New Horizons of Museum Experiences: Between Physical and Digital

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Abstract. Museums [1] represent a collection of ancient and modern knowledge that needs to be protected, disseminated and passed on in the best possible way. The development of digital technologies in recent years is providing an answer to this need, with the transformation of research and restoration sections of museums into veritable FabLabs. The outputs generated by these specialised laboratories range from faithful physical/virtual reproductions of historical artefacts to digital libraries that can be used by experts and others. The museum framework is ideal for testing the quality and flexibility of these new technologies aimed at preserving and at the same time disseminating cultural heritage [2]. The global spread of this practice and the sharing of research data is progressively giving rise to new application scenarios within the community, with the aim of generating cultural networks and inclusion. The macro-scenario of "museum digitisation" triggers a series of micro-scenarios with scientific and public implications, generating social value. The methodology applied involves a preliminary analysis of the current museum context, taking into account the possibilities provided by technological innovation. Subsequently, through the research of case studies, the importance that these technologies, linked to a conscious use, can assume in the museum context was consolidated. The last phase sets out how design approaches can strategically guide museum realities towards the generation of innovative and accessible experiences and modes of use. The aim of the paper is to investigate, through the use of case studies, how design can catalyse the potential of digital fabrication and digital technologies. All this can lead to new kinds of scientific and public fruition, reaching an increasingly wide audience.

Keywords: Museum · Design for all · Experience design · Digital technologies · Digital fabrication · Public art · Social responsibility

1 Introduction

"Design innovation generally does not conform to dominant aesthetic standards, but creates new canons and seeks to transmit them to society, which is constantly evolving" [3]. This process of innovation and refinement can generate multiple scenarios and opportunities for growth [4]. In this context, the designer assumes a relevant role, as he is prompted to rethink spaces, experiences and habits of future users. This is possible thanks to the transversal and multidisciplinary skills that characterise them, combined with a

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human-centred approach and a propensity to manage complexity. If from the design point of view, the progress-user relationship encourages the rethinking of "contextual" (futuristic) spaces and services, from the museum point of view, the same relationship requires a rethinking of its offer: catalysed in all-round experiences. The adoption of new technologies, both by individual users and institutions, enables the generation of new outputs, creating new meanings and influencing changes in the context [5]. In this framework, the museum is identified as a dynamic reality born in conjunction with cultural and social transformations since the Renaissance, which continues to develop today [1].

In this context, new technologies, applied to the cultural context with a design approach, aim at the democratisation of knowledge (Fig. 1). The Human-Centred Design approach in museums gives rise to a new practice of designing cultural heritage through digital means. Design becomes the catalyst for digitally enriched museum experiences, involving both designers and external professionals in the design process. This practice plays a central role in a broader panorama of design innovation in museums [6].

The process of museum digitisation would allow various groups of users, differing in age, interests, profession and culture, to have access to a huge amount of: information, images and historical reproductions through any device. The aim of this practice is to make knowledge usable through a strategy that facilitates cultural accessibility, involves citizens and enhances local and large-scale participation.

The adoption of technology by these institutions can be read, through "Design for all", as an important driver of innovation in the museum experience [7]. Managing and understanding the complexity of new technologies activates a series of strategies that aim to:

- Enhance cultural participation.
- Strengthen and innovate ways of involving the public.
- Design methodologies and tools for accessibility and inclusion of people.

Experience Design methodologies [8] enable the design of the whole museum experience, from pre to post visit. The design process is based not only on the visit itself, but also on the moments of "contact" that precede and follow the experience. The phases of the customer journey can be further enriched by the implementation of the digitisation process of the museum resources, eliminating through innovative methods of use the geographical barriers between the user and the museum artefact. This vision would allow both the public and professionals to openly enjoy cultural heritage by highlighting the artistic value, strengths and opportunities, strategy and overall objectives. In this frame of reference, "design-driven innovation", defined by Verganti as an "innovation of meaning", absorbs "technology-push" innovation [9] and becomes itself a means that allows technology to redesign the competitive logic of the market and the way in which users access/use it.

The presence of design is widespread in museums, from the exhibition to the types of service offered. The adoption of technology by these institutions can be read, through "design for all", as an important driver of innovation in the museum experience.

