Developing Hyper-stories in the Context of Cultural Heritage Appreciation

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Abstract. Storytelling has been used as a powerful methodology to design learning activities. By producing their own stories, students learn while developing artifacts, which can be shared with other peer learners generating a rich collaborative learning environment based on constructivism. Digital media and especially hypermedia have been successfully used to support storytelling in learning contexts since it eases the collaborative authoring process and allows for the creation of stories with parallel threads and multiple versions, supporting various viewpoints of the same story. Inspired by the context of learning the cultural heritage of the Armenian cross-stones or Khachkars, we developed a tool in which students can create their own hyper-stories to discuss their different aspects. The tool reflects the inherent attachment of the Khachkars to a geographical location by offering a map on which learners can present the location of the stones. We conducted a preliminary test for answers to our research objectives on the effectiveness of a tool that raises the interest and knowledge of the users in cultural heritage objects, which are located in open-air settings. We also address the tool's usability when using a mobile interface. The results indicate that there is a slight increase in the interest and knowledge of users in objects associated with cultural and historical heritage. The usability of the tool over mobile interfaces was acceptable, although it is necessary to improve certain functionalities.

Keywords: Mobile learning · Hyper-storytelling · Collaboration · Cultural heritage

1 Introduction

Tangible cultural heritage (ruins, ancient churches, vestiges of certain original cultures, etc.) are scattered along various geographical places around the world. Most of them remain in physical locations where they were originally created and have not been

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moved to museums for various reasons. Some are impossible or very difficult to transport. There lacks systematic efforts to "discover" and classify them, in addition to a lack of knowledge of their existence. In some cases, only those who live within close proximity to the place know of them. In many cases, the geographical context is important so as to give meaning to the information and knowledge of the historical facts associated with these patrimonies.

Since these heritage sites cannot be taken to museums, a computational tool that is able to take the museum to the geographical places where they are located would contribute to learning more about these places. Our proposed method uses hyper storytelling to make collaborative descriptions of these places, where any person interested in contributing with can generate a unique story, interpret it from various points of view and offer multiple stories that account for a more realistic and vivid way. The developed computational tool will be used to collaboratively describe places of cultural heritage value, as done in similar scenarios applied in other contexts of storytelling activities, [1–4].

The heritage sites around which stories can be built correspond to archaeological sites and the objects they contain. For example, in the archaeological site of Noratus, Armenia, there are patrimonial objects called Khachkars. In Tiahuanaco, Bolivia, there are archaeological vestiges of vessels or containers scattered in the area that have not been registered yet nor classified, and little or nothing is known about them. Videos, photos (from the internet or taken in the same place), links to web pages with complementary information, virtual 3D representations of objects (virtual museums), and georeferentiations of the places where they are located may be used to describe patrimonial objects.

Authors in [5, 6] identified what is known as the problem of "getting lost in hyperspace", which is basically the user's difficulty in building a map or a systematic representation of the structure of the hypertext program and, by extension, the structure of the information it contains. Our approach includes the georeferentiation over maps as a central scaffold that addresses the sense of being lost in a spatial context in a map while creating connections between sites with spatial location.

Several tools for supporting storytelling activities for learning have been developed in the past for students of basic and middle school [1, 7–10]. Most of them implement linear stories, instead of non-linear narratives (hyper-stories) [9, 11], for example, European history for children [9], Australian history [3], natural history of America in Chicago and New York [5]; or for increasing the intercultural awareness in higher education [12]. Narratives can also be used within the design of new technologies to support lifelong learning in a cultural setting [4]. Mulholland and Collins [4] present a tool which comes close to the idea presented in this work which is a media integrated storytelling platform for non-linear digital storytelling, which can be used as a cultural heritage learning platform. However, the authors only consider the descriptions, and not the location factors.

We would like to study whether making hyper-stories raises people's knowledge and interest in heritage and culture. We therefore conducted a preliminary test to obtain first answers to two main research objectives: (1) the effectiveness of the developed tool to raise the interest and knowledge of the users in cultural heritage objects, which are

located in open air settings, and (2) the usability of the tool, especially when using a mobile interface.

Users participating in the test were purposely recruited from an engineering Masters degree program. This circumvents a positive bias towards topics of cultural heritage, as would have been the case if we had recruited students from the Humanities. During the test, we focused on users who build hyper-stories "in-situ" by using mobile devices; although thereafter, other users could use the hyper-stories for learning purposes. We consider building hyper-stories as the first step and therefore the most important one.

2 Hyper Storytelling as a Support of Cultural Heritage

Digital storytelling is a powerful teaching tool in the cultural and educational field [13–15], which facilitates the presentation of ideas, communication or knowledge transmission, through the integration and organization of multimedia resources on technological platforms of various kinds, including Web 2.0 tools [2, 3]. Digital storytelling takes advantage of the contributions of content generated by students, through a simple procedure consisting of selecting a topic, performing research on it, writing a script, and developing a story with multiple purposes: descriptive, informative, creative, etc. [13].

The construction and elaboration of stories generates attractive scenarios for learning, in which each student adopts the role of a multimedia content producer [14]. This entails applying the narrative, descriptive and creative capacity of the authors and taking the design of an initial script or storyboard as a starting point. It also implies the development of digital narratives that promote new forms of writing and interpretation of multimedia messages, thus training specific digital skills needed to interact in a technological environment, known as digital literacy of the 21st century [15, 16].

