Accessibility of Cultural Heritage Exhibits

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Abstract. The global impact of the digital revolution in the cultural sector worldwide brings about the need to ensure the accessibility of physical exhibits, interactive digital exhibits, digital media and digital content for disabled people. The paper addresses the accessibility of CH resources, and the need for a new approach to accessible user interaction with CH exhibits.

Keywords: Accessibility · User interaction · Cultural heritage resources

1 Introduction

The impact of the digital revolution has resulted in the emergence of many and diverse opportunities for people to engage with culture also through the digital media. But are these opportunities granted in equal measure to all citizens? Although Cultural Heritage Institutions (CHIs) worldwide are developing strategies towards widening the public's interest through digitalization, while progressively paying increasing attention to the physical accessibility of their premises, there has barely been any discussion in the cultural sector worldwide about the accessibility of interactive digital exhibits, digital media and content for disabled people. An audit regarding the accessibility of museum web sites published in 2005 [26] has shown that disabled people face numerous potential stumbling blocks on the average cultural sector webpage. The idea that cultural venues, as a service to the public, have a responsibility to welcome all in inclusive settings is far from being universally embraced in the cultural sector. Only a few CHIs have planned access measures for casual visitors who are visually impaired, deaf or who have learning disabilities, whether or not digital media are deployed [3]. The accessibility of cultural venues is a complex and multi-dimensional reality. The creation of accessible cultural experiences requires a systematic approach. Accessibility and equality is not yet part of the script in cultural bodies worldwide, and the idea of equal access to cultural heritage for people with disabilities has not matured, although this right has been formally declared (see [5–7, 22, 23]). This paper provides an overview of the current trends in the CH digitalisation towards widening access to the public at large, followed by some scenarios of universally accessible digital cultural

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exhibits that are envisioned as feasible in the near future based on existing and emerging technologies. Finally, the paper concludes with a roadmap of further research and development required towards realizing the vision of accessible universally accessible digital cultural exhibits in the contemporary museum, focusing on issues related to software architecture.

2 Digital Experiences with Museums

Recent research on capturing and understanding the museum visiting experience focuses on conceptual and methodological approaches to planning, designing and assessing the integration and deployment of interactive technologies in the museum context. A study conducted on the use of multi-touch interfaces in museums [15] addresses methodological aspects and advocates the adoption of broader approaches targeting not only user performance, but also the user overall satisfaction and experience, also exploiting quantitative data of the museum visit provided by sensing technologies). [10] discusses engagement, appropriation and personalisation in experiencing digital arts, and supports the conclusion that empowering people to make an artefact their own lies at the centre of user-centred designed in domain of culture. Multidisciplinary co-design of cultural exhibits involving museologists, designers, computer scientists, domain experts, etc. is applied in [4] to the design of interactive exhibits based on Augmented Reality and Tangible Interfaces. The co-design process includes requirements definition, museum exhibit and interaction design, implementation and evaluation phases, thus covering the entire development from the earliest analysis phase until the final concrete installation. The formative evaluation of touch screen and table based interactive museum artefacts in real settings is discussed in [13], aiming at ecological validity and at understanding 'natural' group interaction involving users of different ages. Finally, [17] elaborates on design principles for museum exhibitions, identifying five main principles and exemplifying their applications through case studies. The principles are summarised by the keywords clarity, layering, engagement, authenticity and resonance.

Personalised Information in Museums. Nowadays museums strive to design and implement exhibitions that offer enjoyable and educational experiences. The provision of a personalised experience to the visitors may help alleviate the problem of limited time and may more generally enhance the experience of any visitor if properly customized. Personalised access to information is also essential for people with diverse backgrounds, physical abilities, knowledge and interests to seamlessly access cultural resources. For example, Museum Guide 2.0 is an eye-tracking based personal assistant for museums and exhibits. Visitors wear a head mounted eye tracker whilst strolling through the exhibition. As soon as gaze on a specific exhibit is detected, the application plays an audio file that provides additional information about the specific exhibit [21]. The AGAMEMNON project aimed at providing visitors of sites of historical interest with personalized, information enriched experience through 3G cell phones [27]. The Macrographia system [12], installed in the Archaeological Museum of Thessaloniki, presents personalised information to users based on their position and language. Virtual Digital assistants have been also been employed for providing personalised information

to users. The virtual agent Max has a full-time job as a central exhibit at the Heinz Nixdorf Museums Forum since 2004. He welcomes and entertains visitors though text based and gestures based interaction [18].