In this perspective, the advent of Digital Fabrication has greatly stimulated the development of digital technologies for acquisition, modelling and prototyping, opening new

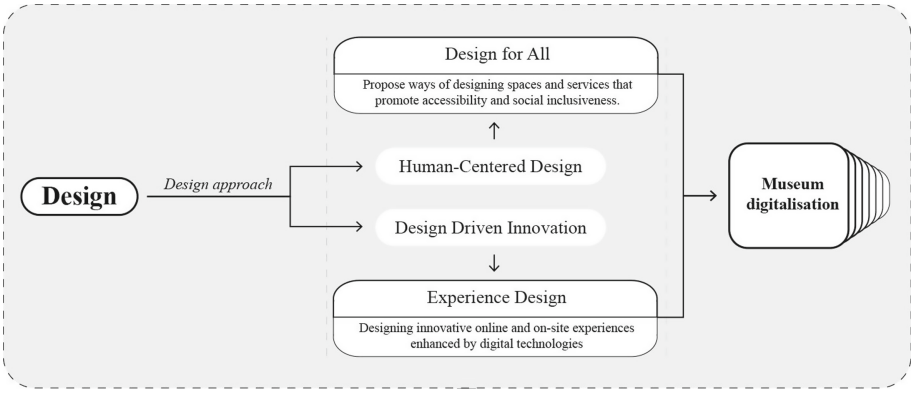

Fig. 1. Pictured is the diagram that contextualises and describes the design approach of the paper.

perspectives of application in the cultural field. This phenomenon is progressively integrating with museum realities by intervening on the reorganisation of physical spaces, destined to change due to the advancement of technological progress but more than ever due to the issues raised by the current Covid-19 pandemic.

The aim of the paper is to analyse the impact that new technologies and digitisation can have on museum experiences. The survey revealed that design principles lend themselves well to the design of spaces, exhibitions and guided workshops. In this perspective, the designer's intervention aims to increase the levels of accessibility in relation to the use of cultural heritage by an increasingly wide range of users in the light of the principles of accessibility, social inclusion and enhancement of cultural heritage (Fig. 2).

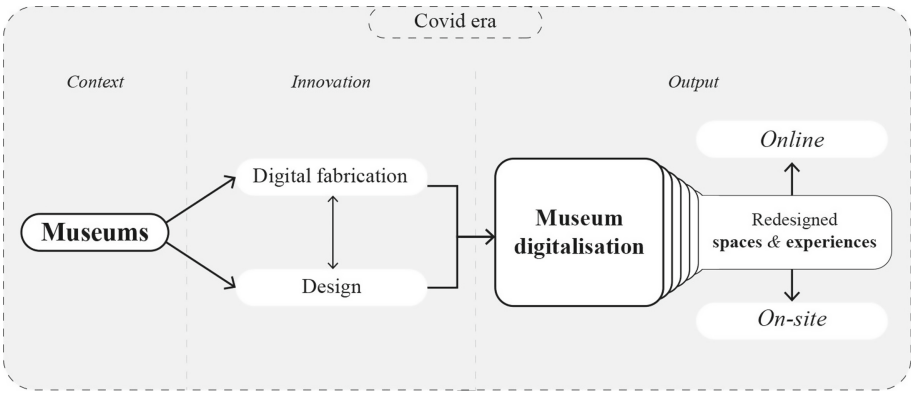

Fig. 2. Pictured is the diagram that contextualises and describes the research objective of the paper.

2 Digital Fabrication

Digital fabrication is a design and production process in which tangible outputs are generated from digital files. Accessible digital fabrication tools bridge the gap between design and production. Reducing the gap in technological skills that differentiate professionals and ordinary users makes it easier for anyone with the skills to create products. This enables designers and small businesses to produce anything from prototypes to final products [10]. Democratising science and access to research samples is the process by which scientific knowledge and resources are made freely available to the community at large without marginalising any population of people [11]. The technologies derived from digital fabrication are a source of new tools and opportunities for museums. Specifically, the production of digital models, starting from real samples, with reality-based surveying and modelling techniques, is becoming an essential practice. This leads to processes of integration and implementation of traditional systems of: analysis, conservation, documentation and use of historical and artistic heritage.