Web 2.0 allows for the development of collaborative spaces that enable users to produce information pills, digital stories and all kinds of stories that can be shared with each other through various social network platforms, using narrative formulas and simple technological tools capable of integrating multimedia resources with great expressiveness and communicative value. From a technical point of view, digital stories are constructed using hypermedia language, which can lead to complex stories, thus requiring careful elaboration of a literary and technical script that integrates the optionality and alternatives that hypertext allows. Increasingly, educational units at elementary, middle school, college and graduate levels, use activities focused on the construction of stories from this perspective, given their characteristics and educational potential, obtaining interesting results [10].

There exists a classification of the most relevant approaches for managing digital storytelling processes in the literature [14, 16], as presented below.

(a) Linear vs. non-linear storytelling types are differentiated based on action sequences of media occurring in the story. Non-linearity enables storytellers to tell more complex stories with different storylines within the same story [5, 9, 11], i.e. Hyper Storytelling. Different points of view on individual media could affect the normal flow of a story. Non-linear stories may be told in several versions with various

content sequences [10]. The interactive storytelling process enables storytellers as well as story listeners to make their own decisions actively to determine the subsequent course of the storyline. Dynamic narratives are created by which users can interact at each part.

(b) Collaborative/social storytelling processes can assist in designing the active experience. In particular reference is made to typical web 2.0 environments for narration to define and design multimedia pathways using social features (annotation, collaborative writing, video-sharing, etc.) enabling a continuous improvement of the narrative structure [2].

(c) Mobile/ubiquitous storytelling takes place in a physical environment where the digital natives actually move around and interact with digital content as well as with others using mobile devices and communication technologies. Mobile storytelling is considered a part of the transmedia storytelling, the process where key elements of narration are spread out from various devices like smartphones, tablets, etc. [17].

3 Tool Design Requirements

Based on the previous discussion, we present the requirements for the tool that can support the construction of hyper-stories based on georeferenced archeological artifacts. We exemplify the requirements by a hyper-story constructed around the topic of Khachkars (Armenian cross stones).

R1. Archeological artifacts or sites are the bases for the building blocks of the hyper-stories. Users build a story by adding descriptions, comments, multimedia material, including their 3D representation in a virtual environment and links to other building blocks. To make an association with a film telling a story we call each building block a "scene" of the hyper-story, which has a scenario (the 3D environment) and a (geographic) location where it develops. In our example the core of a scene might be a single or a group of Khachkars.

R2. Each scene should be georeferenced in the place where the artifacts are currently located or where they were originally found. The georeferencing of the archeological objects can be done while the users are at the same place, using mobile computing devices with positioning capabilities, or it can be done remotely on a desktop computer. In our example the scenes were georeferenced at the place where the Khatchkars were originally found.

R3. Archeological artifacts or sites within a scene should have a digital multimedia representation (pictures, videos, animations, etc.) and a 3D model with metadata, which describes them. In our example there is a virtual 3D model of the stone and metadata describing important information like the year of creation, the sculptor who carved it, important ornamental elements it contains, etc.

R4. Descriptions of the objects and archaeological sites will be carried out collaboratively among the participants. Collaborative work can develop synchronously, as well as asynchronously. The use of tags and colors will

allow sorting, classifying and grouping the described historical objects and places.

R5. Each scene may have zero or many links to other scenes, which are related to it and may continue the topic or introduce a new hyper-story. This requirement is stated in order to implement a hyper-story with multiple scenes. A link may be labeled with a text in order to describe the relation between the two scenes it connects. Links might be one or bi-directional.

R6. Provide visual support for traversing the multiple linear stories within the hyper-story, through the use of a graph that will show its nodes corresponding to the scenes georeferenced in the map, and where the edges are labeled according to the relationship that the user determines that exists between two nodes. The visual support to go through the hyper-stories will allow the users to specify the interrelations between the scenes. The nodes linkage generates semantics. Examples of this semantics are: sequences of routes, hierarchical ordering, and scenes grouped under specific criteria. The scenes grouping can be achieved by the combined use of colors and links

Regarding **R6**, the interrelations between nodes can generate different semantics associated with each georeferenced scene/node, where each of its combinations can correspond to a story within the hyper-story. The basic semantics associated with the stories that can be generated on the basis of a hyper-story scheme of Fig. 1, can help the user's understanding of the associated semantics. These are:

(a) The first basic relation between scenes (Nodes) is the **arc,** which means after visiting one scene, the ones linked to that should be visited. In Fig. 1, we see that after Node 4, Node 5 should be visited; also, after Node 1.1, Node 1.2 and/or Node 3, AND? Node 2 should be visited. This basic relation may define sets of related scenes according to the paths defined by the links (see section c and d)

(b) The second basic way to relate scenes is specifying a **group of scenes,** which have common characteristics by assigning the same color to them. In Fig. 1 Node 1.2, Node 2 and Node 4 were created with red color, similarly, Node 1 and Node 1.1 in yellow, and 5.1 and Node 5 in green, defining three groups of scenes.

(c) **Ordered traversal** between Node 1 and Node 2: One option would be Node 1, Node 1.1, Node 1.2, and finally Node 2. An alternative path would be Node 1, Node 1.1, and Node 2 - skipping Node 1.2; or Node 1, Node 1.1, Node 1.2, Node 3 and finally Node 2 – (additionally visiting Node 3). Ordered traversal paths emerge when implementing what is known as "depth first" traversing of a graph.

(d) **Hierarchical traversal**: A hierarchical traversing path emerges when implementing a "width first" graph traversal. They are defined by starting from a node (any) and visiting the neighbors (in any order) and then the neighbors of the neighbors recursively. In Fig. 1 we can start from Node 1.2 and then visiting 1.1, 2 and 3 (in any order), after which we can visit 1 and 4, and finally Node 5.1 and then Node 5.

