# Personalization of Mobile Applications in Cultural Heritage Environments

Christos A. Fidas and Nikolaos M. Avouris

*Abstract*— **Mobile technology has been used for indoors and outdoors applications related to Cultural Heritage over many years. Mobile applications in museums and other sites of culture can satisfy visitors' needs through the provision of contextualized contents and services. Personalization of these services is necessary as the amount of available information often exceeds the cognitive capacity of the visitors. The factors to be taken in consideration during design of personalized mobile applications in cultural heritage environments are the subject of this paper. A formal description of these factors allows both for a systematic survey of existing practice, and for supporting the design process of mobile CH applications in the future.**

*Index Terms*—**Human Factors, Personalization, Context Aware Systems, Cultural Heritage Mobile Design Frameworks**

## I. Introduction

Cultural heritage has been a favored application domain for personalization for many years. Falk [1], in his attempt to define a predictive model of the museum experience, points out that as museum visitors differ, their visit experience is composed of the physical, the personal, and the socio-cultural context, and identity-related aspects. Hence the visitors may benefit from individualized support that takes into account contextual and personal attributes. Moreover, visitors' behavior may not remain consistent during the visit and this may require ongoing adaptation. Mobile applications represent a suitable solution to enhance cultural experiences in museums and other sites of culture, as they can satisfy visitors' needs through the provision of contextualized content and services.

Cultural heritage institutions (e.g. museums, archaeological and historical sites etc.), as well as places of historic interest can benefit from these kind of applications, that are today based on widely used technologies and devices. Attempts to personalize the cultural heritage experience have been reported for a number of years. In a recent survey of the field, Ardissono et al. [2], observe that despite some progress and interesting results, the cultural heritage industry has yet to adopt personalization. In the same article they conclude that "*while mobile guides and other technologies are common in cultural heritage settings and social web technology is spreading fast, personalized services are not*". The applications of such approaches are limited to tailoring content to distinct groups of visitors, like kids, parents and teachers (see the example of kids programs for Tate Modern, discussed by Jackson, Adamson [3]). There have been various experimental prototypes applying personalization techniques, almost exclusively addressing the problem of delivering appropriate content to the visitor. The rationale for applying such techniques is that cultural heritage sites have a huge amount of information to present, which must be filtered and personalized in order to enable the individual user to easily access it. This is even more applicable if we consider the current trend of including in the content, user generated material, produced by crowd sourcing museum applications [4], social media etc., or use data from social behavior tracking. Some background research already exists in this direction: In the Kubadji project that is investigating user modeling and language technologies to support the creation of personalized guides [5], collaborative filtering was applied to select the next object to visit, based on the cumulative visitors' history, while social recommendation techniques, based on user-generated content (e.g., tags and comments) have being integrated to enrich further the systems' capabilities in selecting the most appropriate content for the user in the CHAT prototype [6]. One limitation of such approaches is that they assume that the site content is of equal importance. Most personalization techniques eager to attract more visitors focus on the visitor and forget the cultural institution. However, sites of culture are not storage places. Museums are structured spaces which try to make a point about their exhibits and this is depicted in the structuring of an exhibition, on the narratives of the curators, on the educational programs etc. The side effect of this approach is to narrow down the cultural experience into what the visitor has described to fall under his/her interests, habits and cultural experience, instead of opening up and enriching this experience. In many cases however a visitor may not know what he or she wants to see, and the visit might have the purpose to open up his or her mind with things that the visitor would never imagined that they would interest him or her. Another issue is the difficulty of creating a profile of the user during the short time of the visit, while previous interaction data are usually not available.

So, the design of effective personalized mobile applications is still an elusive task, as it is related to an interdisciplinary background, which needs to find a compromise taking in consideration various physical, social, human, technological and application design factors. A brief overview of these factors is attempted next.