2.1 Digital Fabrication Applied to the Museum Context

These tools, in addition to their purely scientific and academic value, can be a valuable teaching aid in the laboratories that museums offer, enabling new learning experiences for an increasingly wide range of audiences. The blurring of the perimeters between physical and digital spaces leads to the creation of new learning resources on site or remotely, underlining how these technologies are progressively transforming the very concept of the museum experience. In the context of digital fabrication, the research and restoration sections of museums have been transformed into veritable FabLabs, capable of creating faithful physical reproductions of historical artefacts and digital libraries that can be used by experts in the field and beyond. This practice can be used not only for dissemination but also for conservation. The use of new technologies guarantees the structural integrity and intrinsic cultural value of the artefact. The generation of digital outputs is done through mapping processes, which in addition to revealing characteristics of the way the artefact was made, guarantees the protection of the museum's property, as well as the possibility of handing down an accurate three-dimensional "snapshot" of the artefact's state of health. The implementation of these specialised workshops within the museum's perimeter has triggered and facilitated the creation of new innovative environments and services for the museum.

3 The Pioneers of Digital Capture

Advances in 3D modelling techniques and the dissemination of 3D data through online archives have facilitated scientific research, formal and informal education and public awareness [12]. One of the first museums to adopt digital tools and practices was the British Museum in London [13]. This centuries-old institution opened its doors to online and on-site digital experiences by encouraging interaction with various museum works. One of the most well-known platforms to mark this change is Sketchfab [14]. The website is widely used by researchers and educators because its platform tends to

facilitate interest in museums and cultural institutions by making digital models of artefacts widely available. The provision of 'complete' and downloadable digital models, from the institution to the individual user originated in 2014 when the British Museum partnered with the SketchFab platform (Fig. 3) [15].

By accessing the website it is possible to view and download museum works from various eras and cultures, through an up-to-date library that informs the user not only about the morphological and material characteristics of the work, but provides additional historical data that enriches and fills this new experience with meaning.

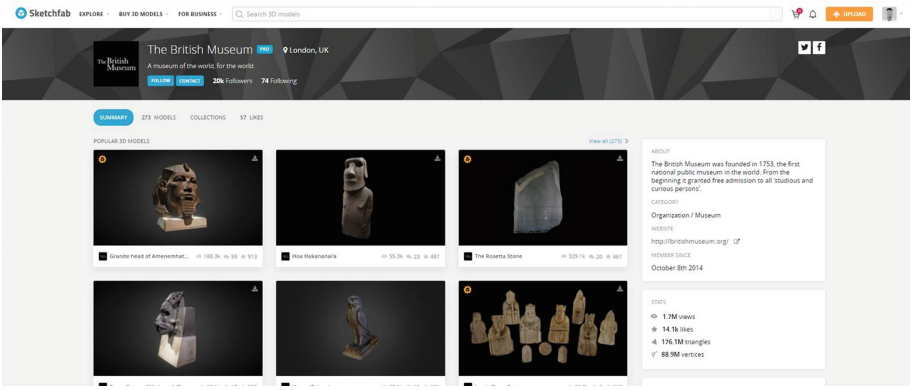

Fig. 3. Open source library of 3D models taken from the British Museum [13].

Virtual reproduction techniques are based on three-dimensional acquisition processes that exploit CT scanning technologies. This methodology is important for non-destructive study through the creation of 3D virtual model replicas of paleontological specimens [16]. The use of these tools provides various types of information about the historical artefact analysed, such as: age, materials, thickness, processing techniques, morphology and texture. Among the works that have been analysed by the British Museum with these technologies [17], the case studies of the Buddha head belonging to the "Ganfhara" series and a Tibetan "thangka" are interesting (Fig. 4).

X-ray scanning of the clay head revealed the morphology of the find, which consisted of two layers. In a first phase, a coarse clay was used to define the proportions of the head. Subsequently, the face, hair and headdress were covered with a more compact material which was then painted. The study conducted on this artefact allowed us to highlight the technique used to make this head, while also showing its chemical composition through a digital section that analyses the objects without damaging them (Fig. 5).

The 'thangka' (painting on fabric) is an atypical find to study, as most of the works are three-dimensional (Fig. 6). However, the use of X-rays has also proved effective on two-dimensional elements such as paintings.

Showing characteristics related to the type of painting, its chemical composition up to the reconstruction of the initial sketch.