(e) **Labels** on the arc may be used to further refine the ways to relate nodes among them. In Fig. 1 Node 1.2, the link labels relate Node 1, Node 2 and Node 1 among one another. Also, Node 1.2, Node 3, Node 4 and Node 5.1 form another related Node group.

Along with the various ways of implementing interrelations between the nodes, an additional functionality has been added to the graph that allows the user to be shown the possible paths that the links generate between two nodes, without repeating them, and based on the addresses of the edges. To see this functionality, the user must mark two nodes, the start node and the end node, and the implemented functionality will immediately show all possible paths. In this way, a user can go through several possible stories within a hyper-story. For example, in the graph of Fig. 1, if the selected start and end nodes are Node 1 and Node 2 respectively, the possible paths that will be shown to the users corresponding each one to a story would be two, (i) Node 1, Node 1.1, and Node 2; and (ii): Node 1, Node 1.1, Node 1.2, and Node 2.

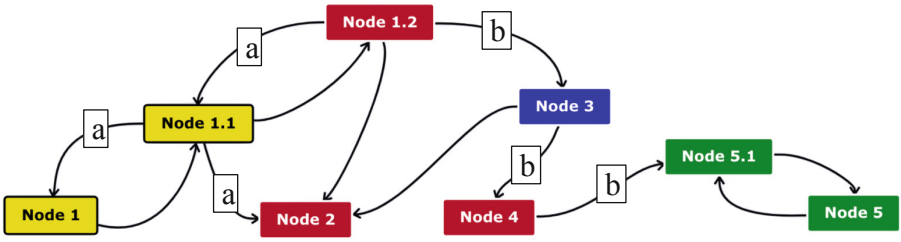

Fig. 1. The graph illustrates the explanation described in the requirement R6, regarding the use of a visual tool to support users in the monitoring of hyper-stories, explaining the different interrelationships and semantics associated with their use. Each Node is associated with a georeferenced scene. (Color figure online)

4 Tool Description

Figures 2 and 3 show some of the main interfaces of the tool. Various sessions can be created where users can contribute.

To implement the **R1** requirement, the tool presents as a central view the world map taken from Google Maps (see the left-hand side view of Fig. 2), on which points, or geometric figures corresponding to archaeological sites are georeferenced for which a description that corresponds to the construction of the story is given, see the right view of Fig. 2. For each georeferencing, users must specify a title, plus the digital artifacts indicated in the **R2** requirement. Each created georeference can be commented on in the description of each georeferencing or in the comments area, which extends the story in a linear and non-linear way; users can add various digital contents specified in the **R3** requirement, such as photos, descriptions that complement the story, links to other web pages (Wikipedia, YouTube, etc.), other related georeferentiations, and virtual 3D representations of objects in virtual Museums. For example, the view on the right of

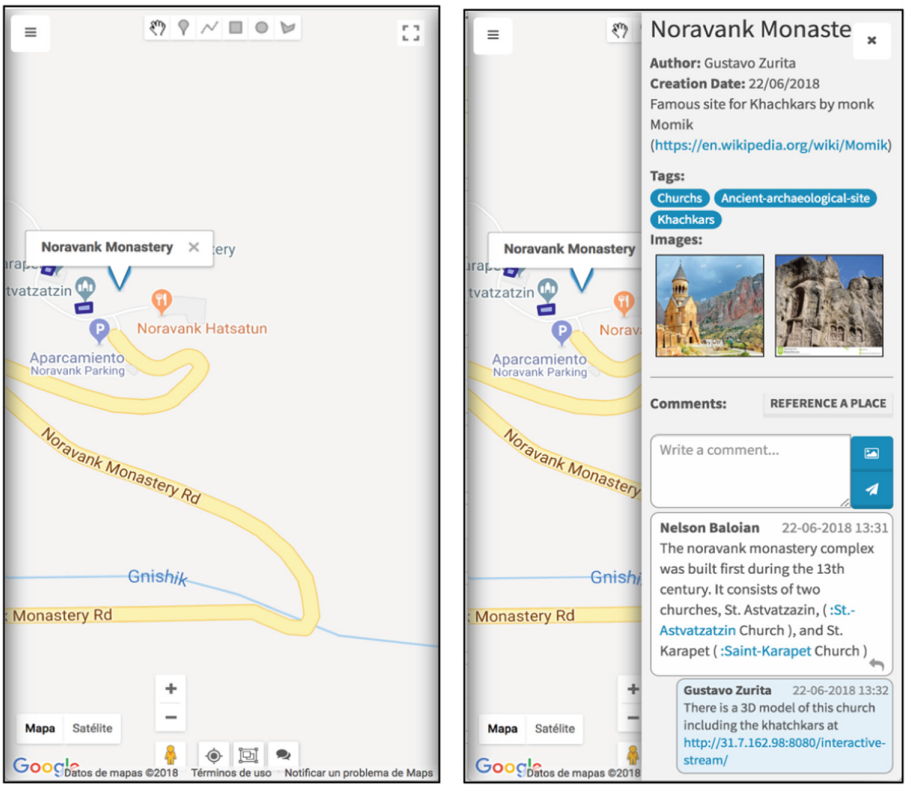

Fig. 2. Screenshots of the tool, seen from the interface of a mobile phone, and showing two different states of the tool, corresponding to one of the sessions in which the students performed the preliminary testing. The screenshot on the left shows the result of having created a new georeferentiation of the site "Noravank Monastery", by using the functions of the buttons that are shown at the top of the interface. The screenshot on the right shows the state in which the interface of the tool changes, after the "Noravank Monastery" site previously created has been chosen. In this last state, the information associated with the site is displayed in a window that overlays the map from the right side of the tool's interface. The information shown corresponds to what was generated and introduced when the site was created: the author of the georeferenced site, the date of creation, its classification labels (Churches, Ancient-archaeological-site and Khachkars), its classification color (blue), links with more information of the site, one or more photos (which can be taken in the same place where the georeference was created or upload remotely). Also, in this state, any user who shares the session can comment on the georeferenced site or read all the comments and their responses that other users have already entered in a collaborative manner. In these comments, it is possible to include links to other georeferenced sites, which allows for the construction of hyper-stories. (Color figure online)