*Interactive Exhibits.*Worldwide, a number of museums have installed, temporarily or permanently, interactive exhibits in their premises. The "Fire and the Mountain" exhibition comprised four hybrid exhibits aiming to promote awareness about the cultural heritage of the people living around the Como Lake [11]. ARoS, an art museum in Denmark, employed four interactive exhibits targeted in an exhibition of the Japanese artist Mariko Mori [16]. The Austrian Technical Museum in Vienna opened a digitally augmented exhibition on the history of modern media [13]. The Archaeological Museum of Thessaloniki hosts "Macedonia from Fragment to Pixels" [28], an interactive exhibition of prototypical interactive systems with subjects drawn from ancient Macedonia. The Panoptes system allows the browsing of artefact collections, while Polyapton offers multitouch, multiuser gaming experiences with archaeological artefacts [12]. The Art-E-Fact Project [14] has developed a generic platform for interactive storytelling in Mixed Reality that facilitates access to a knowledge base of objects of art and art history. One installation was placed in the Bargello Museum (Soprintendenza Speciale pei il Polo Museale Fiorentino).

Museum Mobile Applications. According to [9], existing mobile applications for museums fall into the following categories: 45% provide guided tours of permanent exhibitions and the museum in general, 31% provide guided tours of temporary exhibitions and practical information about the museum visit, 8% provide combinations of the first two, 8% are apps devoted to a single object or artwork from the collection, 4% offer content creation or manipulation from the user inspired by artists' work, and 3% are games based on the exhibits. Some of these applications are designed to be used during the museum visit to enrich the visitors' experience, and can be downloaded once the user enters the museum space (e.g., the TAP app from the Indianapolis Art Museum, [30]). The navigation of these apps is structured according to the spatial arrangement of the exhibits in the museum, include interactive or simple floor plans of the museum's exhibition spaces with the exhibits marked, or offer activities for enriching the museum visit, such as the Gallery Tag! [29].

Museum presence on the Web. As the World Wide Web is being widely used by a constantly growing number and variety of people and that technology has evolved in the area of digital culture and cultural heritage preservation, many museums have established some presence on the Web by creating their web sites. Probably the most important project aiming at making cultural heritage available online was not initiated by a museum, but established very strong collaboration with many art partners around the world. The Art Project [32] is collaboration between Google and 151 acclaimed art partners from across 40 countries. Using a combination of various Google technologies and expert information provided by our museum partners, Google has created a unique online art experience.

Museum Social Applications. Social media tools allow people to interact around ideas conveyed through images, video, audio, and animations. They have proven to be very effective not only in connecting audiences but also in engaging them, providing museums with real opportunities to dialog with their audiences in new conversations and learning experiences. Museums are trying to increase their use of social media for

more two-way and multi-way communication strategies. The Brooklyn Museum uses a social media game (Freeze Tag!) to correct questionable tags that have been applied to its online collection [33]. The Victoria and Albert Museum's "World Beach Project" is an online global art project in which visitors upload photographs of patterns made with stones on beaches around the world. The photographs are linked to a map showing where they were taken [34].

3 Accessibility in the Cultural Heritage Sector

Despite the progress to date, cultural heritage fruition enabled by interactive technologies still presents considerable limitations, as: (i) the accessibility of existing interactive systems has not yet been considered by application providers (ii) current systems offer limited interactivity, personalisation and contextual grounding of the fruition experience, (iii) very few efforts are focused on exploiting the wealth of available digital content and specialised knowledge for the benefit of the public at large that would help further capitalise on significant investments in this area, (iv) there are no systematic technological solutions available for supporting museums and cultural heritage institutions in more effectively satisfying visitors' expectations. According to a Eurobarometer survey [30], culture is very important for the vast majority of Europeans (77%, including citizens educated to the age of 15 or below). While cultural expenditure in Europe is typically the preserve of wealthier citizens, modern ICTs have a significant impact on the way people interact and socialise, creating new practices and forms of cultural participation in step with technology, primarily the Internet (65% of Europeans had Internet connection in 2009 as opposed to 49% in 2006).