With regards to human factors, design of cultural heritage applications must comply with the diversity of users who commonly have different goals, motivations, learning styles and cognitive abilities [7]. So one may need to consider that individuals have differences in the way they process and remember information [8]. For instance socio-cognitive theories claim that individuals develop different learning

C. Fidas and N. Avouris are with the Human-Computer Interaction Group, University of Patras, Greece. C. Fidas is also with the Department of Cultural Heritage Management and new Technologies, University of Patras, Greece (e-mail: fidas@ece.upatras.gr, avouris@upatras.gr).

styles and internal knowledge presentation approaches [9]. So designers may adjust the application to the fact that some individuals process, store and retrieve/remember text or audio information more efficiently and effectively than image or video information, whilst others the opposite, see Bellotti et al [8].

An important aspect is also related to the social character of the activities involved, since most individuals visit cultural heritage places, in groups, e.g. families, school visits etc. [2, 10].

As far as the physical context and the technology point of view, these applications follow the ubiquitous computing paradigm since users access, manipulate, and/or share information as well as accomplish tasks while being on the move [11]. The designers need to complement real world experiences by overlaying computerized information to specific artifacts (e.g. cultural objects, monuments, buildings etc.) often following an augmented reality paradigm [12]. As a result, the design of such applications must take in consideration a variety of continuously shifting technological factors (e.g. mobile devices characteristics, location technologies, sensing and networking infrastructure, etc.). A major related issue is the location technology used. While in outdoors sites, GPS provides a relatively acceptable solution, combined with other sensor networks and visual identifiers, indoors there is no prevailing positioning technology [2]. An interesting survey of existing indoor positioning technologies can be found in Barberis et al. [13], while (Manesis and Avouris, [14]), provide an overview of position location techniques in mobile applications.

The design space of such applications is complex, as several interdependencies exist among social, human, technology, physical and mobile application design factors. The relation of these factors is usually determined by the characteristics of the specific application and the targeted user groups e.g. social factors play an important role in games; content presentation issues in guides and learning activities, etc.

There is need to identify the interplay among the aforementioned factors, through a framework that will map to the shifting ground of technologies and requirements of this domain (Stock et al. [15], Not and Petrelli, [16]). The underlying idea and added value of such approach could drive the design of more efficient mobile applications aiming to deliver content and functionality to specific user groups (e.g. through deductive context modeling) or to individual users (e.g. through inductive context modeling).

In this context, this paper further contributes to the design for personalization by proposing an extendible factor-based framework that can be used in order to express formally these interdependencies and use them in order to personalize content, presentation or functionalities of mobile applications in cultural heritage environments.

The paper is organized as follows: In Section II, we review the area of adaptive interactive systems. We classify existing approaches and provide examples on how different methods for user modeling and adaptation could provide personalization functionalities in CH. We develop our theoretical framework and problem formulation in Section III. We outline a deployment scenario of the framework in Section IV and finally, we reach our conclusions and describe promising directions of future work in Section V.

## II. RELATED WORK

Adaptation and personalization issues have been subject of research and practice in the cultural heritage domain for many years. Ardissono et al. [2]) have surveyed this subject and discussed limitations of current practice. Out of the 37 applications that were subject of review in that study, 22 (60%) are mobile applications, indicative of their importance in this domain. These are: Hyperaudio, HIPPIE, HIPS, GUIDE, CRUMPET, AmbieSense, Archeoguide, ARCHIE, DeepMap, MUSE, Smartmuseum, PIL, CHIP, iCITY, PEACH, UbiCicero, UbiquiTO, COMPASS, INTRIGUE, Gulliver's Genie, AgentSalon and Tiddler. Since early days of mobile applications, personalization issues have been matter of concern for researchers and practicioners. Vlahakis et al. [17] presented Archeoguide, an early example of a personalized augmented reality application for an archaelogical site. The iCITY tourist guide (Carmagnola et al. [18]) recommends cultural events and resources to visitors of a historic city, based on information from social media, also adapting to various devices, while CHIP (van Hage et al. [19]) used semantic web technologies in a personalized guide of the Rijskmuseum collection with information retrieved from public ontologies. In the case of CHESS [20], personalization in a museum storytelling application was done through the use of personas for categorization of visitors, in addition to real time adaptivity through the use of localization systems.