Fig. 3, corresponding to a virtual 3D representation of the church of "St. Astvatzatzin Church" entered by the user "Gustavo Zurita" in the view of Fig. 2 (right).

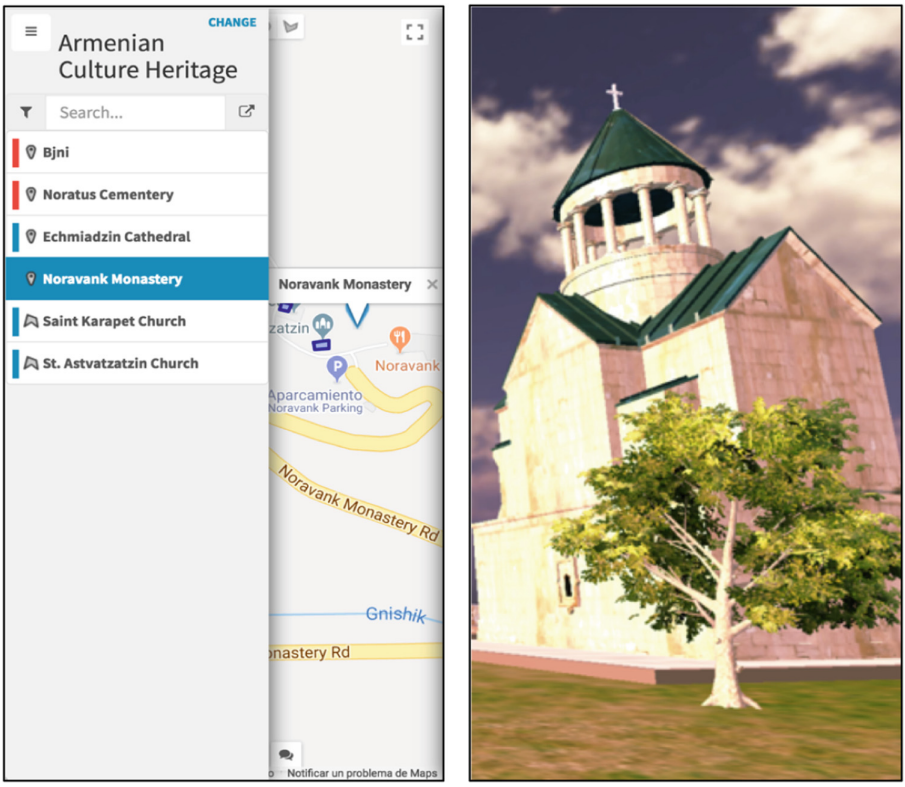

Fig. 3. The screenshot on the left shows a status of the interface with a list of six previously created archaeological sites, by the users who worked collaboratively in a session entitled "Armenian Culture Heritage". As with the association of labels when a site is georeferenced, the use of colors (associated when the site is created) can also be used to classify them. For this session, the students chose the color red for the first two sites with the purpose of denoting "ancient cemeteries", and the blue color for the following four sites that denote the "ancient churches". This list is displayed in a window that overlaps the map from the left side, by clicking on a button with an icon that contains three lines located in the upper left part of the tool interface. In this state of interface, once you choose one of the sites displayed in the list of the overlaid window, as is the case of "Noravank Monastery" and that is highlighted in blue in the list (whose information is displayed in the state of the interface shown in the screenshot on the right of Fig. 2), it is georeferenced on the map, as seen behind the window on the right side of this interface state. The screenshot on the right shows an activation of another state that shows an interactive 3D view that was associated through a link at the time the site "Noravank Monastery" was georeferenced. (Color figure online)

These hyperlinked extensions can be resources generated by data from the crowd, like Wikipedia or YouTube. In the case of the virtual 3D Khachkar museum, it is a co-curated virtual 3D resource, in which both "the crowd" and Khatchkar experts work together. On the one hand, mobile hyperlinked storytelling helps promote cultural heritage sites by making them part of an interactive story. On the other hand, users who

learn about crowd-based 3D museums are potential future contributors to sites like this one, e.g., by taking photographs or scans on-site or by generating or validating sensor metadata for the cultural objects, like GPS data. In return, story paths and comments by mobile users using this tool can be used as a feedback channel to learn about the cultural heritage resource linked therein.

Any user can create a georeferencing, or various users can together create one. The generated stories can be constructed based on the comments that users make to each georeferencing, thus allowing collaborative work that corresponds to the R4 requirement, see Fig. 2 (right).

In the description and comments associated to each georeferentiation, other locations can be georeferenced, which allows the creation of hyper-stories as stated in the R5 requirement; Thus, e.g., the georeferencing "Noravank Monastery", which can be seen in Fig. 2 (right), is associated with the georeferentiations "Saint Karapet Church" and "St. Astvatzatzin Church". Please see comment from user "Nelson Baloian".