3.1 Accessibility of Cultural Heritage Resources

Accessibility in the context of individual applications and services has been defined as follows: for each task a user has to accomplish through an interactive system, and taking into account specific functional limitations and abilities, as well as other relevant contextual factors, there is a sequence of input and output actions which leads to successful task accomplishment [19]. The accessibility of cultural venues is a complex and multi-dimensional reality. It needs to be seamlessly integrated into all aspects of the museum experience: visitor information– including via digital media, the physical environment, signage, exhibitions, interpretation, and, more importantly, modern technology penetrating to the museum experience. The creation of accessible cultural experiences requires a systematic approach. The accessibility of public installations poses different problems and is more complex than currently available approaches to the accessibility of desktop or web applications and services, as these installations do not simply introduce a new technology, but an integrated set of technologies. Different levels of accessibility may be distinguished. A first level concerns accessibility of individual devices. Such devices need to be accessible in the first place to their owners according to their needs, but basic accessibility features should also be provided for other users with potentially different needs. A second level concerns the accessibility of

the environment that should enable an equivalent access to content and functions for users with diverse characteristics, not necessarily through the same devices, but through a set of interaction options integrated in the environment in a dynamic configuration / ensemble.

Multimodality and the availability of alternative means of interaction is a key feature towards facilitating the provisioning of a personalisable museum exhibit that will be accessible by users with functional limitations and varying abilities and preferences. Different modalities can be used concurrently, to increase the quantity of information made available or present the same information in different contexts, or redundantly, to address different interaction channels, both to reinforce a particular piece of information or to cater for the different abilities of users. Although several interaction technologies, such as, for example, voice output, are already widely available, and others, such as, for example eye-tracking, are reaching a maturity stage where they can be robustly exploited for accessibility purposes, developing truly accessible solutions for CHIs is currently still very expensive in terms of time, effort, cost and required knowledge, and the results have often limited flexibility and reusability in terms of the accessibility of solutions and addressed target user groups.

3.2 Ambient Intelligence and Interaction Techniques for Enhancing Accessibility

The emergence of Ambient Intelligence (AmI) is leading to the elaboration of new interaction concepts that extend beyond current user interfaces based on the desktop metaphor and menu driven interfaces, thus driving a transition to more natural and intuitive interaction with everyday things [1]. Natural interaction refers to people interacting with technology as they are used to interact with the real world in everyday life, through gestures, expressions, movements, etc., and discovering the world by looking around and manipulating physical objects [24]. Typical examples are input techniques such as touch, gestures, head and body position tracking and manipulation of physical objects, which seamlessly integrate the physical and digital worlds and support the direct engagement of the user with the environment [1]. Augmented Reality (AR) allows virtual imagery to augment and enhance physical objects in real time. Users may interact with the virtual images using real objects in a seamless way [25]. Progress in computer vision approaches largely contributes to innovative interaction in AmI environments through techniques such as like image acquisition, image processing, object recognition (2D and 3D), scene analysis, and image flow analysis, which can be exploited for humans' and objects' recognition and tracking. At the same time, ICT components are embedded into everyday objects like furniture, clothing, white goods, toys, etc. [2]. Augmented objects can be used for providing implicit or explicit input to systems while their physical and mental existence as computational devices disappear. Ambient interaction merges real and virtual worlds to produce new environments and visualisations where physical and digital objects co-exist and interact in real time. Additionally, in Ambient Intelligence environments interaction is monitored and implicit input is also extended to include empathy to understand human's feeling or states. The centrality and role of user-centred design approaches in the

emergence and development of Ambient Intelligence environments is discussed in [20]. The user-centred design process is analysed in the light of the requirements posed by AmI, focusing on emerging problems and potential solutions towards applying and revising existing methods and techniques or developing new ones. User experience factors which are considered as critical in such context include natural interaction, accessibility, cognitive demands, emotions, health, safety and privacy, social aspects, cultural aspects, and aesthetics.

4 Scenarios for Universally Accessible Digital Cultural Exhibits

The vision for universally accessible digital cultural exhibits can be better described through indicative scenarios. This section presents scenarios based on personas, i.e., virtual users with specific characteristics used to help defining their interaction with cultural heritage exhibits.