Another museum that has embraced the advent of digital technologies is the Egyptian Museum in Turin [18]. In the research project "B.A.C.K. TO T.H.E. F.U.T.U.RE." [19] in

Fig. 4. On the left, the moulded and painted clay head of a female bodhisattva wearing a diadem. On the right, the thangka after conservation treatment, showing the coloured front as well as the reverse [17].

Fig. 5. X-ray CT scanning shows the internal composition of one of the heads and how this type of imaging can show the hidden cross-section of objects without damaging them [17].

Fig. 6. Detail from the visible image and X-ray of the thangka. The latter shows two sets of golden lines radiating from the Mahasiddha Saraha [17].

collaboration with the Polytechnic of Turin, the museum has contributed to the creation of digital models of "maquettes" usable from an online library [20]. The collection, which includes 14 temples and an obelisk, arrived in Turin at the end of 1823, together with other objects collected by B. Drovetti during his expedition to Egypt and Nubia. The wooden models, covered in stucco, were an attempt to represent a culture still largely unknown in Europe, together with the many drawings produced by J.J. Rifaud, a sculptor who accompanied Drovetti on the expedition. In the online library, each virtual architectural structure can be explored in first person, through autonomous navigation enriched with historical information and mini-games to entertain the user in an educational way (Fig. 7).

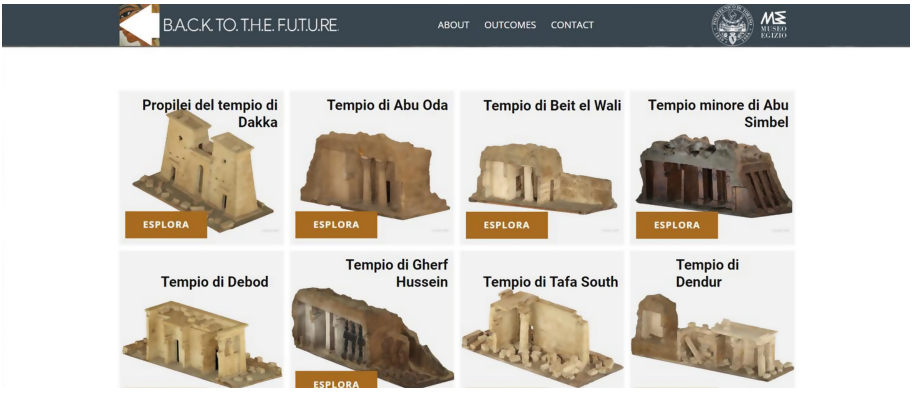

Fig. 7. Open source library of 3D models created in the project "B.A.C.K. TO T.H.E. F.U.T.U.RE." [20].

In this new global scenario, digital and detection technologies meet the new needs of museums. They offer a view from perspectives that improve the understanding of the meanings of an object, through the acquisition of additional information that has value both from a scientific point of view and for public use.

4 Design and Accessibility in Museums

Design is a founding element within museum realities and services, the nuance of application of this discipline, embracing the concept of social inclusion, is "Design for all". "Accessibility and equal opportunities for all in the digital age have become increasingly important in the last decade. In one form or another, the concept of accessibility is considered to a greater or lesser extent in most projects developing interactive systems. However, the concept varies between different professions, cultures and interest groups. Design for all, universal access and inclusive design are all different names for approaches that largely focus on increasing the accessibility of the interactive system for the widest possible range of users" [21]. This approach to museum experiences is reinforced by technologies, which help to define new resources and experiences that take into account a wider audience.

4.1 Educational Workshops

The social implications of "museum digitisation", guided by an appropriate project strategy, can affect various categories of users, starting with the generations of the future. The museum, like the school, is one of the driving factors for the cultural and moral growth of society, so it is necessary to bring these two worlds together as active and irreplaceable elements for positive individual growth. The educational workshop in the museum is the place where knowledge of cultural heritage and creative experimentation are combined [22]. Here the young visitor can benefit from transversal experiences ranging from the acquisition of knowledge to the conscious use of new prototyping and scanning technologies, always passing through practical experimentation which remains a fundamental moment of training. In this way the museum becomes a pedagogical arena aimed at broadening the experiences of the individual. Every activity carried out according to this vision has the objective of encouraging the unfolding of an experience where the cultural asset becomes a means of stimulating curiosity, aptitude and creativity. To educate is to act as a mediator, providing the tools to understand cultural heritage, while having fun and interacting with others. Experiences of this kind take root and generate affection for places of culture, nurturing a sense of civic and social responsibility and a desire to share.