Adaptive interactive systems build and maintain a user model throughout usage, which includes information considered essential for adapting content and functionalities to the specific characteristics of the user. In this section we analyze user modeling and adaptation in the context of cultural heritage applications. The analysis aims to elicit how diverse user modeling and adaptation approaches can be of value for designing adaptive cultural heritage experiences, by focusing on what characteristics of the users are important to be included in user models in the context of mobile cultural heritage systems, and what adaptation mechanisms to use for personalizing cultural heritage tasks.

### A. Modeling Interactions in the Cultural Heritage Domain

User models can be generated utilizing explicit information from the user (e.g., through registration forms, questionnaires, etc.), and/or implicit information by using the interactions of the user with the system (e.g., time being active on a certain mobile application, interaction history, preferences, etc.) and further infer meaningful information about the user. The simplest approach of user model generation is in the case where the information collected by the user is used as-is and remains unprocessed.

For example, users might explicitly express their interest on specific topics of museums exhibits which will be further used by simple rule-based mechanisms to adapt the interface by displaying the selected topics on the top of the users' interface. More intelligent approaches for generating user models include cases in which the activities of users may be utilized by machine learning and statistical techniques to recognize regularities in user paths and integrate them in a user model. We next summarize the main approaches in user modeling (according to the type of information that is being modeled) and classify them accordingly.

*Human Factor-User knowledge* indicates the level of expertise or previous experience a user has on a specific subject. Throughout user's interactions with the system the level of knowledge may vary on different domain concepts (i.e., expert in history, novice in archeology), and might change over time (i.e., learning or forgetting). Thus, an adaptive interactive system relying on user's knowledge has to update the user model accordingly. An overview of adaptive interactive systems based on users' knowledge can be found in Brusilovsky et al. [21] and Maritins et al. [22] from the domain of adaptive hypermedia.

*Human Factor-User goals or tasks* indicate the user's objective and intention in a system. Jin et al. [23] suggest different goal modeling approaches for personalization depending on the application domain since the goal of the user varies accordingly. User goals are dynamic processes as they change frequently in the frame of a given session of the user.

*Human Factor- Individual Traits.* Finally, user modeling can be based as well on certain individual traits of users, i.e. features that define a user as an individual. Most common examples are personality traits (e.g., introvert/extravert), cognitive styles (e.g., imager/verbal), cognitive factors (e.g., working memory capacity) and learning styles. Individual traits are static user features that might change only over a long period of time or might not change at all. Interactive systems that personalize the users' interactions based on traits typically classify users in a particular type and further provide the user with adaptive content presentation and different navigation organization, amount of user control, and navigation support tools.

Adapting to the user's context of use is also an important aspect in adaptive interactive systems that does not directly relate to the user's individual characteristics but to the user's contextual characteristics such as the user's location, device, physical environment, social context. Two major context models that have been proposed in the literature are related to the user's platform and location characteristics.

*Technology Factor-Platform-oriented context modeling* indicates information related to the user's computing environment, such as the device used, its hardware and software, and the available network bandwidth, today facilitated by technologies like HTML 5 and responsive web design framework, also based on a model approach as discussed by Kulkarni and Klemmer [24]. These platform oriented settings might affect the effectiveness and efficiency of mobile applications in cultural heritage environments as they can affect performance oriented attributes. As an example, low connection bandwidth can lead to a negative user experience in cases in which the mobile application implements a collaboration activity among several peers within the frame of a certain game play.

*Physical Factor- Location-oriented context modeling* indicates information related to the user's current physical location. This kind of adaptation has been popular in several social activity contexts such as culture, tourist and gastronomy guides, as it was pioneered by GUIDE (Cheverst et al., [25]), which used a Tablet PC to deliver information on points of interest in the city of Lancaster, UK, using cellular WiFi technology. In particular location-based games (Avouris and Yiannoutsou, [26]) use such features with the aim to provide to the users more content related to the artifact or exhibit they are currently looking at

### *B. Adaptation Mechanisms*

Adaptation mechanisms apply specific algorithms that decide what adaptation will be performed on the content and functionality of the system. Various approaches have been proposed, including among others rule-based, content-based and collaborative mechanisms. Comprehensive reviews of state of the art adaptation mechanisms for the web are discussed by Brusilovsky et al. [22]. These in great extend are valid also for mobile applications.