Persona: Nick, blind: Nick is 41 years old and has been blind since the age of eight. He is a lover of ancient Greece and spends his free time at museums. His main problem is that although he is familiar with public transportation and can easily travel within the city, when visiting museums he has to either visit with company or hire a guide. He would love to have the freedom of visiting by himself. He recently heard that the Archaeological Museum of Thessaloniki has upgraded its interactive exhibition to address the needs of all visitors including people with disabilities. This might be the only museum I could visit by myself he thought. While entering the museum at the reception a lady informs him that the museum has an easy-to-use device that could help him navigate through the exhibition. This device announces the user's location within the museum and can automatically understand exhibits so as to provide information. Nick takes the device and starts moving within the museum. He realises that while moving the device announces him his current location. For example, the device informs Nick that he is at the ancient pottery department and that on his right are the potteries found at the grave of King Phillip. Moving on the right and approximating an exhibit the device starts announcing information. He can also request for more information if he wishes so. When entering the interactive section of the museum, the device informs him that Macrographia [12] has been updated to support tactile interaction. I will be able to feel a real Wall Painting he thinks. He move towards the direction pointed by the device and encounters something like a kiosk. The device informs him that right in front of him is the tactile version of Macrographia. He touches the display to feel a fascinating experience. While interacting with the Wall Painting, the device tells him the story of The Royal Hunt of Philip the second. This unique sensory experience reveals him the history of ancient Macedonia.

Personas: Maria and John, reduced visual acuity and difficulty in adjusting focus: Maria and John are retired teachers. Being on their early seventies Maria and John are experiencing problems regarding their visual acuity and difficulty in adjusting focus for near vision. They both have an interest in Art and Archaeology and they spend a lot of time visiting museums and picture galleries. Today they have decided to visit the

Archaeological Museum of Thessaloniki. While on the reception they are informed that a section with interactive exhibits is available at the museum. The girl at the reception informs them that they could use their mobile phone to personalise the content provided by the exhibits to their advanced experience in Art and Archaeology, and helps them download the museum client and fill in their profile. They are tempted by the fact that the museum can provide personalised information to them so they decide to try. It's not too difficult they think, we have just to show our mobile phone to the exhibits. While entering a section of the museum Maria shows John a kiosk presenting a puzzle game with words. It is Cryptolexon [12], the hidden crossword, a game which combines entertainment with knowledge. The names of ancient gods and heroes are hidden within a matrix of letters for the visitors to discover. Maria shows her mobile phone towards the puzzle and gets notified that the game has entered an advance difficulty level (due to her experience) and fonts-contrast are adjusted so as to be more readable. At least I don't have to wear my reading glasses, she thinks. After playing for some time Maria and John sees people moving their hands in front of an informative display. This must present all the treasures in the museum they think but it seems quite difficult to keep your hand up for such a long time. They decide to give it a shot so they show their mobile phone to the exhibit. At the same time they are informed that they could use their eyes to interact with the display instead of waving their hands. Just by looking at different locations within the screen they can browse information. Having the desire to see the rest of the museum too they notice that small tablets are mounted on the sides of each exhibit. People are interacting and learning by these displays. What happened to the captions they think? When approaching one of these tablets Maria shows her mobile phone and she notices that fonts are increased, contrast has been changed and navigation arrows appear. It is like browsing a history book they think. Maria and John leave the museum after a couple of hours. "We should definitely return to see the rest" they think.

Persona: Luigi, elder, upper limb impairment. Luigi is 60 years old, retired and has lost the use of both his hands due to a car accident. Among his interests are painting (he had taken a number of classes on painting using his mouth to control brushes) and art in general. He is interested in technology but he faces difficulties due to his disability. Recently he was told that the Archaeological Museum of Thessaloniki has updated its section of interactive exhibits to address the requirements of all including people with disabilities. Visiting the museum with his wife, he enters the interactive section when the virtual character welcomes him. He also notices the existence of large push buttons that he could use to make questions to the character while also being able to ask questions orally. He tries both ways and the character responds well to both forms of interaction. He notices the existence a table, whose surface is covered by a printed map on which the location of various cities and other notable sites is projected. White paper tablets with a coloured frame are used by visitors to access information. Well I can't do that he thinks but decides to move closer. When in front on the table, museum staff informs him that he could use a HMD for gazing to the location within the map in order to access information. After wearing the device he notices that information is always located in front of him in order to have access and on the most distant POIs of the map. On another location of the museum he encounters a system called "Peridexion,