Georeferentiations can be organized by colors and tags, to allow users to track and characterize the descriptions of the historical places of several sites at the same time, or to generate multiple stories of the same archaeological objects or places. At the left of Fig. 3, a list of georeferentiations is shown, where the first two in red ("Bjni" and "Noratus Cemetery") correspond to ancient Cemeteries, and the next four in blue ("Echmiadzin Cathedral", "Noravank Monastery", "Saint Kaparet Church", and "St. Astvatzatzin Church") correspond to places where churches are located. In this way the georeferentiations in red allow the building of a story associated with the churches, and the blue ones correspond to another story associated with cemeteries.

Figure 4 shows two views in different states, resulting from the activation of the graph that shows all the scenes of a hyper-story built with the aim to present the museums located at the center of the city of Yerevan. They have been georeferenced on the map using the red color, and with labeled edges that explain the rationale or their associations. These views correspond to the actual work done by three graduate students of the Master program in computer science at the American University of Armenia (see next section for more detailed description of this activity). Figure 4, shows the nodes corresponding to the scenes or nodes of beginning at the "Avetik Isahayakyan House-Museum" and ending at "The Gallery of Mariam and Yeranuhi Aslmazyan Sisters" on the right-hand side of Fig. 4, another more extensive path is depicted, which visits the nodes "Avetik Isahayakyan House-Museum", "Isahakyan Museum", "Hovhannes Shiraz Home and Museum", "Hovhannes Tumanyan Museum", "Silva Kaputikyan House-Museum", and "The Gallery of Mariam and Yeranuhi Aslmazyan Sisters". In the lower part of the view on the right the interface shows the list of all possible trips. In this case, each of these scenes was added and linked in order to advise people while taking a tour of the museums in Yerevan in a convenient order according to their geographic proximity. In another similar session, three other students generated a similar graph, but in that case, students decided to link the museums according to their thematic nature, e.g., by painters, poets or sculptors.

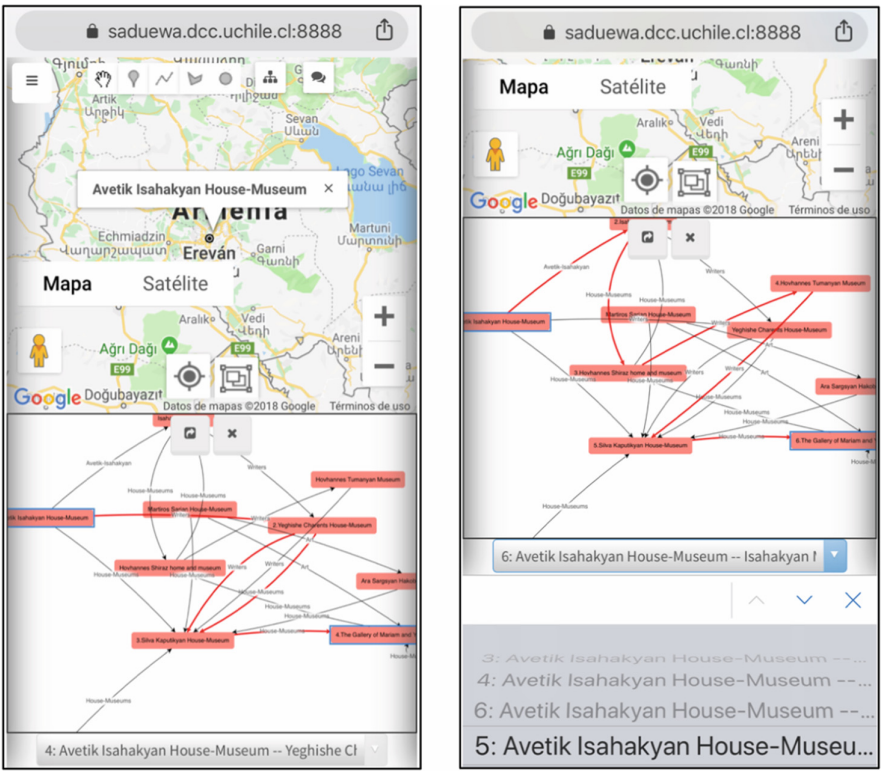

Fig. 4. The screenshot on the left shows a state that displays in the lower half of the interface, the graph that visualizes the links between the stories (or hyper-stories) constructed collaboratively by the students. In this session all the georeferenced sites were associated with the red color, so each node of the graph is displayed in a red rectangle containing the name of the site and connected by black arcs. Specifically, in this graph you can see the selection of a path between the site "Avetik Isahakyan House-Museum" and the site "The Gallery of Mariam and Yeranuhi Aslmazyan" labeled with a prefix "4:" (followed by the list of names of the sites of the chosen route) whose connection arcs are shown in red, and their origin and destination nodes framed with a blue border. The screenshot on the right shows another state of the interface where at the bottom are displayed other possible paths labeled with prefixes corresponding to numbers from "1:" to "5:", which can also be chosen as other routes between the same sites chosen in the screenshot on the left. In this way, a user can choose a route between two sites, choose them in sequence, while they are shown on the map, and in turn open them to access their detailed information, along with the comments built collaboratively. (Color figure online)

5 Preliminary Testing

We conducted a preliminary test to answer our research objectives about the effectiveness of a tool like the one described to raise the interest and knowledge of the users in cultural heritage objects that are located in open-air settings, as well as the usability of the tool, especially when using the mobile interface. Users participating in the test

were purposely recruited from an engineering Master degree program in order to avoid a positive bias towards topics of cultural heritage, as would have been the case if we had recruited students from the Humanities. As mentioned in the first section of this document, engineers are clearly better subjects to measure the degree of motivation that the use of the tool can generate, since these students, due to their training, are more interested in aspects of the technical type than the cultural.