*Rule-based mechanisms* refer to the process of producing high-level information from a set of low-level metrics, related to both static and dynamic user context information. Bearing in mind that as the dynamic part of the context data model can be updated in real time, reasoning capabilities provide an added value for supporting the users in a variety of contextual settings. Such rules can initiate automated system actions or compare predictive user interaction models with actual user interaction data gathered in real time, providing thus valuable insights related to the current user goals and efficiency of interactions.

*Content-based mechanisms* suggest labeling and classification of specific museum exhibits. A typical content-based mechanism includes the following steps: i) pre-fetch the artifacts/content of a cultural heritage institution, ii) create a weighted keyword vector of each artifact, iii) compare the weighted keyword vector of each artifact with the user's preferences, that are also usually represented using a weighted keyword vector, iv) suggest artifacts whose keyword vectors match user's preferences.

*Collaborative mechanisms* exploit the social process of people recommending their experiences (e.g., read a book, watched a movie, etc.) to other people. Collaborative mechanisms are based on the assumption that if users $X$ and $Y$ rate $n$ items similarly, or have similar behaviors (e.g., buying, watching), hence will have similar interests. Adaptive interactive systems utilize collaborative mechanisms to provide navigation support by recommending exhibits/artifacts of interest to the user based on earlier expressed ratings or navigation behavior of similar users.

*Data mining mechanisms. D*ata mining enables pattern discovery through clustering and classification, association rules (or association discovery) and sequence mining (or sequential pattern discovery). Mobasher [27] describes data mining algorithms based on clustering, association rule discovery, sequential pattern mining, Markov models and probabilistic mixture and hidden (latent) variable models for web personalization purposes. A review on how data mining techniques can be applied to personalization systems is presented by Pierrakos et al. [28].

## III. Factor-Based Personalization of Cultural Heritage Applications

The discussion in the previous Section leads to a problem formulation layered in two levels. At the first level, we argue that system designers require a framework with the aim to model various contextual factors that can be used for personalization purposes. These factors need to be specified for each mobile application during the design phase and affect user experience in cultural heritage mobile applications. At the second level, we argue that specific formalization attempts are needed in order to describe in detail the context in which users' interaction takes place.

With regards to the first challenge, we propose a dynamic factor-based approach which incorporates under a single ontology the users, as well as the social and the physical context in which user interaction takes place.

The *user context* includes static data that describe information of the involved entities which do not change over time, e.g., demographic information about the users, characteristics, as well as dynamic data that consists of relevant information, which is being captured during task execution and corresponds to the user activity and therefore changes often in time (e.g., user goals, interaction device attributes). Also, the history of the entities of previous interactions constitutes part of the dynamic data.

The *social context* includes the socio-cultural aspects of user interaction and corresponds to social attributes and sensory input, based on interactions the users have with other people of the same context. The social context is of particular importance in mobile games that are played in cultural heritage environments like museums and other cultural places, which engage several user groups in collaboration activities or game play activities.

The *physical context* includes the physical information of the environment and is specified based on a particular location with its coordinates (e.g., museum, historical place, etc.). Furthermore, the physical context includes information about the physical objects that are placed in the particular environment the user is interacting with (e.g., particular cultural objects or exhibits of a museum etc.). Often, physical objects within a museum or cultural institution relate to multimedia content. These different content types can be further used for personalization purposes but they can be as well connected to a variety of social factors like users opinions in social networks about the quality and accuracy of the content, user group ratings, recommendations for improvements, etc. Such approaches can be useful for a variety of stakeholders in museums and cultural organizations to approach their audience and provide them with personalized ways and means to engage them with culture.

We present next a formalization that describes user interactions in such settings.