the dexterous" [12]. Peridexion presents a masterpiece of 6th c. BC Athenian black-figured pottery, known as the Crater of Lydos, as well as three exceptional examples of Roman sculpture from the AMTh collection, all inspired by the legend of the hunt of a monstrous boar in Calydonia, Aetolia. The objects included in this presentation span eight centuries. He notices that people are interacting through touch while blind people use a device to announce them information about the exhibit and make selections. When approaching the exhibit, he notices that he could use it just by looking different areas of the screen. For selecting items, he just has to look a specific region of the artefact for a couple of seconds (a progress bar is filling while staring). When more than one pages of information is presented he can, in order to reduce interaction time, press the large buttons embedded on the exhibit. Luigi leaves the museum very pleased, as he was able to all exhibits without help from his wife.

5 Towards Accessibility of CHRs - Beyond the State of Art

Assistive solutions and accessibility technologies have so far supported the augmentation of the capabilities of the individuals and the adaptation of single artefacts for accessibility. Building on current approaches in the field, it becomes instrumental for accessibility to develop new interaction methods as they emerge in the context of interactive museum exhibits, taking advantage of multimodality.

5.1 Research Challenges

The provision of universally accessible multimodal solutions for Cultural Heritage Institutions is fundamental for offering equal access to cultural resources to all citizens including the elderly and people with disability. Thus, a number of challenges towards achieving accessibility for cultural heritage exhibits need to be addressed. These include:

Novel interaction paradigms for experiencing cultural heritage by developing pools of accessible, reusable interaction modules, which may constitute integral parts of a framework targeted to allow users to interact naturally with physical and digital artefacts in the museum and in living space environments, through various integrated devices.

Novel forms of UIs adaptation that are distributed in the environment responding also intelligently to context and situation changes.

New accessibility interaction techniques, designed for all, beyond the spectrum of the conventional computational devices need to be investigated, and an inclusive interaction model, addressing the needs of interaction with Cultural Heritage Resources within CHIs elaborated, encompassing both emerging and standardized techniques.

Alternative means of information display. Accessible augmented interaction with physical and digital artefacts should be supported by providing alternative means of information display through mobile devices, as well as ambient set-ups offering rich interaction techniques through mainstream devices such as Microsoft Kinect (http://www.xbox.com/en-GB/kinect/). Investigation and development of techniques for

measuring various aspects of users' engagement and experience with Cultural Heritage by monitoring and capturing average time of visit, head orientation, etc.

Mechanisms for personalised retrieval based on user characteristics, annotation and presentation supporting individual users in shaping their interests and cultural heritage fruition experiences.

Personalised cross – domain smart assistive solutions to address the accessibility and usability needs of disabled and older users need to be designed and developed, building upon state-of-art solutions in voice interaction, scanning, visual layout adaptation, touch and haptics interaction, gestures, eye tracking, head pose interaction, sign language, persuasive and affective interaction, serious games and augmented reality. Improvement in specific existing technologies is also necessary:

- Both low-cost eye-aware appliances as well as high-end gaze tracking solutions need to be developed and tested in the context of interactive museum exhibits, with emphasis on making the solutions robust and safe, and ensuring that the solutions will adapt to different abilities, needs and preferences of individual users.
- Touch and gesture interfaces that allow people with visual impairments, or anyone in eyes-busy situations, to interact with cultural heritage resources should be further studied, and different modalities based on users' needs and preferences need to be offered.
- Both video and avatar -based representations need to be explored to assist deaf individuals in their interactions with museum exhibits. These should cover the needs of the different use cases and application scenarios, with properly coded linguistic resources to provide options for multilingual content maintenance and 3D representation editing.
- Interaction solutions to provide alternative input, output and information rendering modalities capable of addressing each individual's needs should be widely offered, supporting interoperability of assistive technologies and conventional computational devices (PCs, smart phones, etc.) with innovative high-end technology artefacts.