Since this was the first testing of the tool by users not involved in its development, we also wanted to get information about the usability of the system to improve its interface in future versions.

5.1 Experimental Setting

We recruited 12 graduate students, 7 male and 5 female, ages 22 to 24 years old, enrolled in the capstone project preparation course in which they learn how to conduct a research project in general. In the frame of this course, this test was a student activity for "learning by doing" on how to conduct an experiment in order to validate hypotheses about the ability of a certain system for fulfilling requirements. The activity started with a 15-min demonstration where the teachers showed how to use the system, and the students composed a small test hyper-story. The teacher then instructed the students to form six groups of two students each and choose a topic related to cultural heritage, giving as possible examples "ancient churches", "modern churches", "museums", "archeological sites", "soviet architecture", "modern architecture" and "monuments". At the end of the session they had to answer a pre-questionnaire (see next subsection for the content).

Fig. 5. A student takes a photograph of the Armenian parliament, which was georeferenced as an example of Soviet architecture.

After this session, the students worked for one week creating the hyper-stories by using the tool in their mobile devices. The students were not told beforehand, which were the research objectives, in order not to bias them.

After the week, the students presented their work to the teacher and the other students explaining what message they wanted to convey with their story. After all groups presented their work, they answered a post-questionnaire, which also included questions for measuring usability. After that they participated in a 30-min focus group.

5.2 Students' Produced Hyper-stories

From the six groups, two chose the Armenian Churches (one with exclusively ancient churches and the other included some new ones), two Monuments and Statues in Yerevan, one example of Soviet Architecture (see Fig. 5), and the last one Galleries and Museums, as their topics for the hyper-story they had to create with the tool, each of them in six different sessions created with the tool.

Table 1 summarizes the main objective characteristics of the created hyper-stories. The table shows a wide range in the value of the parameters considered for this description, which are, apart from the topic itself, the total number of nodes, the number of those which were created while being physically in the place (thus using a mobile device), the number of links, the links semantics, which are the meanings or concepts students used to organize the graph structure with the links and thus the structure of the hyper-story, and the number of photos.

Table 1. Summary of the hyper-stories created by the students according to the number of nodes created (in place and remotely), number of links, links semantic, and number of photos.

Topic	#Nodes remotely	#Nodes in place	#Links	Link semantics	#Photos
Churches, new/old	8	15	29	Hierarchic	60
Statues in Yerevan	2	4	12	A walking tour	20
Statues in Yerevan	5	12	22	A walking tour	34
Soviet architecture	4	8	27	Thematic	10
Galleries & Museums	3	9	18	Thematic	17
Ancient Churches	5	5	8	Location, style, history	13

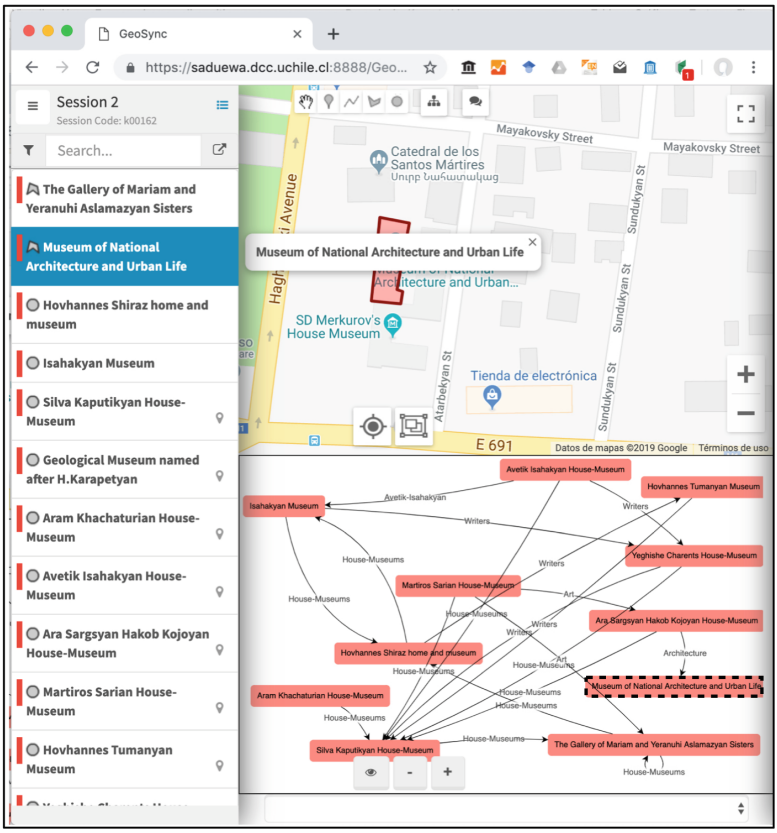

Fig. 6. Screen capture of the interface of the tool executed on a desktop computer, showing the graph of the hyper-story created by a group of students that chose to geo-reference "Galleries and museums", in a session called "Session 2". In the screenshot, a user chose the "Museum of National Architecture and Urban Life" from the list on the left, at the same time that its georeferencing is shown on the map, and its representation in the graph, shown by a represented node by a rectangle with black border of dotted lines. The relationship of this node, with other nodes that correspond to other sites of museums, is denoted through the labeled arcs that leave or enter it. In this graph in particular, the nodes and their arcs between one another, were created to relate museums according to different criteria; that is, this is the basis of the hyper-story constructed. For example, in this screenshot some arcs of the graph associate museums according to their nature; e.g. the type of link semantic is thematic, ("house-museum" means the former house where an artist used to live was converted into a museum after passing away), and others link museums by the type of artists that exhibit their works of art in these museums (mostly writers, one architect and a painter).

