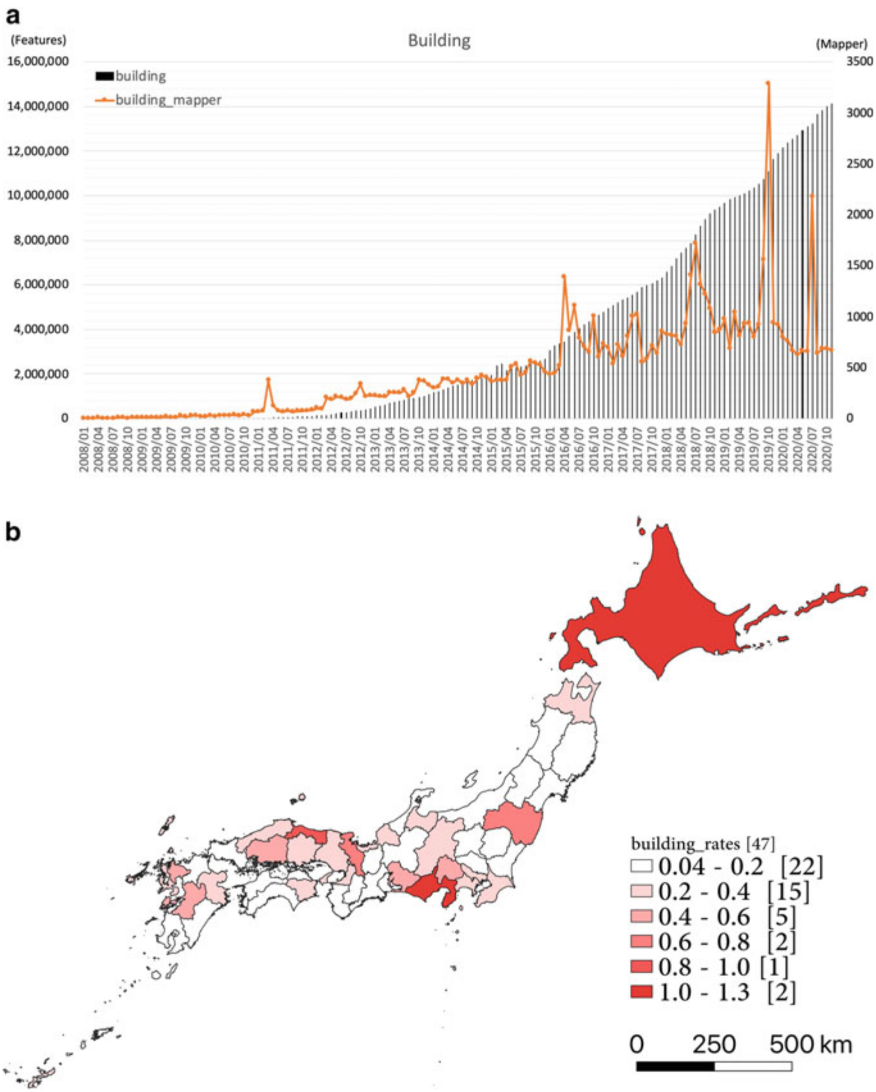

Fig. 7 Evolution of the development of building data. **a** Number of OSM features and contributors by month. **b** Number of features per building registered in each prefecture

by OSM. It found that some prefectures had not updated their data after importing Yahoo! Japan's data.

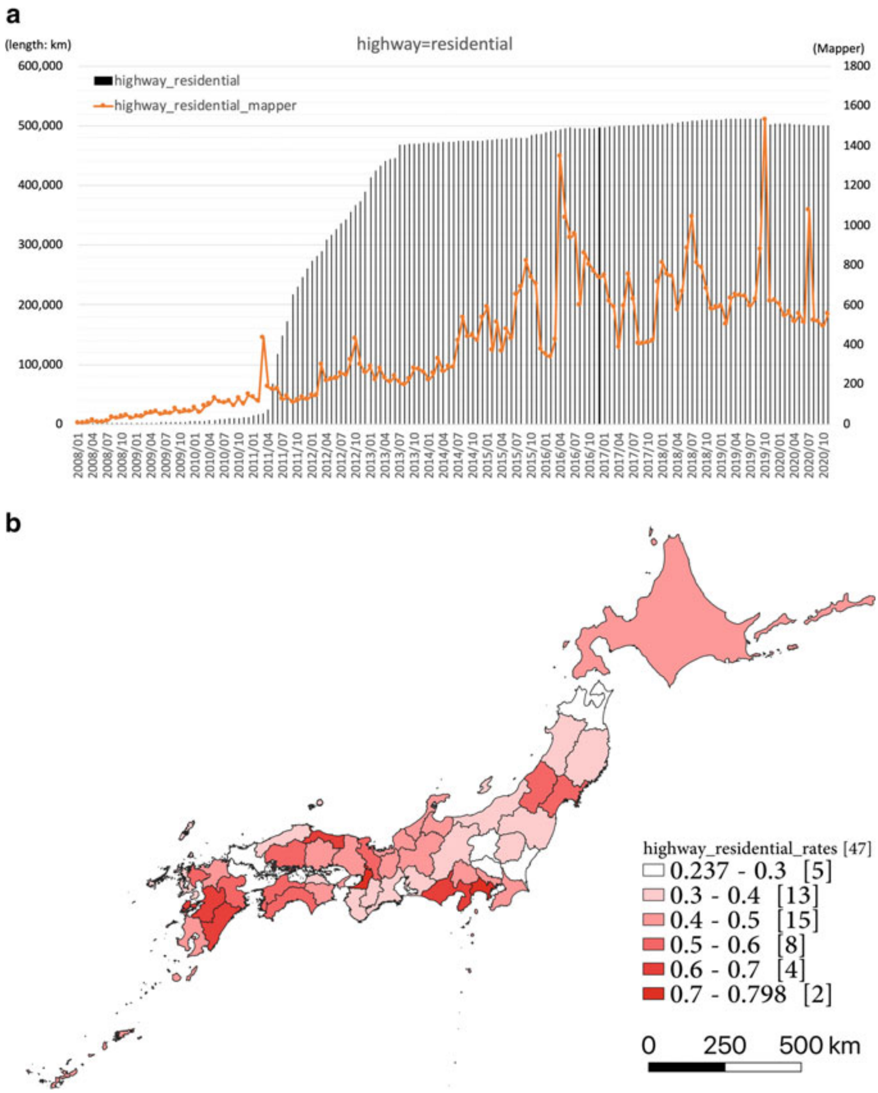

Fig. 8 Evolution of "highway = residential" data development. **a** Number of features and contributors by month. **b** Length of OSM road data per total length of roads by prefecture

5 Conclusions

This paper presents a time-series analysis of OSM dump data to clarify the trends in the creation of OSM data over the last 12 years, including the number of mappers and regional differences in Japan. The number of mappers editing OSM data in Japan increased significantly in response to several disaster events in Japan, where analysis of the cumulative values showed that there were several turning points in 2016 and 2019. The highest number of mappers per month was about 3000 in October 2019, where about 2000 of them were the first mappers to edit a region in Japan. In addition, the spatial analysis of several characteristic keys showed that OSM activities have been developed outside of large cities since 2016, in particular for building data. In contrast, the data for residential roads has not progressed significantly, and there are some issues regarding data maintenance, where some road data has not been updated significantly for approximately 2–3 years. Because roads do not change as frequently as amenities and buildings, the updating of such data is less developed.

Considering the findings of this study, the recent progress of automatic mapping technology using artificial intelligence, and the increasing participation of various corporate stakeholders in OSM, further analysis from other angles is required. Traditionally, OSM has been performed by individual volunteers, but this is changing with the participation of companies that use OSM data. While the full-scale participation of companies is expected to improve the quality of data that cannot be covered by individuals and eliminate data gaps outside of urban areas, it may also cause conflicts with the OSM community, which has always placed importance on the type of data to be input. In addition, the activities of the OSM community itself as a data contributor are becoming increasingly influential in society through VGI and crowdsourcing, which is expected to allow evaluation of the data quality and deepen the understanding of OSM activities in Japan.

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Part III
Social and Practical Issues

Stigmatization on the Web: Ethical Consideration of Geospatial Stigmatization via Online Mapping

Koshiro Suzuki

Abstract Since the 1990s, the possibilities of geospatial analysis in conjunction with GIS have dramatically increased in the context of the consolidation of geostatistical data, high-precision GPS, improvement of PC processing capability, and expedited LAN access. In light of the new situation, the author discusses how social networking tools have permeated our daily lives, and how the unfounded rumours fly over the internet are easily spread, how easy for people to obtain such unconfirmed information and be instigated, and how the intangible online rumours have a concrete effect on the real world. It is the location information that links virtual world to the real world and makes possible to cause an action to really occur. In this chapter, the author intends to establish a notion of "geospatial stigmatization"—the geospatial dimension of stigmatization. In doing so, two recently published Japanese websites, Oshimaland and Hasansha-Map, are illustrated as cases of the present study. These two are both digital archives of human-related ulterior properties geotagged to electronic maps and caused massive controversies. By investigating these websites, we will be able to obtain a better understanding on how better PGIS should be, because they both created under the influence of people-powered mapping paradigm.

Keywords Geospatial stigmatization · Geovigilantism · Artificial incubator for urban legends

1 Introduction

In 2020, when COVID-19 took the world by storm, the Black Lives Matter (BLM) movement swept through the United States. For many in the USA, 2020 will be remembered as the year of the BLM movement.

In May 2020, George Floyd, an African-American man, was killed in Minneapolis, Minnesota, after being restrained by a white police officer. This incident inspired a movement, triggered by a bystander recording the scene and posting it on the

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web. It quickly became viral via social media and spurred public demonstrations against racism across the USA. This showcased the strength of the power of online communication tools.

At the time, rumours ran through angry crowds. It was said that Derek Chauvin, one of the four police officers who killed Floyd, "relocated to his Central Florida home after protests following Floyd's death turned violent in Minneapolis" (Cruz et al. 2020).

Someone geodoxed Chauvin's home location information and posted it on Twitter. Immediately, an outraged crowd rushed to his alleged home near Windermore, Orange County, Florida, to hold a demonstration (Ruiz and Sharp 2020). Although no violence occurred there, people held up placards reading "Murderer" and painted "racist" across the door of what was believed to be the Chauvin house, and threw eggs at the door (Fig. 1). Soon after, however, a local resident and the county sheriff office announced that the home was not actually the policeman's residence, but the home of an unrelated third party who had rented it since 2011 (Jaramillo 2020; Staff 2020). In summary, while BLM displayed the power of this growing movement spreading through society, it also showed that the power of social networking lacks a sufficient self-restraint function compared to the magnitude of its power and influence.

This episode shows us how social networking tools have permeated our daily lives, and how unfounded rumours fly across the Internet and are easily spread, how easy it is for people to receive unconfirmed information, and how intangible online rumours have a concrete effect on the real world. It should be noted here that it

Fig. 1 Angry protesters left "a murderer lives HERE" on the ground outside Chauvin's real home in Oakdale, Minneapolis (©Toby Canham for DailyMail)

is location information that links the virtual world to the real world and makes it possible to incite events like mentioned above. This issue is not only an issue of information ethics, but also an issue that should be discussed in geographic information science. The author calls this new phenomenon geovigilantism in several previously published papers (Suzuki 2019a, 2019b, 2021), which has emerged with the progress of two-way online communication, including participatory GIS/PGIS, and has called for the establishment of geographic information ethics in geographic information science. In this chapter, the author intends to develop the concept further with a notion of "geospatial stigmatization"—the geospatial dimension of stigmatization. Two recently published Japanese websites, Oshimaland and Hasansha-Map, are illustrated as cases in the present study. These two are both digital archives of location information of the targets damaged by human factors geotagged to electronic maps and have caused massive controversies. By investigating these websites, we will be able to obtain a better understanding of how to improve PGIS, as they were both created under the influence of a people-powered mapping paradigm.