5.2 An Envisioned Architecture to Support the Accessibility of CHRs

This paper brings forward an approach to the development of multimodal accessible applications taking into account the majority of existing limitations of systems designed for all (a single interface designed for all results to reduced user experience for all). The most important aspects of accessible multimodal interaction such as the users, context and assignment of multimodal technologies are modeled in the form of ontologies to specific user and context. CH models can be developed to ensure the provision of appropriate cultural experience to all users taking into account aspects such as disability, functional limitations, technology, expertise and domain knowledge. When appropriate, these models could build on external knowledge such as existing domain standards to ensure maximum reusability and exploitation of results. Knowledge can be made available through a number of alternative end-point such as web-services, sparql end points and databases. For knowledge management by CHI

personnel, an ontology manager can be created while curators have the option to form the visitors' experience through an exhibition designer. A number of sensors, assistive technologies, and smart and augmented objects can be made available through the "Sensor & Smart Objects & Assistive Devices Integration layer" (Fig. 1).

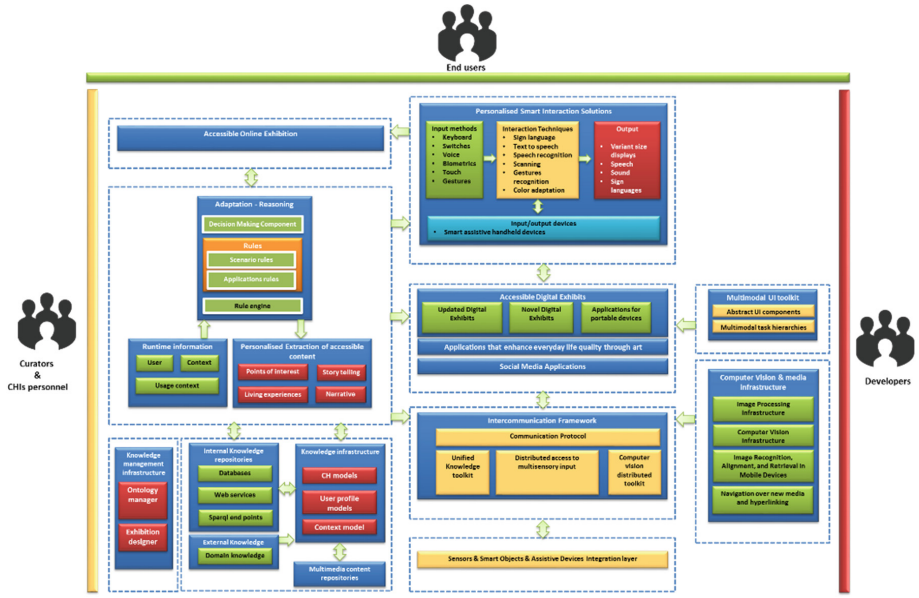

Fig. 1. Envisioned architecture

These technologies will be facilitated through the use of a common distributed service oriented Intercommunication Framework providing access to the sensory infrastructure, quick and inexpensive ways of knowledge retrieval, and the "Computer Vision & media infrastructure". This infrastructure offers a number of facilities for advanced interaction with CH resources including 3D models, image recognition and processing and at the same time can be used for offering visitor recognition and tracking facilities to be employed into complex space aware exhibits. The "Multimodal Interaction Toolkit" builds on these technologies to provide a unified ready to use solution for all interactive digital exhibits and applications. Additionally, the Adaptation – Reasoning components, employ "Runtime Information" gathered through interaction monitoring and the facilities for "Personalized Extraction of accessible content" to take decision regarding interface adaptation, modality selection and modality enhancement. Accessible Digital Exhibits can then be built on top of the aforementioned facilities and Personalized Smart Interaction Solutions for all to offer the optimal experience to end users.

6 Conclusion

Advanced interactive technologies have a significant role to play in enriching the fruition experience for all citizens, and unleash economic potential for new tools and services. Information and Communication Technology will have a profound impact on the means of interacting with Cultural Heritage Resources in the near future. Developing truly accessible ICT solutions CHIs is currently perceived as very expensive in terms of time, costs and required knowledge, and the results are of limited flexibility and reusability. To address this challenge, it is crucial to support the development of generic solutions effectively addressing accessible interaction with CHRs within CHIs, and make them available to designers, developers, and the industry, as well as to support the direct involvement of end users and facilitators.

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