### *A. Context Reasoning and Formalization.*

From a technological perspective, the challenge is to generate a unified abstraction of the users' context of interaction by converting it to a set of statements based to the predefined model which entails appropriate information for each involved entity (user, interaction device, and environment). Thus, semantic capabilities can be added, allowing the adaptation mechanisms based on pre-defined and specific context-based reasoning to personalize content to the benefit of the users. Context reasoning refers to the process of producing high-level context information from a set of low-level contexts, supporting thus reasoning functionalities. Following this rational, an inference mechanism which is based on Boolean algebra is proposed as an alternative solution of using general purpose reasoners, such as Jena (Carroll, et al. [29]). As such, simple user customization and rule-based mechanisms are suggested to be used to decide what adaptation will be performed. Furthermore, collaborative mechanisms could assist the adaptation process by modeling the behavior of users with similar preferences and characteristics.

Table 1 describes the symbols of the formalization. Accordingly, let $U$ denote a set of users $\{u_1,u_2,\ldots,u_n\}$. Let $FC$ denote a set of factors which can be:

- Human: $\{\boldsymbol{hfc_1},\boldsymbol{hfc_2},\ldots,\boldsymbol{hfc_n}\}$
- Technological: $\{\boldsymbol{tfc_1},\boldsymbol{tfc_2},\ldots,\boldsymbol{tfc_n}\}$
- Application: $\{\boldsymbol{afc_1},\boldsymbol{afc_2},\ldots,\boldsymbol{afc_n}\}$
- Social: $\{\boldsymbol{sfc_1},\boldsymbol{sfc_2},\ldots,\boldsymbol{sfc_n}\}$
- Physical: $\{\boldsymbol{pfc_1},\boldsymbol{pfc_2},\ldots,\boldsymbol{pfc_n}\}$

Let $UCM_j(u_i)$ denote a set of factors of the individual context model of user $u_i$. The result of $UCM_j(u_i)$ is a set of triplets of the form $(u_i, fc_i, val)$, where $i$ is the triplet identifier, $u_i$ is the user, $fc_i$ is the factor of the model and $val$ is the value of the factor $fc_i$, where $val$ can be any value type (e.g., Numeric, String, Boolean, etc.). Accordingly, let $GCM$ denote a set of users' context models $\{g_{ucm1}, g_{ucm2},\ldots, g_{ucmn}\}$. Such collective users' context models are particular helpful in group based collaborative user interactions like social games or groupware location based games.

| Symbols | Description |
|---|---|
| $U$ | Set of users $\{u_1,u_2,\ldots,u_n\}$ |
| $FC$ | Set of factors $\{hfc_1,hfc_2,\ldots,hfc_n, tfc_1,tfc_2,\ldots,tfc_n, afc_1,afc_2,\ldots,afc_n, sc_1,sfc_2,\ldots,sfc_n, pfc_1,pfc_2,\ldots,pfc_n\}$ |
| $UCM_j(u_i)$ | Set of factors of the individual context model of user $u_i$ |
| $GCM$ | Set of factors user context models $ucm_i$ |
| $CR$ | Set of context rules $\{cr_1,cr_2,\ldots,cr_n\}$ |
| $Blc$ | Boolean logical connectives $\{and,or,not,xor,\ldots\}$ |
| $Opr$ | Operators $\{=,==,<,>,!=,\ldots\}$ |

Table 1. Table of symbols (derived from [30] and slightly improved to be applicable for the cultural heritage domain).

Let $CR$ denote a set of context rules which are maintained by the service provider $\{cr_1,cr_2,\ldots,cr_n\}$. Each context-based rule is based on a decision making model which has one hypothesis part related to physical, social, human and technology factors and precisely one decision part related to content presentation and application design factors.

As such, personalization could be achieved through the selection of certain factors properties/attributes, set the desired values and relate them with the appropriate Boolean logical connectives ($Blc=\{AND,OR,NOT,XOR,\ldots\}$) and Operators ($Opr=\{=,==,<,>,!=,\ldots\}$) in order to construct fully parenthesized expressions of arbitrary complexity that can be applied to a group of users or to specific individuals following deductive or inductive reasoning approaches, e.g., $cr_i$=$IF($ $(UCM_{hf1}\ Opr\ val)$ $Blc$ $(UCM_{tf2}\ Opr\ val)$ … $Blc$ $(UCM_{tfn}\ Opr\ val)$ $)$ $THEN$ $\{$ $(UCM_{cdf1}\ Opr\ val)$ $AND$ $(UCM_{cdf2}\ Opr\ val)$ … $AND$ $(UCM_{tfn}\ Opr\ val)$ $\}$, where $val$ can be any value type (e.g., Numeric, String, Boolean, etc.).