2 Conceptualizing Geospatial Stigmatization

2.1 Cyberbullying and Cyberstalking

Since the 1990s, the possibilities of geospatial analysis in conjunction with GIS have dramatically increased in the context of the consolidation of geostatistical data, high-precision GPS, improvement of PC processing capability, and expedited LAN access. Geographers gradually became aware of the magnitude of the social impacts of the GISystem, which became capable of analysing and outputting even personal-level data (Miller 2007). On the basis of the rapid development in information technology, there is an emerging trend in the use of electronic maps/mapping as a tool for social participation, empowerment, and public involvement by grassroots mappers. This trend has attracted much attention from geographers who referred to it as volunteered geographic information (Goodchild 2007), bottom-up GIS (Talen 2000), and neogeography (Turner 2006).

Initially and historically, maps were made primarily by cartographers, while citizens were situated simply as receivers of geographic information. The recent technical evolution has dramatically changed the situation. Public citizens were enabled to become senders, sharers, and communicators of geographic information using social networking services and online mapping devices. However, little attention has been paid to the potential threat of technology-aided incidents in GeoIT-aided ubiquitous mapping, especially in geographic information science. So far, with a few exceptions, only studies on cyberbullying and cyberstalking provide us with insights into malicious intent over the Internet. Although these studies do not necessarily use electronic maps, we can learn how people abuse online communication tools when the Internet becomes ubiquitous.

Online slander itself is not a new phenomenon, and a considerable amount of research on cyberbullying and cyberstalking has been published. However, most of these studies have focused on school incidents. Moreover, such bullying usually occurs based on real relationships. They can be divided into two subgroups.

The first group consists of behavioural and educational studies that deal with cyberbullying based on in-school relationships. Kowalski and Limber (2007) conducted questionnaire surveys of 3767 elementary and middle school students in the USA and found that 11% had been bullied online in the last couple of months, and 4% had electronically bullied someone else. They further reported that the most common means of bullying were instant messaging, chat messaging, and e-mail.

Furthermore, the form of bullying differed according to gender. Many studies have reported that males tend to engage more in direct and physical forms of aggression, while females use insults or ostracize others, similar to offline or face-to-face in-school bullying (Björkqvist et al. 1992; Ostrov and Keating 2004; Card et al. 2008). In addition, males are more likely to be both offenders and victims (Salmivalli and Kaukiainen 2004; Li 2006; Erdur-Baker 2010).

The second group deals with sex crimes toward adolescents via the Internet in a criminological context. Alexy et al. (2005) asked 756 university students about their cyberstalking experiences and found that males were more likely to have been cyber-stalked, most likely by a former intimate partner. Likewise, Sheridan and Grant (2007) conducted an online questionnaire survey of 1,051 self-defined stalking victims about their experience of victimization. They found that cyberstalking did not differ from traditional, proximal stalking, that online harassment did not necessarily hold broad appeal to stalkers, and that most stalkers targeted ex-intimate partners.

In research targeting younger school-aged children, pupils and students were considered victims. The Crime against Children Research Center at the University of New Hampshire has conducted a series of youth Internet safety surveys every five years since 2005, including the National Juvenile Online Victimization Study, the only research investigating internet-initiated sex crimes. According to the survey, 73% of victims who had face-to-face sexual encounters with offenders did so more than once because most loved or were affectionate toward their offenders (Wolak et al. 2008). Despite the victim's agreement, their acts induce research concern regarding the linkage of sex crimes to juveniles in the legal context. In summary, apart from the recentness of the method used, offenders must establish spatial proximity to some extent when seeking physical contact. Therefore, by nature, cyberbullying and cyberstalking are geographically constrained.

Although they investigated the usage of online devices and tools used when bullying, this act is based on students' in-school social relationships and geographic proximity. Therefore, except for the novelty of the medium, cyberbullying in this context is neither an Internet-specific nor a new phenomenon.

Another thing that should be noted here is that cyberbullying and cyberstalking are carried out by people who have connections in the real world, even if the prefix "cyber-" is used. Geographical proximity is not a major issue in these studies because it already exists as a premise.

2.2 Stigma Theory and Geospatial Stigmatization

The spread of malicious information on the web itself is essentially different from the subject of this study. The objective of this study is to identify someone from their geographic information (e.g. place of residence) to make it continuously targeted with malicious information in a geographical hostage state. In this study, the author calls this geospatial stigmatization.

In an academic context, the concept of stigma was originally coined by Erving Goffman as a sociological and social psychological term. Goffman (1963: 3) defined stigma with the following sentence, “While a stranger is present before us, evidence can arise of his possessing an attribute that makes him different from others in the category of persons available for him to be, and of a less desirable kind—in the extreme, a person who is quite thoroughly bad, or dangerous, or weak. He is thus reduced in our minds from a whole and usual person to a tainted discounted one. Such an attribute is a stigma, especially when its discrediting effect is very extensive; sometimes it is also called a failing, a shortcoming, a handicap. It constitutes a special discrepancy between virtual and actual social identity.” According to Goffman, there are three types of stigma. (a) Abominations of the body—physical deformities such as scars and physical impairment, (b) blemishes of individual character perceived as weak will, including alcoholism and addiction, and (c) tribal stigma, including race, religion, and nation. Link and Phelan (2001) further defined stigma as the co-occurrence of the following four components: (1) differentiation and labelling, (2) linking them to stereotypes, (3) establishing a sense of disconnection between us and them, and (4) status loss and discrimination. Once stigmatized, they are ostracized, rejected, devalued, scorned, shunned, and/or neglected.

Goffman’s stigma theory has had a great influence in a wide range of research areas involved in the processes and mechanisms of discrimination and stereotyping. As an example of studies dealing with social stigma directed towards minorities, Lee et al. (2005) investigated stigmatization from family, spouses, friends, and colleagues toward persons with schizophrenia and diabetes. Likewise, Shellenberg et al. (2011) investigated how social stigma is perceived by women who had an abortion to end an unintended pregnancy and how it affects their subsequent disclosure behaviour. Orne (2013) also investigated how people of queer nation manage their identities and confront hostile reactions from others. Despite the diversity in scope, however, stigma theory has been primarily used to explain the negative reactions from the predominant group to socially vulnerable groups, as those studies describe the imprints directed at the groups as “social stigma.”

In stigma studies, the emphasis is on individuals and groups with common attributes that are stigmatized. As cyberbullying and cyberstalking studies have shown, the geographic placement of stigmatized people is only one of the prerequisites and is often overlooked in those studies. In the real world, the daily life within a certain geographic realm constitutes strong ties so that malicious intent and act also reflect the social relationship in a given realm. However, there is no premise of geographic proximity to the Internet.

A lovable person who devotedly serves their immediate family and friends does not always show the same level of affection for the poorest people in the wider world. The farther away you are from others, the less likely you are to feel their predicaments and suffering. The Internet amplifies this tendency because online encounters are not subject to the restrictions of geographical proximity. Personal computers and mobile phones with social networking tools are digital windows that allow you to look into the lives of people who have no connection with us in terms of socio-economic or age attributes in real life. Thus, someone's suffering in a distant land is more likely to be perceived through online interaction. Moreover, despite the fact that they are actually identifiable by referring to IP addresses, people are more likely to perceive superficial anonymity while online, as Suler (2004) called "the online disinhibition effect" to describe people who "do not have to worry about how others look or sound in response to what they say" and "in the case of expressed hostilities or other deviant behaviours, the person can avert responsibility for those behaviours, almost as if superego restrictions and moral cognitive processes have been temporarily suspended from the online psyche" (Ibid. 322). These may be factors that amplify unethical behaviour specific to the Internet.

Thus far, PGIS scholars have struggled to achieve an online democracy and lower the technical and societal barriers for people's social participation, and an enormous amount of research has revealed how people of color, non-elites, women, and non-English-speaking people who live in rural areas or the Global South are more likely to be underrepresented online (Carraro and Wissink 2018; Verplanke et al. 2016). Numerous case studies have focused on marginalized people, regions, and countries (Weiner et al. 1995; Fox 2002; Williams and Dunn 2003).

As mentioned before, current studies that focus on GeoIT-aided ubiquitous mapping generally portray users as naïve, well-intentioned, and cooperative people. However, these people can also employ and utilize new tools for their purposes when they become available (Kingsbury and Jones 2009). In fact, previous studies have demonstrated that terrorists and criminals use GeoIT to implement their plans (Sui 2011; Awan 2017). As demonstrated by studies on cyberbullying or cyberstalking, new technology can be used in both good and bad ways. Consequently, although we became technically capable of interactive people-powered mapping owing to the recent rapid progress in the PGIS movement powered by GeoIT, our geographic information ethics still remain in the 1.0 generation and are not sufficiently responsive to new threats stemming from Web 2.0.

Therefore, in the present chapter, the author instantiates a user-generated web mapping website called Oshimaland (a.k.a. Caveat Emptor) and the Hasansha-Map (Map of Bankrupts) created by an anonymous user as case studies. Despite these differences, these two sites offer good material for the discussion of geospatial stigmatization.

3 The Subjects of Research

3.1 Oshimaland: La rumeur d'Orléans in the Digital Age

In the Japanese legal system, the seller's warranty against concealed defects is defined in the Civil Code (Act No. 89 of 1896). In Article 570, Chap. 2, Part 3 of the code, it is prescribed that "If there is any latent defect in the subject matter of a sale, the provisions of Article 566 shall apply mutatis mutandis; provided, however, that this shall not apply in cases of compulsory auction" In addition, in Article 566(1), it is mentioned that "In cases where the subject matter of the sale is encumbered with for the purpose of a superficies, an emphyteusis, an easement, a right of retention, or a pledge, if the buyer does not know the same and cannot achieve the purpose of the contract, the buyer may cancel the contract. In such cases, if the contract cannot be cancelled, the buyer may only demand compensation for damages" (Ministry of Justice 2018).

Defects of property can be categorized into physical, legal, and psychological restraint. According to several lower court judgments, psychological defects can be categorized into five types: property in which (1) the location of the toilet is directed to the Kimon (demon's gate), (2) has a history of suicide or murder, (3) is adjacent to a gang group office, (4) has an annoying neighbour, and (5) is adjacent to a sex business facility (Nagashima 2018). Of the five types of defects, psychological defects due to suicides and murders are deeply linked to the scope of the current study. Although psychological defects are by nature subjective, and it is difficult to distinguish whether and to what degree the defects prejudice the economic value of the properties, recent lower court precedents sustained that the lessor's failure to inform the existence of reported suicide incidents upon commitment to lease were illegal (Kaneko 2015; Nakato 2015). Owing to the tacit social consensus as stated above, it is a common practice in Japan that the real estate agency is obliged to disclose the occurrence of a murder or suicide on the property to at least the next occupier. It is also important to note that disclosure obligation is a type of established business practice. There is no uniform legal criterion over the terms and conditions of performance and it is left to the lessors' own devices. This ultimately means that the lessee does not have access to the entire record of the psychological defects of the property unless the lessors and/or real estate agencies are willing to comply with the disclosure.

In September 2005, Manabu Oshima (hereinafter called "MO"), who identified himself as the managing director of the business corporation Oshima-Teru, launched a website called Oshimaland (http://www.oshimaland.com/). He also attached the motto Caveat Emptor, a Latin apothegm of "Let the buyer beware" on the homepage of the website (Fig. 2). Google Maps was launched in February of the same year. As this immediacy of the temporal axis clearly indicates, Oshimaland embedded Google Maps on the top page, although in later years the base map has changed to OpenStreetMaps and Yahoo! Maps, possibly because of copyright claims.