4.2 The Contribution of Design

The use of technology is progressively renewing the concept of museum accessibility. The term "accessibility" applied to the museum context, refers to all spatial characteristics that facilitate the autonomous use of public facilities, taking into account the characteristics of "extended" users. Disability, whether temporary or permanent, should not be an obstacle or a reason for exclusion for anyone. An ever wider range of users should be able to fully enjoy services, spaces and environments, so it is essential to adopt functional solutions in museums that have social inclusion as a fundamental value [23]. The use of digital technologies intervenes to facilitate the sight-impaired users through the creation of faithful reproductions that they can freely touch. In this way, each tactile nuance is able to thoroughly define what is being "observed".

Using Experience Design methodologies [8], it is possible to design the whole museum experience, from pre- to post-visit [24]. This design is based not only on the visit itself, but also considers the moments of "contact" that precede and follow the experience [25]. The stages of the customer journey can be further enriched by the implementation of the digitisation process of museum resources, eliminating, through innovative ways of use, the geographical barriers between the user and the museum artefact. The task that the museum can and must fulfil is to revive the dialogue between visitors and museum objects, activating the emotional and cognitive process that is the indispensable prerequisite for a full understanding and appreciation of museums. The application of Design for all, enriched by the design features derived from Experience Design, guarantees these principles; through the conscious design of spaces and experiences aimed at a wider public.

5 Case Study

5.1 The MUSE of Trento and the "Extrilon" Project

An example of application comes from the MUSE in Trento with the "Extrilon" project launched in 2018 [26]. This involves the three-dimensional, virtual and physical reproduction of Trilobites, selected within the paleontological collections present in the museum. The geometric and surface features of these specimens were acquired three-dimensionally through the use of structured light scanners, suitable for small objects. These systems are equipped with a light wave emitter and one or more passive sensors positioned at a known distance, which use the principle of triangulation to derive metric information. In this case, coded light patterns are projected onto the object, highlighting surface roughness captured by the sensors. The instrumentation is thus able to analyse the deformation of the known geometry projected onto the object. For each trilobite, a variable number of scans were acquired, depending on the complexity of the individual find. Using automatic and semi-automatic alignment procedures, mesh models of 15 genera of trilobites were produced. The polygonal models produced were optimised, reducing the number of polygons without compromising the geometry, in the open-source solid modelling software Blender 2.76. Reducing the complexity of the models allowed them to be better managed for 3D printing and online sharing. "Extrilon" has enabled the creation of several full-size physical replicas and aims to produce others on a larger scale to allow millimetre details to be visible, making the work accessible to the visually impaired. The models reproduced thanks to the use of the 3D printers in the MUSE FabLab will become part of an educational laboratory aimed at exploring biodiversity, and in particular the morphological diversity of Trilobites, their evolution and extinction, through free tactile experiences and targeted educational lessons.

The dissemination of these technologies and the sharing of the research data produced also generates significant spin-offs in the broader context of Open Science [27], which is seeing a growing diffusion and adherence within the scientific community.

5.2 The FLMNH

The second case study concerns the Florida Museum of Natural History (FLMNH) [28]. This American museum institution engages the public through exhibitions and community outreach programmes, which can be categorised under the umbrella of 'informal education'. The content of these experiences is derived from the research and formal education practices employed by the museum. Given the usefulness of technologies in research, these new tools are also intrinsically present in public awareness and information processes. In order to make this content accessible to a wide range of users, figures within the museum institution translate the processes and results into narratives usable by "any" category of user.

In 2017, the FLMNH celebrated its 100th anniversary with the exhibition "Rare, Beautiful and Fascinating: 100 years of Florida Museum". The event, with the aim of broadening the museum's user standard, exhibited various pieces that can be enjoyed safely thanks to new technologies. Among these extraordinary objects and natural history specimens, a 3D printer was constantly at work printing models of various objects

on display. The use of digital technology in natural history disciplines reflects one of the main practices associated with the museum. The reproduction of tangible three-dimensional models fascinated museum visitors and provided them with experience of facilitated technological applications in research and education. The presence of 3D models was also included in the publicity for this event, "Hands-on stations will allow guests to examine museum artefacts, specimens and 3D printed replicas" [29]. The event was structured to the extent that, during each centenary week, a different section of the museum occupied a portion of the exhibition space to interact directly with the public.