Through a review of student hyper-stories we observe various semantics that they associated to the links created among the georeferenced sites. This is not about the label of the link itself, but about how the links were relating to the nodes in general and thus giving a structure to the whole graph (see requirement R6 in Sect. 3). Except for one case, all groups were very consistent in assigning a semantic meaning to the links. For

example, Fig. 6 displays the graph for the group that implemented a hyper-story on Galleries & Museums. They related the nodes according to what was the gallery or museum about. Therefore we see that "house-museum" means that it is (also) a house where an artist used to live and was converted to a museum after she passed away. Additionally, there are also links used to relate the nodes by the type of artist, so most of the nodes in the shown part of the graph represent a writer's museum. This means, the "reader" of the hyper-story can traverse it by following a "house-museum" path or a "writers" path.

By contrast, in Fig. 7 the graph shows that nodes are connected hierarchically: There are two nodes representing monastery complexes (Haghbat and Sanahin), as well as single structures belonging to them. The arcs go from the nodes representing single structures to the nodes representing the complex to which they belong.

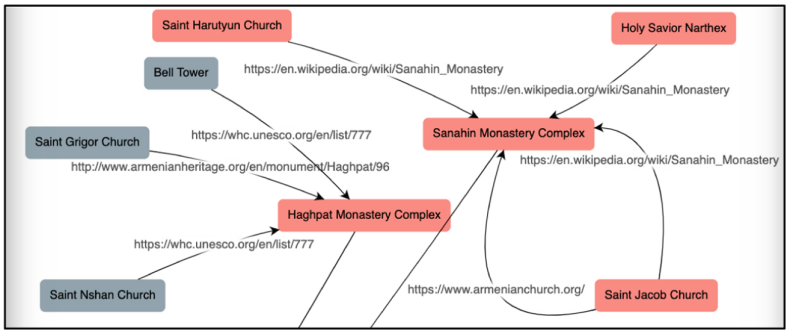

Fig. 7. This figure shows part of the graphic that represents the hyper-history elaborated by the group that georeferenced "Ancient Churches" in a session called "Session 6". The arrows of the arcs were used to indicate the nodes with greater importance; that is, according to the classification of Table 1, the semantics of the links is hierarchical. Specifically, the graph has two central nodes, each representing the complexes of the ancient churches "Haghpat Monastery Complex" and "Sanahin Monastery Complex" to which other arches point, from nodes corresponding to less relevant ancient churches that are part of these complexes.

5.3 Questionnaire Results

To obtain feedback from the students about the perceived utility; i.e., its effectiveness in increasing the interest and knowledge of users in objects associated with cultural heritage found in outdoor environments, we conducted a pre-test and a post-test. Table 2 summarizes the answers of the pre-test. The two questions, "what is your knowledge about the topic?" and "what is your interest on the topic?" are asked to find out if there is any variation before and after performing the activity with the tool, since these are two of the most basic research objectives that we had in mind when conducting the experiment.

Table 2. The table shows the two questions the students answered in a pre-test, and the answer given by each student (labeled with s1 to s12).

	s1	s2	s3	s4	s5	s6	s7	s8	s9	s10	s11	s12	Mean min/max
1 - On a scale from 1 to 10, what would you say is your knowledge about the topic you chose for the experiment?	9	3	5	1	2	4	5	5	6	4	7	9	6.5 1/9
2 - On a scale from 1 to 10, what would you say is your interest on the topic?	10	5	7	4	8	5	7	7	7	5	8	9	7.75 4/10

In the post-test, besides the same two questions of the pre-test, we included three more related to the perceived utility. We can note that the mean value of the answers to the questions about the knowledge level and the interest level rose from 6.5 to 7.6 (17%) and from 7.75 to 8.3 (7%) respectively, which might not be too impressive. This might be because the initial values were already high before the experiment, especially the one for the interest (second) question. It is however noteworthy that the minimum answer for both questions rose much more dramatically for both questions, from 1 to 4 for the knowledge and from 4 to 7 for the interest (Table 3).

Table 3. Two questions the students answered in a post-test, and the answer given by each student. The identification s1 to s12 does not correspond to the same student in Table 2 with the same ID since the post and pre-test were performed anonymously.

	s1	s2	s3	s4	s5	s6	s7	s8	s9	s10	s11	s12	Mean min/max
1 - On a scale from 1 to 10, what would you say is your current knowledge about the topic you chose for the experiment?	9	9	6	7	8	8	6	4	8	9	9	8	7.6 4/9
2 - On a scale from 1 to 10, what would you say is your current interest on the topic?	9	9	8	7	8	9	7	8	8	9	10	7	8.3 7/10
3 - On a scale 1 to 10 please indicate if you enjoyed performing the activity (1 not at all, 10 yes, I fully enjoyed it)	10	6	8	4	6	8	10	10	10	10	10	8	8.4 4/10
4 - On a scale from 1 to 10, what would you say is the ability of developing hyper-stories to raise interest in the topic the hyper-story is about	10	7	7	5	7	6	6	6	4	8	10	7	6.9 4/10
5 - On a scale from 1 to 10, what would you say is the ability of developing hyper-stories to implement an “open air” Museum?	10	7	9	5	5	8	7	5	7	9	9	9	7.5 5/10

For evaluating the usability of the system we applied the System Usability Scale (SUS) test, which has been widely used for more than 30 years as a "quick and dirty" but effective and reliable instrument [18, 19]. This instrument requires a minimum of 12 participants that also matched our sample. The test consists of 10 questions that are answered according to the Likert scale, of which 7 measure the usability and 3 measure how easy it is to learn to use the system. The output of this test is a number between 0 and 100, which does not correspond to a percentage, but is interpreted in the following way:

- 80.3 or higher means a high level of usability.
- Around 70 signifies that the usability of the system is acceptable, but can be improved.
- 51 or under signifies the HCI of the application should be redesigned in depth.