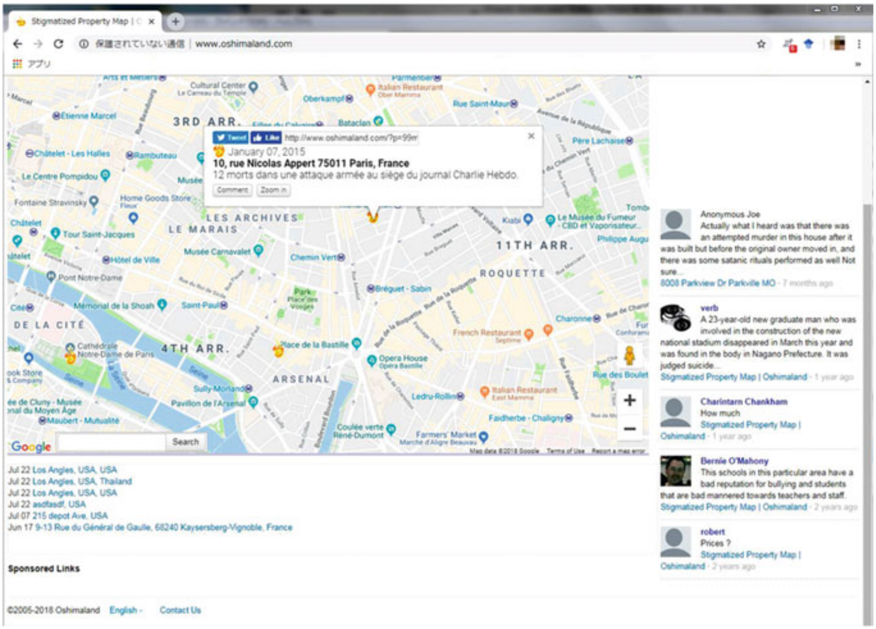

Fig. 2 A screenshot of the top page of http://www.oshimaland.com (as of 13 Sept. 2018)

With use of GeoAPI, MO started to upload his compiled information about the properties with histories of murders and suicides, what he called "stigmatized properties" on the site. A brief description of each incident, date and time of occurrence, a photo of the exterior as well as the property location and address are pinned on the electronic map and are displayed as clickable icons (Furuta 2010). For the first six years, he continued to use newspaper articles to construct a verified property map with psychological defects.

Because the uploaded information was based on his personal effort, the initial geographic distribution of the properties was spatially constrained and almost entirely confined to the realm of Tokyo's 23 wards. Although the web map caused a massive controversy over the claims for the right to know and interference of business, MO acquired information from legitimate data that was publicly available. In fact, he successfully won a slander lawsuit in 2011 when he was sued by the land owner of a condominium building.

One of the key components of the website was the posting form "public hearing". According to MO, he erected it to gather the power of collective wisdom for psychologically defected properties, even if many of them were unassured (Furuta 2010). He confirmed by checking newspapers and adding verified information to the web maps. The public hearing window contributed to a rapid growth in the number of cases, ensuring information quality in a relatively short period of time.

In 2011, there were several fundamental changes in the operational policy of the website. Above all, the most notable things were the launch of the English version and the additional function of posting. In an interview report of a web journal in 2014, OM stated that he strived to maximize access from many unspecified users because they were expected to correct mistakes and deficiencies. Meanwhile, he also confessed that the main duty of Oshimaland was transformed into website management rather than defect disclosure, and his status also got closer to the editor-in-chief rather than an investigator (Oshima 2014). A flood of unmoderated posts from anonymous users exceeded their managerial capacity, and they could verify the authenticity of every post. In contrast, the amount of posted information dramatically increased. As of September 21, 2018 there were 54,851 posts throughout Japan. The geographical scope also expanded to every region of Japan, including remote islands as well as a growing number of locations in foreign countries. This strongly suggests that the birth of a computerized focal point for rumours and became functional as an artificial incubator for urban legends in cyberspace.

3.2 Hasansha-Map: Stand-in Action of Public Authority Without Permission

While Oshimaland stigmatizes real estate, which has no personal rights, the "Hasansha-Map/Map of Bankrupts" (http://www.hasanmap.tokyo/) emerged online on 2 December 2018 and showed that it is possible to spatially stigmatize individual anonymous citizens (Japan Federation of Bar Associations 2020).

In Japan, bankruptcy decisions and civil bankruptcy information are publicly announced in accordance with the Bankruptcy Act No. 75 of June 2 2004 constituted Article 10–1 stating "a public notice under the provisions of this Act shall be effected by publication in an official gazette" (Ministry of Justice 2020). The anonymous webmaster assembled the names of individuals and corporations and their respective address information that had been published in the official bulletin leaflets retroactively for the past 10 years, converted them into a database, and pinned them on the website containing an embedded Google Map that represents the locations of bankruptcy and enables anonymous individuals to browse and look up the names and locations of residence (Masuda and Kubota 2019; Teshima 2019; Oshima 2020). The basic appearance and structure of the website resembled that of Oshimaland. A noteworthy difference in visual appearance was that Oshimaland changed the base map from Google Maps to Apple Maps due to copyright law issues a few years after its release.

After its launch, the site received broad criticism primarily from legal experts, forcing managers to apologize on Twitter and voluntarily shut down the service just a say after launch on 19 March 2020. However, someone copied the database and subsequently recreated an analogous website, entitled Monster Map.

It is likely to avoid prosecution and criticism under the Personal Information Protection Law. The publisher posted the announcement that "The Monster map is a fiction. The individuals and organisations listed here have nothing to do with actual individuals or organisations" on the top page. Following the lessons of Hasansha-Map, the Japan Federation of Bar Associations published a position document on 20 July 2020. They suggested that "Regarding the information related to [the person has taken steps related to bankruptcy, civil rehabilitation and other bankruptcy cases], the national government has decided that it corresponds to 'personal information requiring consideration' under the 'Personal Information Protection Law.' It should be stipulated in the law enforcement ordinance" (Japan Federation of Bar Associations 2020).

Based on Article 42, the Act on the Protection of Personal Information, which noted "The Personal Information Protection Commission may … recommend the personal information handling business operator etc. to suspend the act of violating or take other necessary action to rectify the violation." The Personal Information Protection Commission issued a suspension order to the webmasters of Hasansha-Map as well as Monster map, although the former had already closed, based on the fact that they violated the Act on the Protection of Personal Information because they retrieved personal information without promptly informing the utilization purpose (Article 18 of the law) and provided it to a third party without obtaining consent (Article 23 Paragraph 1 of the same law) on 29 July 2020. Subsequently, the Monster Map was closed on 20 August 2020 (Bengoshi.com 2020).

However, the situation is ongoing. There is no way to truly erase personal information once it is published on the internet. Following the Bankruptcy and Monster maps, an anonymous user acquired the domain on 19 September 2019 and launched another "self-bankruptcy/special clearing/regeneration database." Unlike the Monster Map, it contained only information from after 1 August 2019, one month before the site was launched, so the source was thought to be the internet version of the official gazettes. This site also accepts deletion requests, and personal information may be exploited through this procedure.

In addition, hasandb, which acquired Iceland's top-level domain "is" on March 12, 2020 and set up a server in Tallinn, Estonia (ICSNIC 2020) to avoid the jurisdiction of Japanese domestic law, launched and spread the database in text format, which made downloading it even easier. As mushrooms shoot up after a rain, slanderous sites jeopardizing privacy emerged one after another.

4 Concluding Remarks

The realization of infrastructure for high-speed telecommunications, the dramatic performance upgrades of mobile and desktop devices, and the increased convenience of cartographic communication through GeoAPI has ushered in an era in which people can easily participate in and exercise their influence on society. Of course, if we shed a light on the positive side, we can position Participatory GIS as an activity that brings the SDGs ideal of "No one will be left behind" closer to realization geographically. However, we have been surprisingly optimistic and unprepared for the social implications of this technology, given the rapidity of its innovation. In this chapter, I have argued, drawing on the stigma/social stigma terminology coined by Goffman (1963), that innovations in location-acquisition technology are increasing the likelihood that people will intervene in the lives of unrelated third parties from anywhere in the world, sometimes imprinting an unwarranted stigma on them.

So far, there is no tangible indication that the various ethical issues are being recognized as a direct crisis in the operating model presented in the PGIS, as citizen programmers with both high awareness and high technical levels are involved in the building and maintenance of web-based projects. However, lowering the barriers to citizen participation means lowering the hurdles not only for technology but also for norms and ethical awareness.

While Oshimaland is skillfully managed by real estate administrators like many PGIS projects, viewers can easily pin a property using the geotagging function, which can make the information inaccurate and increase the risk of viral posts. The ability to pin unsubstantiated information on real properties makes it possible to project a virtual threat into a real geographic space. In the context of diluted online relationships, disclosure of location information is far more fatal than stigma against human attributes. There may be more than one Derek Chauvin in the USA, but the latitude–longitude location and full postal address are unique. That is why "geospatial stigmatization" is the most serious threat in the online world. Likewise, HasanshaMap shows that even an anonymous individual can widely disclose sensitive information and have a huge impact on the world. We should acknowledge that, as the impact of PGIS increases, the more explicit such ethical and legal risks will become. In order to cope with such an era, we need to develop a more applied geographic information ethics within the field of geographic information science with the guidance of law and information ethics.

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How Have Tactile Maps for the Visually Impaired Been Situated in Japan?: From the Analysis of Newspaper Articles

Masahiro Tanaka

Abstract This paper analyzes the content of newspaper articles that mentioned tactile maps for the visually impaired, and examines how such types of maps have been situated in Japan. From the mid-1990s to mid-2000s, the number of newspaper articles mentioning tactile maps has increased, and such types of maps have become known to the public. This trend was based on the enforcement of the acts on accessible design of public facilities. In parallel with this trend, the newspaper articles have reported efforts by welfare organizations to transcribe existing graphical maps into Braille. There seem to be two types of thought behind these situations. The first is the thought of "transforming a tool for the sighted into a tool for the visually impaired." Another is the thought of "preparing tools for the visually impaired in addition to those for the sighted." They both presuppose a clear distinction between the abled and the disabled, and have a danger of falling into ableism. It is important to note that the latest high-tech tactile maps are also placed in this context. The author believes that we need *mapmaking with the visually impaired* instead of *mapmaking for the visually impaired* in order to avoid ableism.

Keywords Tactile maps · Visually impaired · Newspapers · Japan

1 Introduction

Visually impaired people's well-being has been affected by the development and pervasiveness of mapping technologies. Contemporary cartography is characterized by its multimedia nature and its use of the Internet. This is very meaningful for the visually impaired. Since they cannot or hardly use visual maps, it is necessary to prepare maps for them that stimulate their tactile or auditory senses. Those non-visual maps such as tactile maps (Fig. 1) can now be manipulated on the Internet (e.g., Lawrence et al. 2009). Non-visual maps are becoming increasingly high tech and ubiquitous.

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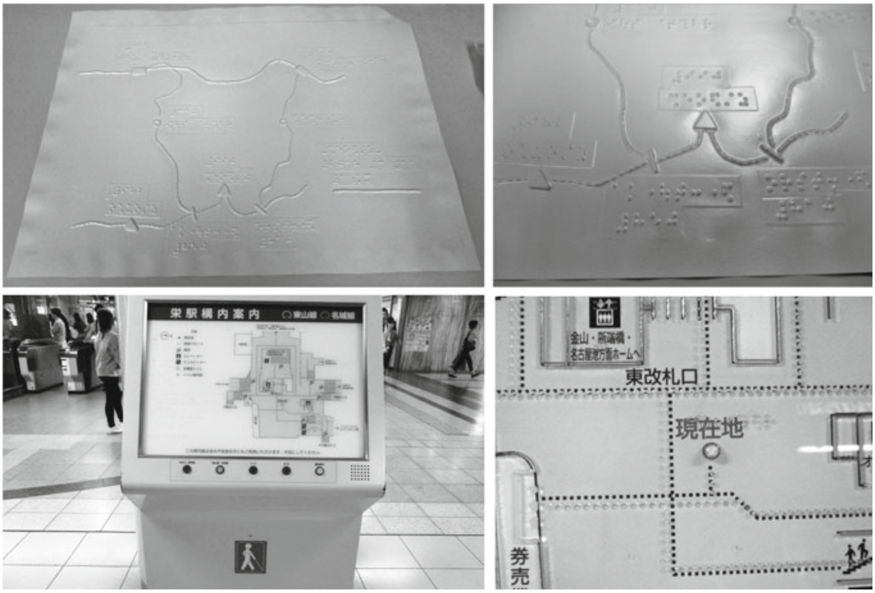

Fig. 1 Examples of tactile maps for the visually impaired (the above shows a tactile map made by a volunteer group, and the below shows a tactile map installed at a station. All photographs were taken by the author in 2017)

However, we should not place undue expectations on the sophistication and ubiquity of mapping technologies. In the field of social sciences, especially in disability studies (e.g., Oliver 1990), critical studies on disability have been undertaken. One of the important lessons provided by those studies is that a deterministic, optimistic, and utopian ways of thinking on technology should be avoided, and we need to think about society-based technology for people with disability (e.g., Gleeson 1999; Chouinard et al. 2010; Roulstone et al. 2016).