6 The Museum in the Covid Era

Another factor related to "museum digitisation" is the Covid-19 pandemic. This historical moment has pushed museum institutions to maintain an open dialogue with the public by inevitably moving towards an online experience. The time of the Coronavirus is acting as an incubator for the evolution of digital presence in museum culture.

The typology of the proposals is varied, ranging from the website to the social pages up to Google Arts&Culture [30] and Spotify [31], used by museums as an integrated audio-guided visit tool. Among the Italian realities we find the digital exhibitions of Hangar Bicocca [32], the Uffizi Gallery [33] and audio-meetings realised by the Triennale di Milano [34].

The current challenge will be to make the digital and real spheres interact in an effective and interesting way, adapted to the conditions of both these worlds: the web and social pages of the museums will therefore have to function first as an attraction, then as an in-depth study, representing an authentic and culturally rich experience. It remains to be seen to what extent the multiplication of initiatives will have a response in terms of user enjoyment.

7 Conclusions

In the light of this analysis, digital technologies lay the basis for rethinking the concept of the museum as an institution. This metamorphosis is progressively freeing the museum space from the stereotype of the occasional or single visit, through an updated and innovative fruition that involves the user with the conscious design of targeted experiences. The role that design can and must play within the museum institution inevitably brings with it metamorphoses both from a spatial and professional point of view, described and summarised in the concept of Systemic Design [35]. These transformations have redefined professional figures and introduced new ones. In addition to the museum curator, there is the Digital Strategy Manager, the Digital Media Curator, and a range of design professionals who are able to promote technological innovation to bring museums into a new era. Added to this is the morphological reorganisation of exhibition spaces and services due to Digital Fabrication and the Covid-19 emergency. Digital is thus becoming a means of making culture accessible, on site and online, without forgetting that the museum must remain the "place" where the user enters into an intimate and direct connection with the objects conserved. There is no doubt that the application of digital

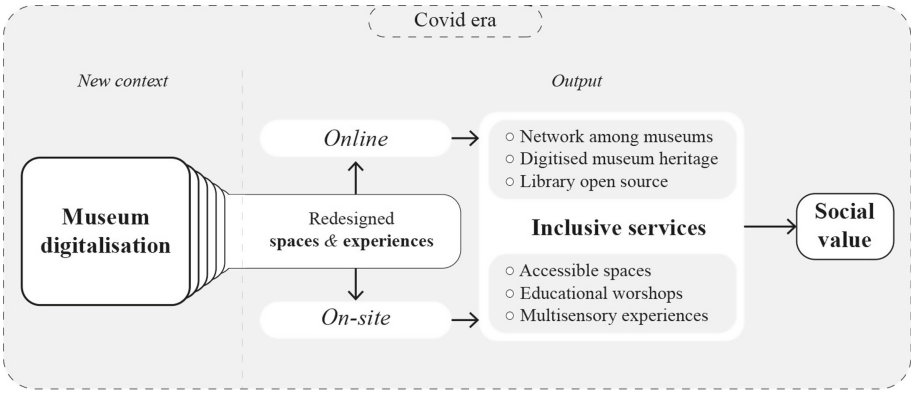

Fig. 8. The diagram describes the project opportunities generated by a design approach.

technologies is progressively expanding the potential of all the basic activities that are characteristic of museums (Fig. 8).

They bring new methodologies that will generate, in the coming years, further changes in the museum landscape, comparable to the one that saw the introduction of the first computers for cataloguing in the 1980s. The creation of three-dimensional models and their printing brings undeniable advantages to museum activities and professions, which are being pushed towards a progressive morphological modification of environments according to new standards of collective learning that take into account the needs of "vulnerable" users.

This new application scenario, outlined by an increasing integration between the virtual and the real world, provides museums with tools that, if exploited in the right way, can widen the pool of users and bring benefits to the social community itself.

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