### *B. Personalization.*

Personalization mechanism aims to decide and deliver the best-fit content presentation to each user, based on the individual user context models (UCM) or the group context models (GCM), described above. In this context, the proposed personalization approach provides the basis information structure for numerous functionalities aiming to support personalization in mobile applications of cultural heritage environments:

- *Defining usage scenarios for personalization and correlate them with raw data:* Defining certain usage scenarios for personalizing certain aspects of an interactive system is important and requires the concrete formulation of the social, physical, user, device or interaction related attribute(s) which will be examined. These attributes need to be related to metrics that will be captured either explicitly or implicitly, to be used for adaptation or recommendation purposes.

- *Defining critical situations through context-aware reasoning:* Bearing in mind that in a ubiquitous computing environment the dynamic part of the context model is updated in real time, it becomes obvious that reasoning capabilities supported through such frameworks provide an added value for various stakeholders (e.g. curators, teachers etc) to focus on certain situations of interest. Focusing on certain users that follow a specific static and/or dynamic user profile (e.g., users have visited specific physical artifacts, use a specific device, etc.) is also an important aspect which can be supported by information processing through context modeling.
- *Supporting user interaction analytics via context-based data collection and classification:* Since a formal context-based model embraces information valuable for understanding user interactions, an evaluator (e.g. a curator or teacher) who created a usage scenario can acquire important information related to the user interactions behavior. Using data acquisition, aggregation, monitoring and reasoning, it is possible to analyze several user interactions in order to investigate their current context with participants who fulfilled some predefined criteria, e.g., in terms of predefined context rules, like sequence of actions, time spent on a task, participant profile, device settings, etc.

## IV. DEPLOYMENT SCENARIO

In this section we provide an example of future use of the proposed framework, in the form of a service with the aim to assist designers and non-technical experts in creating personalized experiences related to mobile applications within the cultural heritage domain.

In particular, cultural heritage application designers could identify, together with non-technical experts, during the development cycle of their applications, the personalization factors of their interest and create appropriate data models according to the formalism of the previous section. Subsequently, domain experts (e.g. teachers, curators, tourist guides etc.) could use direct manipulation and configuration services in order to specify a variety of personalization or recommendation rules with the aim to provide bootstrapped features to their own audiences.

From a technological and architectural point of view the envisioned service could aggregate run time information for each user or groups of users, maintain user models and execute contextual personalization rules in the form of a third party provider. Apparently, such an architectural approach would require a bidirectional communication between the mobile applications and the provided service aiming to exchange data related to user interaction. As such, it is necessary to utilize communication services which could encapsulate data in XML or JSON formats. Such an approach would allow application designers to skip personalization implementation issues which demand increased investments related to time and resources.

From a conceptual and end-user interaction point of view the service could assist application designers and non-technical experts to perform the following tasks:

- ***Initialization:*** As described previously, the main objective of this step is to set-up which contextual factors (e.g. human, physical, social, device, application and technology) are considered important for subsequent personalization procedures. Given that each cultural heritage application embraces intrinsic characteristics, the designers need to specify an instance of the proposed model which incorporates the users, and the social and the physical context in which user interaction takes place. Furthermore, for each factor which describes the contextual model of a user, certain attributes need to be identified which refer to low-level metrics or raw data that will be captured either explicitly or implicitly during user interaction, to be used for adaptation or recommendation purposes.
- ***Configuration:*** The configuration of personalization and recommendation procedures could be realized in direct manipulation interfaces. Through such easy to use interfaces, end-users could apply specific context-based recommendation rules by selecting specific factor properties/attributes, set the desired values and relate them with the appropriate Boolean logical connectives and operators in order to construct fully parenthesized expressions of arbitrary complexity that can be applied to a group of users or to specific individuals following deductive or inductive reasoning approaches.