This paper is not intended to introduce the latest mapping technologies for the visually impaired. While the theme of this book may be to explore the impact of contemporary mapping technologies on various fields, this paper dares to look back to the past. Even the latest technologies are based on the history. Maps for the visually impaired, which becoming increasingly high tech, should be placed in the history. In the following, how tactile maps for the visually impaired (Fig. 1) have been mentioned in newspaper articles is examined. Through this analysis, we will explore how tactile maps have been situated in Japan, note the problems with these situations, and suggest an alternative approach to tactile maps.

2 Previous Studies on Tactile Maps

For people with disabilities, a map has three roles. First, maps are a tool to understand space at different scales (e.g., world, country, region, road, building). For example, tactile maps are used for geographic education and mobility support for the visually impaired. Second, maps are a tool that can visualize and analyze the spatial pattern of physical barriers to mobility for people with disabilities. When people with visual impairments or wheelchair users perform outdoor behavior, they often encounter barriers that impede their movement. For example, steps and steep inclines in sidewalks make it difficult for wheelchair users to move. For people with visual impairments, bicycles and stores signs placed on the street are barriers that prevent them from walking safely. A map is a powerful tool that can show where and how many of these barriers exist. Finally, maps are a tool for dialogue between the abled and the disabled to understand each other. For example, the abled and the disabled can deepen their understanding of each other's lived experience by using the map as a platform for communication and discussing the city they live in.

While maps have multiple roles for people with disabilities, tactile maps are often expected to serve as a tool for the first role (spatial understanding) of the visually impaired. Thus, most of the research on tactile maps has been conducted from this perspective. Perkins (2002) classified the research topics of tactile maps into six categories: (1) cognitive research and map use, (2) map design, (3) standardization, (4) production technology, (5) technological fixes, and (6) ethics. Of these, only (6) relates to the social aspects of tactile maps, and the rest are all technical issues (e.g., Jorhoel et al. 2006; Lobben and Lowrence 2012; Rice et al. 2013; Gual-Orti et al. 2015; Štampach and Mulíčková 2016).

This research trend of tactile maps is also true in Japan. In Japan, tactile maps were originally devised as teaching materials for geographical education for the visually impaired and then began to be used for their walking training around the 1960s as the concept of "rehabilitation" has been popular. Since the 1980s, tactile maps began to be installed in public facilities in line with the spread of the concepts of "accessible design" (which is often expressed in terms of "barrier-free" and "universal design" in Japan). Figure 2 shows the research trend of tactile maps in Japan. It is clear that tactile maps have been studied mainly in the field of science and technology. In particular, since the 1990s, there had been an increase in scientific and technological research that consider accessible design of tactile maps in the field of informatics and architecture.

On the other hand, little has been done to examine how tactile maps have been made and provided, and how they have been mentioned among the public. In other words, the "actually existing cartography" (Pickles 2004: 184) of tactile maps has been little studied. In the words of Kitchin et al. (2009), conventional research on tactile maps has been "representational," and there has been few "post-representational" studies. This paper is based on the latter position. The aim of this paper is not to explore the appropriate design of tactile maps, but to consider the socially situated nature of tactile maps.

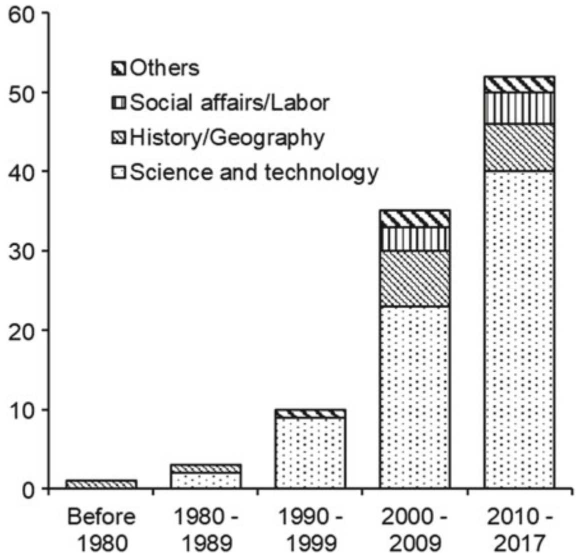

Fig. 2 Number of the research on tactile maps in Japan (we classified journal articles and conference proceedings registered in the Japanese online scholarly and academic information database (CiNii) (https://ci.nii.ac.jp/. Accessed on July 19, 2017) according to the National Diet Library Classification)

3 Methods

In order to investigate how tactile maps for the visually impaired have been situated in Japan, this paper analyzes articles in three major Japanese national newspapers (*Yomiuri Shimbun*, *Mainichi Shimbun,* and *Asahi Shimbun*). Specifically, we extracted 230 articles mentioning tactile maps from the articles registered in each newspaper's online databases as of July 1, 2017.[1] The following items were then investigated.

- Year of publication of the articles
- Main topics of the articles
- Producers of tactile maps mentioned in the articles
- How tactile maps have been called in Japanese (designations of the tactile maps) in the newspaper articles
- What is being explained centrally about tactile maps in the newspaper

[1] Yomidasu (https://database.yomiuri.co.jp/), Maisaku (http://mainichi.jp/contents/edu/maisaku/), and Kikuzo II (https://database.asahi.com/index.shtml).

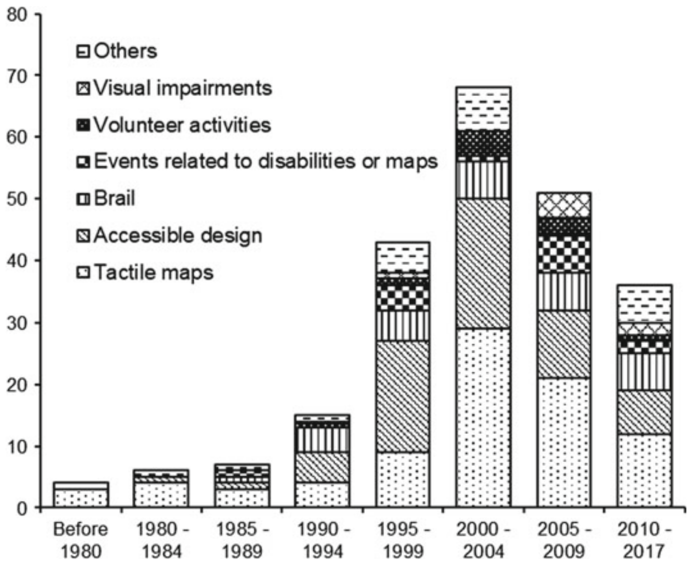

Fig. 3 Number of newspaper articles mentioning tactile maps

4 Results

There are two main ways of referring to tactile maps in the newspaper articles. One is to treat tactile maps as a main topic of the articles, and the other is to mention tactile maps in the context of another topic (i.e., accessible design, Brail, events related to disabilities or maps, volunteer activities, visual impairments, others).

Figure 3 shows the number of the newspaper articles mentioning tactile maps by the topics. In this figure, we can see that the articles increased rapidly from the mid-1990s to the mid-2000s. This suggests that the popularity of tactile maps increased during this period in Japan. In addition, the number of articles in which “accessible design” and “tactile maps” are the main topics has increased in this period. This may be due to the influence of the International Year of Disabled Persons in 1981 and the subsequent enforcement of the Acts on accessible design of buildings and public transportation.[2] However, the number of articles has been decreasing since the late 2000s. This can be attributed to the fact that tactile maps are no longer so rare in the world, that the number of Braille users has decreased, that voice-enabled computer software has been enhanced, and that interest in navigation tools that utilize location-based technology such as GPS has increased.

On the other hand, there were few newspaper articles mentioning tactile maps until the 1980s. It is likely that tactile maps were not well known to the general public at that time. For example, in 1964 Kazuo Honma, the founder of Japan Brail Library

[2] In Japan, Heartful Building Act (1994), Transportation Accessibility Improvement Act (1999), and New Barrier-free Act (2006) were enforced.

(the nation's largest library for the visual impaired), visited all over the world, bought lots of tools for the visually impaired, including tactile maps, at the blind libraries in various places, and brought them back to Japan. In autobiography, he writes about his experience as follows (Honma 1980: 146–149).

> That we bought about one hundred fifty tools in Europe and the United States inspired the development and promotion of welfare equipment for blinds in Japan, which became more and more popular day after day.
>
> ...various clocks (e.g., watches, alarm clocks); measuring instruments (e.g., thermometers, hygrometers, measuring tapes); household items (e.g., clinical thermometers, carpenter's tools, bread slicers); various games; maps representing the six continents by using raised surface, etc. Most of them were known to Japanese blinds for the first time.
>
> Until that time, the only tools for Japanese blinds were white canes, braille writing equipment or braille typewriters, and watches modified for blinds.

Another example is Goto (1975: 5), who wrote the following in a journal on maps.

> In the spring of 1975, Chofu city, an emerging residential area in the west side of Tokyo, made and distributed the maps of the city for 100 citizens with visual impairments. They are the first map for the visually impaired made by the local government in Japan, and I would like to express my sincere respect for the city's efforts to improve welfare.

Goto's report notes that it was rare for local governments to make tactile maps in the 1970s. So, who have made tactile maps in Japan? Figure 4 shows the trend of the producers of tactile maps. Table 1 represents the relationship between the main topics of the newspaper articles and the producer of tactile maps mentioned in the articles.

Until the first half of the 1990s, tactile maps made by welfare organizations and local governments were mainly reported by the newspaper articles. In contrast, since

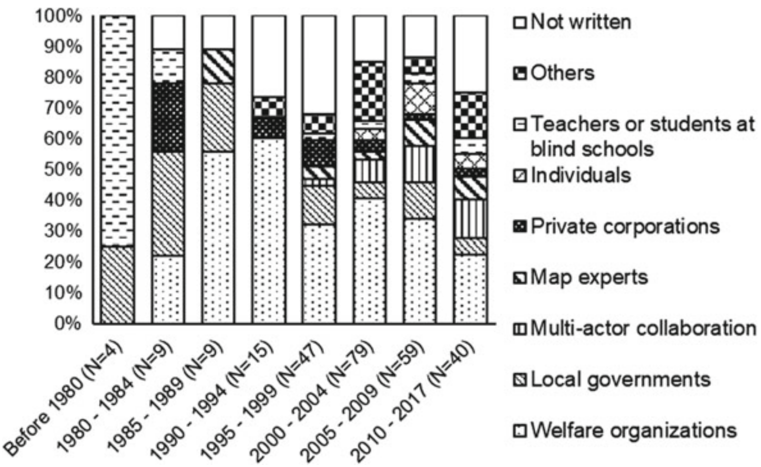

Fig. 4 Composition ratio of the number of the producers of tactile maps mentioned in the newspaper articles

Table 1 Cross-tabulation of the number of the main topics of the articles and the number of the producers of tactile maps mentioned in the articles

Main topics of the article	Producers of tactile maps*									Total
	A	B	C	D	E	F	G	H	I	
Tactile maps	40	15	10	11	3	6	7	16	0	85
Accessible design	12	10	3	1	4	1	0	7	32	64
Brail	23	0	1	0	1	1	0	2	0	28
Events related to disabilities or maps	2	0	1	1	1	0	2	2	6	14
Volunteer activities	10	0	0	0	1	0	0	0	0	10
Visual impairments	1	0	1	0	1	2	0	0	2	7
Others	4	0	3	0	1	1	2	1	11	22
Total	92	25	19	13	12	11	11	28	51	230

* A: Welfare organizations, B: local governments, C: multi-actor collaboration, D: map experts, E: private corporations, F: individuals, G: teachers and students at blind schools, H: others, I: not written

the mid-1990s, the producers of tactile maps featured in the articles have diversified. In recent years, cooperative mapmaking activities by multiple actors have been featured in the articles. Overall, the most frequently focused producer is welfare organizations. There are the articles whose main topic is the tactile maps welfare organizations made, and these articles describe the fact that they made tactile maps as part of their work to transcribe books for the sighted into Braille. On the other hand, when an article on the main topic of accessible design mentions tactile maps, it often does not mention the makers of the maps. For example, in an article that says, "a tactile map was installed in conjunction with the renovation of a public facility," the makers of the maps often were not mentioned (presumably, in such a case, the builders of public facilities have made tactile maps).