Table 4 shows the outcome of the SUS questionnaire, which indicated that the interface is acceptable, but can be improved.

Table 4. The table shows the answers given by the students for the SUS questionnaire. The value on the Rate column was computed for the odd numbered question by subtracting 1 from the mean values. For the even numbered question, the mean value vas subtracted from 5. The total SUS value was computed by adding all the rates and multiplying this number by 2.5 [18].

		s1	s2	s3	s4	s5	s6	s7	s8	s9	s10	s11	s12	Mean	Rate
1	I think that I would like to use this system frequently	5	3	2	2	3	2	2	2	4	4	4	4	3.1	2.1
2	I found the system unnecessarily complex	1	2	2	2	2	1	3	3	1	1	1	2	1.8	3.2
3	I thought the system was easy to use	5	5	2	2	4	5	2	2	4	4	4	4	3.6	2.6
4	I think that I would need the support of a technical person to be able to use this system	2	1	1	2	1	1	5	4	1	2	5	3	2.3	2.7
5	I found the various functions in this system were well integrated	4	3	2	3	5	2	3	3	3	4	5	5	3.5	2.5
6	I found there was too much inconsistency in this system	1	3	2	3	2	4	4	4	3	2	3	4	2.9	3.1
7	I would imagine that most people would learn to use this system very quickly	5	4	2	3	5	4	5	2	5	5	3	4	3.9	2.9
8	I found the system very cumbersome to use	1	3	2	4	1	3	5	3	2	2	2	1	2.4	2.6
9	I felt very confident using the system	5	3	3	2	5	4	1	3	4	4	5	4	3.6	2.6
10	I needed to learn many things before I could get going with this system	5	1	2	3	1	1	3	2	1	1	1	1	1.8	3.2
	Total SUS														68.75

After the students completed the questionnaires, a brief focus group session was held centered on two simple questions: What are the main positive and negative characteristics of the tool?

Regarding the positive aspects, they mentioned very prominently and almost unanimously that the possibility of linking georeferenced sites differentiates this tool from others that are publicly available. They especially appreciated the "view functionality" resulting from the creation and linking of georeferenced, sites that we are referencing as a graph in this article (see Figs. 6 and 7). The members of the two groups, which developed hyper-stories around monuments in Yerevan, commented that this tool could be effectively used for supporting tourists visiting the city if used in a crowdsourcing modality. This aspect is especially interesting, since it shows that the tool is effective in terms of being used in places where historical or archaeological sites are located, thanks to the mobile devices they used. The above is supported by the results shown in Table 1, where from a total of 80 georeferenced nodes, 66.25% correspond to georeferenced nodes "in place" and 33.75% to remotely georeferenced nodes.

Most negative aspects were related with some bugs that they discovered while using the tool, like photos being cropped or rotated when uploading them, and that they had to first enter Google maps independently of the tool in order to activate the GPS functionality of the tool when using it with mobile devices. They also missed the possibility of editing the content of the nodes after being published in order to complete them or correcting some wrong information. Some students also mentioned the idea of having the possibility of linking nodes with undirected arcs, so that it is possible with just adding one link to go indistinctly from one node to the other. This hints at the fact that the usability could be improved after fixing the bugs.

6 Conclusions

The developed tool allows the museum to be taken to the geographical places where archaeological objects belonging to different cultural patrimonies are located through the hyper-storytelling. It also allows users to create linear and nonlinear historical descriptions in a collaborative way, focused on the location of archeological artifacts.

According to the reviewed literature, there is no other proposal similar to ours in which users based on georeferencing, associated with cultural historical sites, can perform collaborative hyper-stories.

With the proposed tool, one can also describe intangible heritage objects, which are associated with specific historical places. For example, the explanation on why the Khachkars were built with certain characteristics can be described for certain regions of Armenia, although their vestiges are not even present nowadays. By hyper-linking co-curated and virtual 3D resources, the awareness of mobile users about the existence of virtual replicas of intangible objects can be raised and they can get access to these resources.

The results of the preliminary testing to answer the achievement of the two research objectives regarding the tool developed indicate that there is a slight increase in the interest and knowledge of users in objects associated with cultural heritage found in

outdoor environments. Regarding this result, it is noteworthy that the users are students of Engineering Sciences, who initially may not have interest in historical and heritage sites as social science students may have. This guess may be confirmed with future inquiry.

Concerning usability of the tool on mobile interfaces, we can say that it was acceptable (68, 75 points over 100). It is necessary to improve certain functionalities, being the most relevant: loading the photos taken "in-situ", and the creation of links between georeferenced nodes directly over the visual view of the graphs.

Furthermore, from our general observation of the preliminary testing, and according to [1], the tool: (a) enhances collaborative storytelling, (b) supports collaborative work and (c) ensures a sense of authorship of the stories in a mobile scenario. These are aspects of future work that we will address with more tests and a variety of final users.

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