How are tactile maps explained in the newspaper articles? Table 2 shows the relationship between the producers of tactile maps and what is being explained centrally about tactile maps in the articles. The most common explanation of tactile maps was "transcribed existing maps into Braille." Table 2 shows that this idea is especially true for tactile maps made by welfare organizations. Such an idea of "transcription" has existed for more than 100 years. For example, in *Akou Nikki* ("diary of a visit to the United States" in English) written by Gohachiro Namura who was a member of Japanese Embassy around 1860, the following passage is written (Steering Committee of the Centennial Celebration of the Treaty of Amity and Commerce Between the United States and the Empire of Japan 1961: 243).

> At 4:30 in the morning, I took a carriage with an American doctor coming from New York City and visited a blind school... Dozens of wooden boards carved on the earth's five continents and islands was there. They are pasted on a disk divided into halves in the east and west to draw a world map. Teachers and students say, "this country is next to the land X," "this city is in the direction of the land Y," "Japan is east of California." They were transiting [their perception] into the words of sited people.

Table 2 Cross-tabulation of the number of newspaper articles by the producers of tactile maps and what is being explained centrally about tactile maps

Producers	Explanations*								Total
	A	B	C	D	E	F	G	H	
Welfare organizations	37	18	26	18	16	10	0	24	92
Local governments	6	9	7	3	8	6	0	7	25
Multi-actor collaboration	2	4	3	5	2	1	0	9	19
Map experts	2	3	5	5	3	3	0	3	13
Private corporations	4	2	4	1	1	0	0	3	12
Individuals	2	4	1	1	1	1	0	6	11
Teachers or students at blind schools	1	5	4	0	2	3	0	2	11
Others	4	5	5	4	5	2	1	8	28
Not written	5	12	5	14	4	0	1	20	51
Total	63	62	60	51	42	26	2	82	262**

* A: Transcription, B: form, C: making methods. D: tactile properties, E: features, F: design, G: others, H: not written
**In some cases, multiple explanations and producers appear in a single article, so the total exceeds 230

Perhaps, Namura thought that the students had acquired the language of the sighted through the use of tactile maps.

This idea of "transcription" is also related to the designation of tactile maps in Japanese. Figure 5 shows how tactile maps have been called in Japanese in the newspaper articles (see the legend for the meaning of each Japanese word in English).

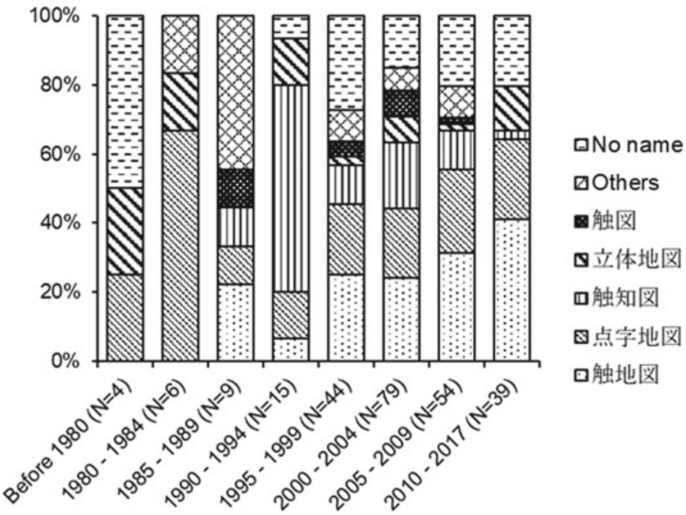

Fig. 5 Composition ratio of the number of designations of tactile maps used in the newspaper articles (触, 触知: tactile, 点字: Brail, 立体: three-dimensional, 図: diagram, 地図: map)

Table 3 Cross-tabulation of the number of producers of tactile maps and the number of the designation of tactile maps mentioned in the newspaper articles

	Designations*							
Producers	触地図	点字地図	触知図	立体地図	触図	Others	No name	Total
Welfare organizations	13	25	10	4	8	10	29	92
Administrative agencies	6	5	3	4	2	1	5	25
Multi-actor collaboration	11	5	4					19
Map experts	10	1		1		2		13
Private corporations		4	1	2		2	3	12
Individuals	3	3		2	1	2	1	11
Teachers or students of blind schools	3	1	1	1		2	2	11
Others	7	11	4	2	3	3	2	28
Not written	22	4	17	4			6	51
Total	75	59	40	20	14	22	48	262**

* 触, 触知: tactile, 点字: Brail, 立体: three-dimensional, 図: diagram, 地図: map
**In some cases, multiple designations and producers appear in a single article, so the total exceeds 230

In this figure, we can see that the term "点字地図" ("Brail map" in English) has been used in Japan for a long time. There are two possible reasons for this. First, tactile maps literally use Braille. Second, Braille is a symbol of the visually impaired: The word Braille is used to emphasize that tactile maps are for the visually impaired.

In addition, the term "触知図" appeared in the late 1980s. This word is often used for tactile maps installed as part of the accessible design of buildings and public transportation, and is sometimes called "触知案内図" ("案内" means "guide" in English). The term "触知案内図" is also used in the guidelines for tactile maps that are publicly installed and distributed (Japanese Industrial Standards Committee 2007). In this guideline, the word "触知案内図" is translated into "tactile guide maps" in English. However, as shown below, "触知案内図" are not geographical "maps" but "diagrams" (Japanese Industrial Standards Committee 2007: 19).

> As is evident from the term "案内図," this is not a map that is strictly on a geographical scale, but a diagram that is organized in such a way that the location of landmarks and public equipment for walking can be easily understood as a result of appropriate selection of information.

The term "触地図," which means "tactile maps" in English has been in public use since almost exactly the same time as the term "触知図" was introduced.

Interestingly, different producers call tactile maps differently. Table 3 shows the relationship between producers and designations of tactile maps. Welfare organizations often refer to tactile maps as “点字地図.” Often, they do not give tactile maps special designations and call them simply “maps for the visually impaired.” On the other hand, in the newspaper articles in which the terms “触地図” or “触知図” are used, the producers of tactile maps are often not specified. Most of them are articles whose main topic is accessible design (Table 1). In short, since the enforcement of the Acts on accessible design, tactile maps have been officially produced, distributed and installed, and terms such as “触地図” and “触知図” have become increasingly used in newspaper articles. In addition, map experts tend to use the term “触地図” to mean tactile maps. They seem to regard this type of map as a distinct kind of map. In fact, in Japan, tactile maps have been discussed in cartographic journals since the 1960s (e.g., Miyata 1965), and they are now recognized as a type of map by cartographers.

5 Discussion and Conclusion

The results of the analysis in the previous chapter can be summarized as follows. In Japan, the number of newspaper articles mentioned in tactile maps for the visually impaired has increased from the mid-1990s to the mid-2000. In this period, tactile maps have become known to the public. This trend was based on the enforcement of the Acts on accessible design of public facilities. In the 1990s, there was a growing tendency to report on the installation of tactile maps in public facilities in the newspaper articles related to accessible design. In parallel with this trend, there have been newspaper articles about efforts by welfare organizations to transcribe visual maps for sighted people into Braille. In addition, the terms “触地図” (tactile maps) and “触知図” (tactile guide maps or tactile diagrams) began to be used in the newspaper articles around 1990. On the other hand, the term “点字地図” (Brail maps) continues to be used mainly by welfare organizations. The term “点字地図” is still in use today.

There seem to be two types of thought behind this situation. The first is the thought of “transforming a tool for the sighted into a tool for the visually impaired.” In particular, welfare organizations have this kind of thought. This is manifested in terms such as “点字地図.” Another is the thought of “preparing tools for the visually impaired in addition to those for the sighted.” This is often seen in the field of accessible design and is foregrounded by terms such as “触地図” and “触知図.” As mentioned in the introduction, maps for the visually impaired are becoming more and more high tech, and expectations for their roles in improving well-being of the visually impaired are rising. It is important to note that this trend can be placed in the context identified in this paper.

Maps have been developed as part of visual culture (Pickles 2004). In a sense, tactile maps are “non-visual entities” that have entered such visual culture. The above two thoughts can be understood as a different perspective on such a visual/non-visual dualism. This dualism corresponds to the dualism of the sighted/the visually impaired and, more specifically, the abled/the disabled. In other words, the current tactile maps assume a clear distinction between the abled and the disabled. This has the danger of falling into a paternalistic ableism that incorporates the disabled into the world of the abled (e.g., Imrie 1996a, 1996b).

Gleeson (1996) said that we need geography *with* the disabled instead of geography *for* the disabled. In a similar fashion, the author believes that we need *mapmaking with the visually impaired* or *visually impaired people's maps* instead of mapmaking or maps for the visually impaired. This is an effort to rethink the map itself and is a social practice of "deconstructing the map" (Harley 1989). It is a need that the visually impaired themselves think about what a map is and obtain their *own map* in order to avoid ableism. Critical cartography and critical GIS (Crampton 2010) may be necessary for tactile map research in the future.

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Mapping Isolation: Distribution of Isolated Foreign Women Living in Rural Japan

Kohei Okamoto and Masatoshi Morita

Abstract The Great East Japan Earthquake drew attention to the fact that many non-Japanese women were resident in dispersed areas of rural Japan. They were the immigrant wives (mostly Chinese, Korean, and Filipinos) married to Japanese men and living in local communities, where they were isolated from other non-Japanese residents. This study analyzed the distribution pattern of such women using the grid-square statistics of Japan's 2010 population census and GIS. We applied statistical data for 1-km × 1-km grids; we identified grids that had only one non-Japanese resident, and that person was a woman as "isolated grids." Among the isolated grids, there were grids where no non-Japanese resided in the eight adjacent grids: We defined such grids as "more-isolated grids." From our analysis using kernel density estimation, isolated grids were distributed in eastern Japan (such as Tohoku); however, more-isolated grids appeared not only in eastern Japan but also in western Japan (such as Kyushu).

Keywords Spatial isolation · non-Japanese women · Foreigner scattered areas · Kernel density estimation · National census

1 Introduction

The Japanese national population census of 2010 was conducted 5 months before the 2011 Great East Japan Earthquake. According to that census, the non-Japanese population in Iwate, Miyagi, and Fukushima Prefectures (which suffered enormous damage in the disaster) was 0.5%: That figure was markedly lower than the national average of 1.3%. In the disaster areas, non-Japanese residents mainly fell into three groups: (1) trainees and technical intern trainees; (2) students at Japanese-language

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schools or universities; and (3) foreign wives of Japanese men. Many of the individuals in groups (1) and (2) returned to their home countries shortly after the earthquake and tsunami; they did so owing to the resultant nuclear disaster and damage to the factories where group (1) had hitherto been working. Thus, support became necessary for the foreign wives in group (3). Most of the wives were Chinese, Filipino, and Korean nationals married to farmers and fishermen in areas where there was a shortage of marriage partners; they were living with their husbands' parents (Okamoto and Sato 2016).

As evident in Fig. 1, the non-Japanese population was distributed in urban areas as well as in farming and fishing areas in the disaster zone. Among the 5,446 smallest census tracts in Fig. 1, 1,938 had non-Japanese residents; of those 1,938 census tracts, 757 had only one non-Japanese; of those 757 non-Japanese, 623 were female. Thus, 32% of the smallest census tracts in the disaster zone where non-Japanese lived had only one non-Japanese, and that person was a woman (Table 1). This distribution pattern was very different from that observed in metropolitan areas. In Tokyo Prefecture, the proportion of non-Japanese residents was highest among Japan's prefectures (2.4% in 2010); there, non-Japanese residents lived in close proximity to other non-Japanese, and the smallest census tracts having only one non-Japanese female were exceptional. Compared with metropolitan areas, Tohoku had far fewer smallest census tracts where non-Japanese resided; however, 32% of those were tracts with only one non-Japanese female, and they lived away from other non-Japanese. Most of them were foreign women married to Japanese men.

Ochiai et al. (2007) were a pioneering study that statistically determined that with the influx of foreign women, the proportion of wives of sons of household heads (daughters-in-law) was high in Tohoku. However, the regional data unit adopted in that study was the prefecture; thus, the authors did not determine the distribution of non-Japanese wives in their analysis. The Great East Japan Earthquake drew attention to the fact that non-Japanese were widely distributed in Tohoku. Komai and Suzuki (2012) referred to the disaster area as "外国人散在地域" (regions with a scattered population of foreigners; foreigner-scattered areas). Previous studies have been of a qualitative nature: They have presented descriptions of the situation facing non-Japanese in Tohoku. Using statistical data, no research has objectively analyzed the distribution of non-Japanese in Tohoku and how that distribution differs from areas outside that region.

Regarding the difference in the number of foreign wives between Tohoku and other parts of Japan, it has been said that there is a difference in the consciousness of ie (family; household) in eastern, to which Tohoku belongs, and western Japan; that will be discussed in the next section. That consciousness has also been used to explain regional differences in Japan's domestic population movements during its period of rapid economic growth centered on the 1960s. However, eastern and western Japan are not uniform. The present study may help abandon the very broad regional classification of eastern and western Japan that has previously existed.

This paper aims to clarify statistically where Japan foreigner-scattered areas exist. In our analysis, we refer to statistical methods applied in ethnic minority studies. First,

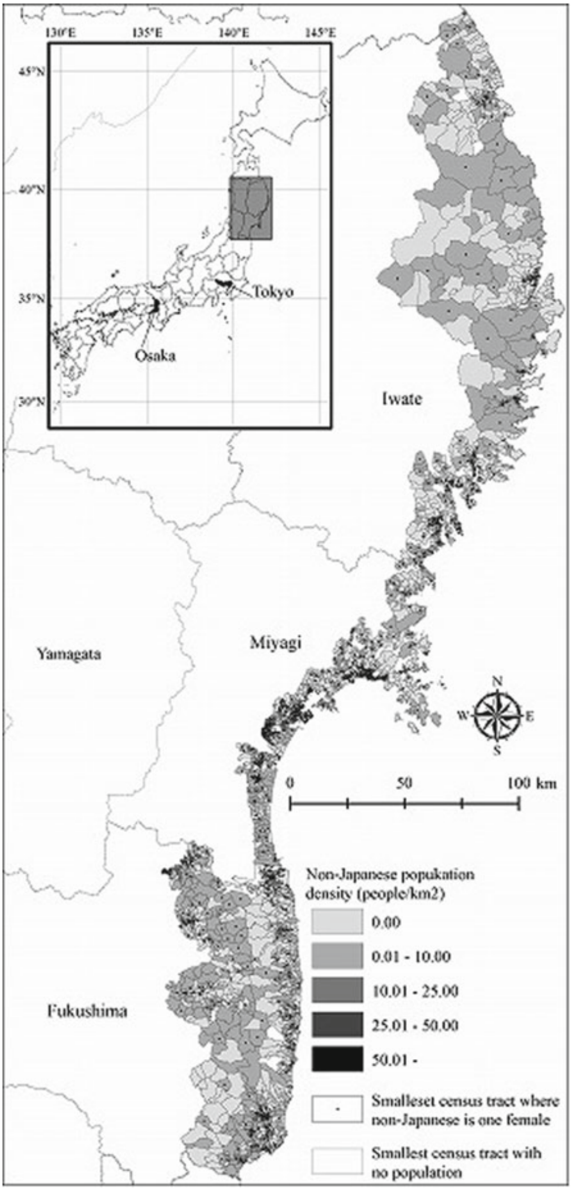

Fig. 1 Distribution of non-Japanese population in coastal areas of the three prefectures of the Tohoku region (as of October 2010). Data: National population census of 2010, summary of smallest census tracts. Areas: Coastal municipalities in Iwate and Miyagi Prefectures; sea coastal municipalities and municipalities with caution zones around nuclear power plants, planned evacuation zones, and specific spots recommended for evacuation in Fukushima Prefecture

Table 1 Comparison of smallest census tracts tabulations on distribution of non-Japanese population for two regions in 2010

	Number	Percentage of all census tracts (%)	Percentage of census tracts with non-Japanese (%)
(a) Coastal areas of the three prefectures of the Tohoku region			
All census tracts	5,446	100.0	–
Census tracts where non-Japanese live	1,938	35.6	100.0
Census tracts where non-Japanese is one	757	13.9	39.1
Census tracts where non-Japanese is one female	623	11.4	32.1
(b) Tokyo Prefecture			
All census tracts	4,992	100.0	–
Census tracts where non-Japanese live	4,656	93.3	100.0
Census tracts where non-Japanese is one	101	2.0	2.2
Census tracts where non-Japanese is one female	63	1.3	1.4

Data 2010 National Census

however, it is necessary to examine whether the non-Japanese wives in the present study belong to ethnic minorities.

2 History of Foreigner-scattered Areas

Before conducting a statistical analysis, we examined why foreigner-scattered areas developed in Tohoku. During Japan's period of rapid economic growth (from the late 1950 to 1960s), its farming and mountain villages faced depopulation problems. Those problems occurred owing to population outflow toward metropolitan areas. That situation differed in eastern and western Japan. In the rural villages of western Japan, it was not uncommon for all family members to abandon farming and rural life and move to the cities. In eastern Japan—especially in Tohoku—children other than the eldest son moved to the city, but the eldest son and his parents remained in the home village (Saito 1976). The eldest son would travel to metropolitan areas for *dekasegi* ("working away from home") and spend a long part of the year away from the home village; however, basic life continued in the rural village of his birth.

To supplement their agricultural income, many men in Tohoku left their homes and traveled to the big cities during the agricultural off-season to work (usually as construction workers). However, during the period of rapid economic growth, the difficulty for men in rural areas to find marriage partners becomes a nationwide problem. That problem became especially serious in Tohoku. Bailey conducted research in rural Iwate Prefecture in Tohoku region from the 1960s to the 1980s; he explained the relationship between *dekasegi* and marriage difficulties as follows:

> One important effect of *dekasegi* was to exacerbate . . . the issue of succession to the family headship. . . . Eldest sons (*chōnan*) must remain at home or leave only temporarily, ready to answer the call of the family council as the next head of the *ie*. Other sons and many of the daughters tended to leave home permanently. This situation results in severe distortion of the population profile of most villages. . . . In this situation the eldest sons are left without a sufficient pool of potential wives. . . . Men who are not married cannot find women to marry. Further complicating life in village society is the plight of those who wish to continue to farm, normally the eldest sons. It becomes even more difficult to find wives for them. What young woman wants the long hours and drudgery of a farm wife? In addition to the hard work she may have to put up with a nagging, domineering mother-in-law. (Bailey 1991, 146–147)

According to the 2010 national census, the proportion of all households with three generations living together was 21.5% in Yamagata Prefecture. That was the highest in Japan and compared with the national average of 7%. It was also high in other prefectures in Tohoku. In rural areas of Tohoku, it was common for three generations to live together.

The term *ie* appears in the above study by Bailey. *Jiten Kazoku* ("Dictionary of the Family") edited by the Japanese Society for Comparative Family History defines *ie* as "the physical house itself; a Japanese traditional familial group (sometimes including non-kin members); and the abstract concept of the familial group represented in family names" (Ochiai 2005). *Ie* is often translated as "stem family." The Japanese *ie* may be regarded as the stem family; however, its character has historically varied greatly from region to region, and such regional differences still exist. Sociologist Ochiai provides the following explanation: "Japanese family sociologists continue to share an implicit assumption that the typical *ie,* large in size and complex in structure with patriarchal power centering on the head and the eldest son, existed and still exists in the northeast. They also regard households in western Japan as closer to the nuclear family system" (Ochiai 2005, 362). The background to the prominence of *dekasegi* in Tohoku during the period of rapid economic growth is the strong sense of *ie* in that region.

To address the problem of finding marriage partners, which had become very serious in Tohoku farming villages, measures were taken to introduce brides from overseas. One of the first well-known examples of that practice was Asahi Village in Yamagata Prefecture. In cooperation with town halls in the Philippines and an international marriage agency, the village authority in 1985 decided to subsidize the travel costs of Asahi bachelors to give them the chance to meet Filipino women. That trial effort led to a heated debate between supporters of the initiatives and critics, who denounced it as a form of human traffic (Le Bail 2017). Subsequently, the local government withdrew from that matching service. However, through international marriage brokers, many foreign women—first from the Philippines, then from Korea and China—went to Tohoku farming villages as brides.

The geographer Mitsuoka was the first scholar to link Japan's rural marriage crisis with international marriage (Mitsuoka 1987). He identified the following problems with international marriage as a means of dealing with the problem of finding marriage partners (Mitsuoka 1996): (1) It is taking advantage of the low economic level of the partner country and low status of women there; (2) any children born may suffer discrimination; (3) the women do not receive beforehand much information about life in Japan; (4) it may be termed human trafficking; (5) assimilation to Japanese society is forced; (6) relationships with parents-in-law do not go well (some parents-in-law confiscate the bride's passport or forbid them from going out); (7) differences in language and habits cause various problems; (8) the wives suffer from mental stress; (9) the wives will have particular problems when they reach old age; and (10) the brokers who handle the transactions are often corrupt.

The psychiatrist Kuwayama concluded that *dekasegi* also contributed to the difficulties experienced by foreign wives. In families where the fathers were absent from home for long periods of time owing to *dekasegi*, the bond between mother and son became very strong. Thus, even after the son grew up and married a foreign wife, the strong bond with the mother continued, which delayed the son's mental independence (Kuwayama 1995).

3 Problems Posed by Spatial Isolation

Since the turn of this century, a growing body of research has viewed non-Japanese wives in rural areas not just as passive victims but also as active agents of their own destiny (Fuwa and Anderson 2006; Nakamatsu 2005). Nevertheless, they continue to face their own specific geographic problems. "The major issue here is that, even though they recognise the fact that they are exploited, they do not have access to a support system because they are isolated from their ethnic communities in trying to secure better prospects" (Uekusa and Lee 2020). The non-Japanese wives feel lonely because they are unable to talk to anyone about their problems; such problems derive from the fact that they are spatially separated from their peers who share their language and culture (Kuwayama 1995).

It is necessary to consider whether non-Japanese wives belong to ethnic minorities. The classic definition of "minorities" is that of the Chicago school sociologist Louis Wirth: "A group of people who, because of their physical or cultural characteristics, are singled out from the others in the society in which they live for differential and unequal treatment and who therefore regard themselves as objects of collective discrimination" (Wirth 1945, 347). The geographer Hans van Amersfoort argues that Wirth's definition is not very satisfactory "because it makes the existence of minorities completely dependent on the feelings of minority group members" (Van Amersfoort 2010, 183). After examining the concept of "minority," Van Amersfoort revised its definition as "a continuous collectivity within the population of a state." This "continuous collectivity" consists of individuals who share the same values. In his definition, "the minority consists of several generations and membership of the minority has priority above other forms of social categorization" (Van Amersfoort 2010, 200).

In the definitions of Wirth and Van Amersfoort, "minority" is a group. It is possible to categorize non-Japanese women married to Japanese men by ethnicity, such as Chinese, Filipinos, and Koreans; however, it is doubtful whether each can be regarded as a substantive group. Filipinos may have a social network centered on the Catholic Church, but Chinese and Koreans lack any network among themselves. Outside their families, the existence of these women is invisible—both to Japanese and to their peers of the same ethnicity. "Many marriage-migrant women, especially from China and Korea who look like the Japanese, often strategically invisibilize themselves … to avoid sanctions and prejudice resulting from negative stereotypes existing in the Tohoku area, such as the 'runaway bride' or the marrying-for-money bride, as well as entrenched racist and patriarchal beliefs" (Uesaka and Lee 2020).

Van Amersfoort's definition of minority includes the terms "several generations" and "membership"; however, non-Japanese wives are expected to join *ie* membership and produce *ie* heirs: That does not lead to the continuation of their ethnic groups. Thus, in light of the definitions of Wirth and Van Amersfoort, non-Japanese wives cannot be considered ethnic minorities. What makes non-Japanese wives invisible to one another are the barriers of the *ie*; however, the biggest factor is the spatial isolation of each individual. These women live apart from one another in sparsely populated rural areas; thus, it would be difficult for them to meet on a daily basis. The spatial isolation of individuals has not previously been addressed in studies on ethnic minority segregation.

4 Methodology and Data

Most conventional geographic studies of ethnic residential patterns have focused on cities and urban areas. As the terms "ghetto," "segregation," "enclave," and "ethnoburb" indicate, the research focus has been on the residential patterns of ethnic minorities and the factors that create these patterns. Indexes have been developed to measure the degree of concentration of such minorities. Among such indexes is the isolation index, which specifies the degree of isolation of ethnic minorities (Massey and Denton 1988; Robinson 1980). However, those indexes are insensitive to the spatial arrangement of populations (Feitosa et al. 2007).

Most segregation measures adopted in previous studies were intended for application with aggregated data to assess segregation patterns. However, "a trend in advancing segregation measurement is the move from ecological or place-based approaches using spatially aggregated data to individual or people-based approaches using individual-level data to focus on individual's experience" (Yao et al. 2019). Schnell and Yoav (2001) observed that most methodological proposals paid greater attention to uneven social distribution of groups in residential spaces; they gave less consideration to the groups' isolation from interethnic interactions in everyday life spaces. Therefore, research has focused on the daily activity of individuals in

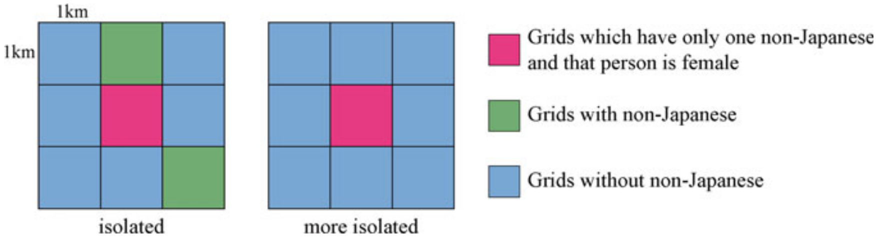

Fig. 2 1-km × 1-km grids and degree of isolation used in this study

everyday life spaces, such as cities and neighborhoods (Schnell and Yoav 2001; Farber et al. 2015).

In the present study, we examined the location of individuals isolated from other members of their own ethnic groups across Japan. To examine the isolation of non-Japanese in Japan, the smallest census tracts in Fig. 1 are inappropriate: They vary in size depending on the location; e.g., they are narrow in urban areas and broad in rural areas. Thus, this study used the grid-square statistics adopted in Japan's 2010 population census. Grid-square statistics are small-area statistics that divide the whole area of Japan into small grids. This study used the statistics for 1-km × 1-km grids. In 2010, there were 152,724 grids in Japan with a population of at least one person that did not require concealment processing; we used those demographic data in this study.

This study identified a grid with only one non-Japanese and that person being a woman as an "isolated grid." Among the isolated grids, there were grids where no non-Japanese lived in the eight adjacent grids: We defined those as "more-isolated grids" (Fig. 2).

5 Distribution of Isolated non-Japanese Women

Figure 3 shows the distribution of non-Japanese in Japan using by grid-square statistics of 2010 population census. In Fig. 3, grids where only Japanese nationals resided in 2010 appear in blue; the grids where non-Japanese lived are shown in green; the isolated grids of non-Japanese women appear in yellow; and the more-isolated grids of non-Japanese women are shown in red. non-Japanese people lived in 60,913 grids, i.e., 40% of the 152,724 grids analyzed. Of these 60,913 grids, 20% (13,270) were isolated grids for non-Japanese women; 17% (2,229) were more-isolated grids. For non-Japanese men, there were 3,563 isolated grids and 523 more-isolated grids; both figures are just one-quarter of the number for women.

When we calculated the proportions of isolated grids for each prefecture, Yamagata Prefecture in Tohoku showed the highest proportion among Japan's 47 prefectures. Among the 2,893 inhabited grids in Yamagata Prefecture in 2010, 1,291 had non-Japanese residents; of those, 509 had only one non-Japanese, and 479 of those

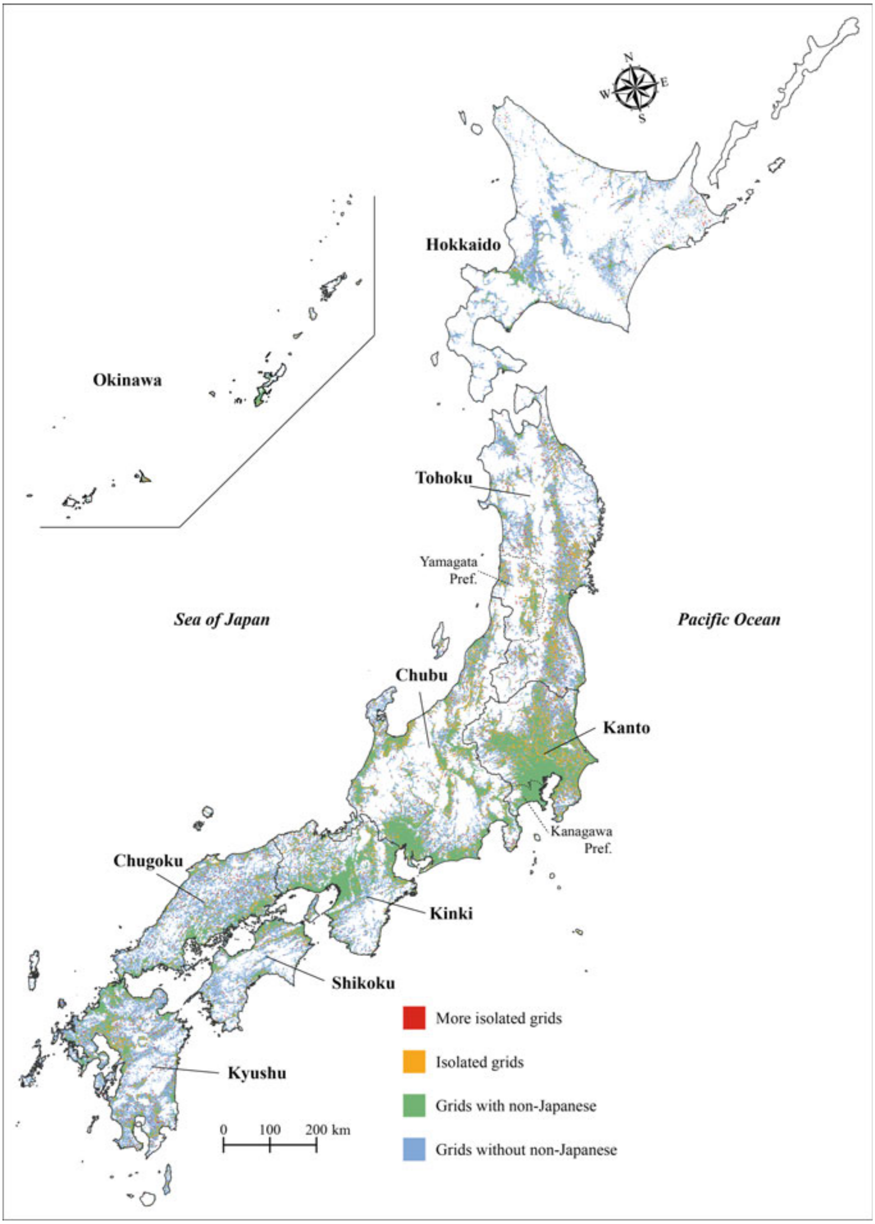

Fig. 3 Distribution of non-Japanese in Japan. This figure shows the locations of Japan's eight regions and locations of Yamaga-ta (Fig. 4) and Kanagawa Prefectures (Fig. 5). Data: Grid-square statistics of 2010 population census)

509 non-Japanese were women. Thus, 16.6% of the 1-km × 1-km grids in Yamagata Prefecture had only one non-Japanese resident and that person was female (Fig. 4).

Of the 479 isolated grids in Yamagata Prefecture shown, 59 were more-isolated grids. As in other prefectures, non-Japanese in Yamagata Prefecture tended to live in

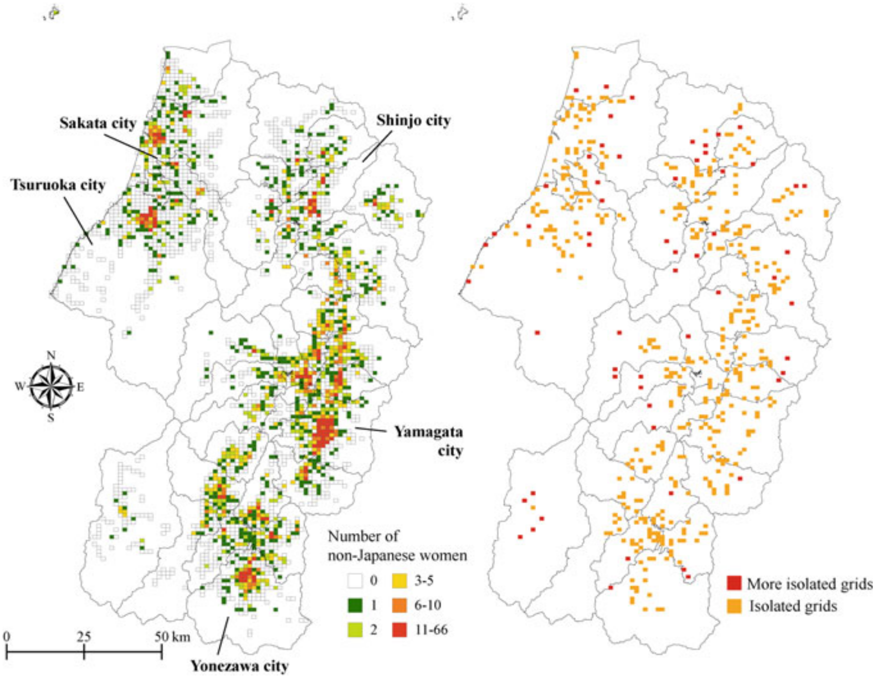

Fig. 4 Distribution of non-Japanese in Yamagata Prefecture (left); distribution of isolated and more-isolated grids (right)

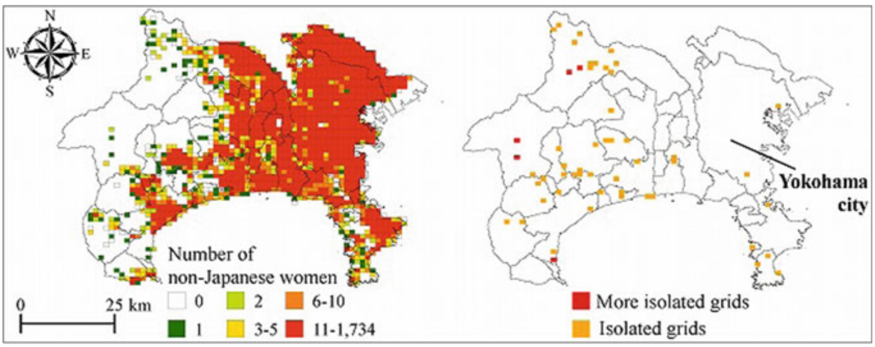

Fig. 5 Distribution of non-Japanese in Kanagawa Prefecture (upper panel); distribution of isolated and more-isolated grids (lower panel)

urban areas (Fig. 4 left); however, in rural and fishing villages, there were grids with only one female foreigner. Furthermore, 12% of the isolated grids were more-isolated grids: a non-Japanese woman who lived far away from other foreigners (Fig. 4 right). The census grid data do not cover details of the marital status of foreign nationals; however, previous studies suggest that almost all the foreign women living in the isolated and more-isolated grids of Yamagata Prefecture were married to Japanese men and were from developing countries.

By contrast, in the case of Kanagawa Prefecture, which is adjacent to Tokyo, the proportions of isolated grids were the lowest, 3.0%. In Kanagawa Prefecture, of the 1,738 grids analyzed for 2010, non-Japanese lived in 1,503 grids (86.5%); thus, non-Japanese resided in most of the population grids (Fig. 5). Of those 1,503 grids, there were 53 isolated grids for non-Japanese women; there were only five more-isolated grids, indicating that most grids had two or more non-Japanese residents.

The two maps in Fig. 6 show the percentage of the isolated grids and the more-isolated grids in the analyzed grids for each prefecture, respectively. When we compare the two maps using quantile classification, the isolated grids were distributed in eastern Japan (such as Tohoku) (Fig. 6, left). However, the more-isolated grids were found in both eastern and western Japan (such as Kyushu) (Fig. 6, right).

As noted above, Yamagata Prefecture had the highest proportion of isolated grids in Japan (16.6%); it was followed by Toyama, Miyagi, Niigata, Fukushima, Tochigi, Nagano, Ibaraki, Chiba, Iwate, Yamanashi, Gunma, and Fukui Prefectures, which had more than 10%. Thus, the foreigner-scattered areas spread from Tohoku to central Japan along the Sea of Japan. That is consistent with the findings of previous studies, whereby women from overseas frequently come to live as wives in rural areas in eastern Japan (except Hokkaido). By contrast, Fig. 6 (right) shows that the highest

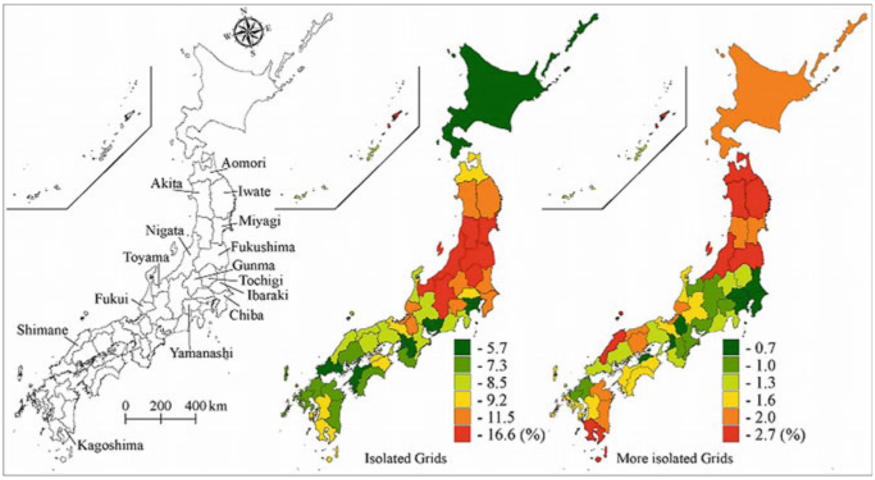

Fig. 6 Proportion of non-Japanese female isolated grids (middle) and more-isolated grids (right) by prefecture. The part on the left shows the locations of prefectures mentioned in the text

proportion of more-isolated grids was in Aomori Prefecture in Tohoku (2.7%); that was followed by Iwate, Akita, Fukushima, Kagoshima, Shimane, Niigata, and Yamagata Prefectures. In addition to prefectures in Tohoku, Kagoshima in Kyushu and Shimane in Chugoku had high rates of more-isolated grids.

These results indicate that the distribution of the foreigner-scattered areas depended on the degree of isolation. The areas with high isolation were not just in Tohoku (as initially supposed) but also in western Japan. This is a completely novel finding.

6 Kernel Density Estimation

In this section, we examine the distribution trend of the isolated and more-isolated grids in greater detail. Figure 3 presents the simple distribution of both grids; however, it is difficult to assess the distribution trend of the 1-km ^{2} grid on a nationwide scale for Japan. By contrast, Fig. 6 shows choropleth maps for both grids using percentages for each prefecture to allow such an assessment. But Fig. 6 does not permit an evaluation of the distribution trend within a prefecture. Further, although both grids are often distributed near prefectural boundaries, Fig. 6 does not allow an assessment of the grid distribution across prefectures.

Accordingly, we applied kernel density estimation (Silverman 1986) to the centroid point data of both grids. Kernel density estimation is often used to express trends with point distribution in a readily understandable manner. With kernel density estimation, the point distribution is covered by a cell of arbitrary size termed an "output cell"; points located within an arbitrary distance from each cell (i.e., "search radius") are searched. From those results, the point density of each cell is estimated using the kernel function. This method allows an easy visual assessment of the distribution trend of isolated and more-isolated grids on a nationwide scale in Japan; it avoids the problem of aggregation by prefecture. However, the results of kernel density estimation vary greatly depending on the setting of the search radius. To take this effect into account, we used three search radius patterns (25, 50, and 100 km) and set the output cell size at 10 km. For kernel density estimation, we employed spatial analyst, an extension of ArcGIS.

Figure 7 shows that the isolated grids were concentrated along the Pacific Coast of eastern Japan (from southern Iwate Prefecture to northern Chiba Prefecture) for all search radii. For the 25 km search radius, the most concentrated areas were near the borders of Fukushima–Miyagi and Miyagi–Fukushima Prefectures. With the longer search radii, areas near the borders of Ibaraki, Tochigi, Saitama, and Chiba Prefectures also appeared as highly concentrated areas.

The 25 km search radius evidenced the most localized accumulation of isolated grids; they were prominent along the Pacific Coast of the Tohoku region (including Iwate, Miyagi, and Fukushima Prefectures). However, with the longer search radii, isolated grids were also widely distributed in the eastern part of the Kanto region. This agglomeration in eastern Kanto did not appear in the choropleth maps (Fig. 6)

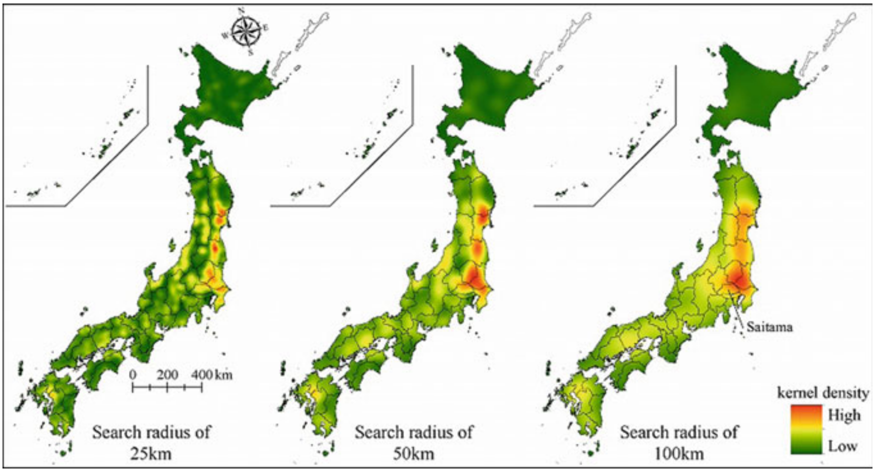

Fig. 7 Distribution of kernel density of isolated grids

using the isolated grid ratio for each prefecture. The reason here may be that most of the isolated grids were located near prefectural borders, and that the proportion of isolated grids was relatively low in prefectures where there were many inhabited grids.

Figure 8 shows the distribution of kernel density using the more-isolated grids. In contrast to Figs. 7 and 8 shows that the concentrations of the more-isolated grids occurred in both eastern and western Japan for all search radii. The more-isolated grids were concentrated around the borders of Okayama, Tottori, Hiroshima,

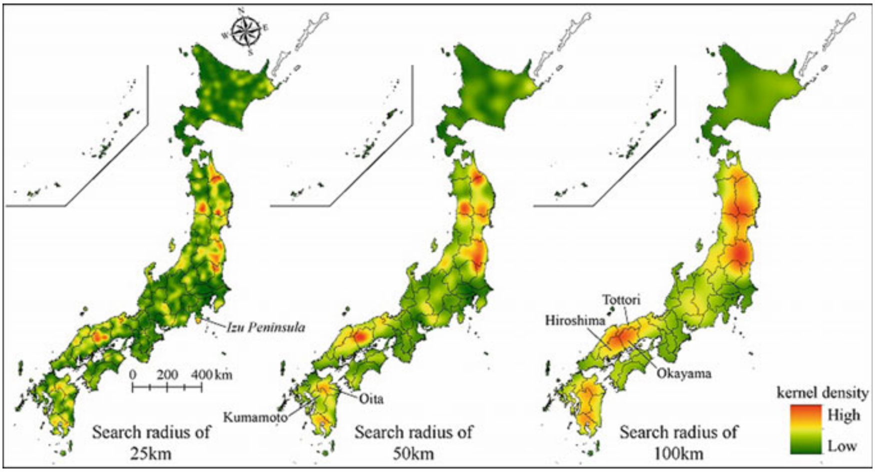

Fig. 8 Distribution of kernel density of more-isolated grids

and Shimane Prefectures in Chugoku and around the Oita–Kumamoto border and Kagoshima Prefecture in Kyushu. Compared with the isolated grids, the more-isolated grids had more localized areas of concentration—as evident with the 25 km search radius. Notably, the concentrations in the Chugoku and Kyushu regions were a feature of the more-isolated grids that did not clearly appear with the isolated grids. Unlike with the isolated grids, the results for the more-isolated grids with the 25 and 50 km search radii indicated concentrations near the Aomori–Iwate border and in Yamagata Prefecture; the concentration in Kanto was limited to the northern part of that region. Thus, the distribution trend for the more-isolated grids in eastern Japan differed from that with the isolated grids.

There were some concentrated areas that became difficult to assess with a longer search radius. For example, the southern part of Izu Peninsula appeared as a locally concentrated area for the more-isolated grids with a 25 km search radius; however, that concentration was not evident with a 50 or 100 km search radius. This finding may be due to the following reasons. Izu Peninsula has the sea on three sides; thus, with a longer search radius, the portion of the sea with no grids in the output cell search radius increased, and the kernel density estimate became relatively small. Also, the southern part of Izu Peninsula had no localized concentrated areas; accordingly, the number of more-isolated grids did not increase even with a longer search radius.

As noted above, the concentrations of isolated and more-isolated grids could be determined by kernel density estimation. Most concentration areas of the two grids were located near prefectural borders, which could not be identified using conventional analysis by prefecture. In this study, we were, however, able to achieve a detailed assessment using kernel density estimation. We also demonstrated the importance of setting and examining multiple search radii when conducting such an estimation.

7 Conclusions

According to the Vital Statistics of Japan, the number of intermarriages between Japanese and other nationalities increased almost continuously from the 1980s until 2006. However, since 2007 that number decreased, and it has significantly declined in Tohoku (Hanaoka et al. 2017). Over the same period, however, international marriages between non-Japanese women and Japanese men have come to be seen in a wider area of Japan (Kamiya 2015).

In contrast to previous studies, which analyzed the distribution of foreign wives in Japan only at the prefectural level, this study examined in detail the distribution of spatially isolated non-Japanese women using data at the 1-km^2 grid scale. We found that non-Japanese women in more-isolated grids resided not only in Tohoku but also in Kyushu and Chugoku. However, as noted above, our data did not reveal the marital status of the non-Japanese women. It is clear from a number of previous studies that almost all non-Japanese women living in foreigner scattered areas of Tohoku had come from overseas as marriage partners. However, further study, including fieldwork, is necessary to identify the non-Japanese women outside Tohoku and determine why they chose to live in areas where they are spatially separated from other foreigners.

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