## V. CONCLUSION AND FUTURE WORK

The overall objective of the proposed framework is to identify and formalize the factors that can be applied for the delivery of personalized experiences on mobile cultural heritage applications. In this context, the main challenge is to personalize content presentation and functionalities to various end-users within a highly dynamic context which needs continuous refinements and maintenance, e.g. museum exhibits change over time, different user groups have different needs and goals, and mobile devices define a shifting technological landscape.

As proposed here, a possible solution to this problem is allowing non technical end users, to configure personalization rules through extendable factor-based frameworks aiming to create more customized, engaging and immersive experiences in the cultural heritage application domain. In particular, we propose an abstract dynamic model which can be utilized as a service along with end-user authoring tools in order to address the ever increasing requirements of non technical cultural heritage experts to actively participate in the creation of interactive cultural heritage experiences through customizing the software they use and to contribute to the design of their own interactive experiences which are bootstrapped to their audience or diverse target groups.

We also emphasized that personalizing experiences in the cultural heritage domain seem to be a promising research direction given the diversity of users' characteristics, goals and contexts of interactions, which however has not produced concrete widely used applications. Apparently, the added value of personalization approaches has been mentioned already by many scholars. Examples are: to provide personalized content with varying level of detail or presentation approaches to specific user groups based on their specific user profiles; adapting location-sensitive mobile games, involving dynamic and collaboration interaction behaviours of users with technology and physical artefacts, with the aim to create more intensive and educational experiences. Furthermore such an approach can facilitate informal learning scenarios in museums, e.g., deliver personalized content to the visitors prior, during and after their visit, based on the artefacts they have spent more time during their visit.

The proposed approach certainly requires validation in the frame of real life conditions and ecologically valid user studies. As such, one interesting direction is to incorporate the envisioned approach in existing mobile applications and evaluate them through user studies aiming to acquire more information related to users experiences and perceived usability. Another direction is to validate the applicability of such an approach with stakeholders of mobile applications in cultural heritage environments. A similar approach, reported by Not and Petrelli [16], who involved Cultural Heritage professionals in defining their audience personalization requirements, a study that reveal that the professionals' perspective enriches the design options of the field. Further user studies can lead to refinement and improvement of our proposal aiming to identify and more concretely define the interplay among human, technology and mobile application design factors through real life use cases and scenarios.

## REFERENCES


[1] Falk, J., (2009), Identity and the Museum Visit Experience. Left Coast Press.

[2] Ardissono, L., T. Kuflik, and D. Petrelli, (2012), "Personalization in Cultural Heritage: The Road Travelled and the One Ahead." User Modeling and User-Adapted Interaction, April 2012, Volume 22, Issue 1-2, pp 73-99.

[3] Jackson, S., Adamson, R. (2009). Doing it for the kids: Tate online on engaging, entertaining and (stealthily) educating six to 12-year-olds. In: Trant, J., Bearman, D. (eds.) Proc. Int. Conf. for Culture and Heritage. Indianapolis, IA, USA.

[4] Ridge, M. (2011). 'Crowdsourcing games: playing with museums', in Beale K. (ed.), Museums At Play: Games, Interaction and Learning, MuseumsEtc, 2011.

[5] Bohnert, F., Zukerman, I., Berkovsky, S., Baldwin, T., Sonenberg, L. (2008), Using interest and transition models to predict visitor locations in museums. AI Commun. 21(2–3), 195–202.

[6] de Gemmis, M.,Lops, P., Semeraro, G., Basile, P. (2008), Integrating tags in a semantic content-based recommender. In: Pu, P., et al. (eds.) Proc. ACM Conference on Recommender Systems 2008, pp. 163–170. Lausanne, Switzerland.

[7] Greitzer F..L, Kuchar O.A and Huston K "Cognitive science implications for enhancing training effectiveness in a serious gaming context."ACM J.Edu. Resources Compt. 7,3 (2007).

[8] Bellotti F., Berta R., De Gloria A., D'Ursi A., Fiore V., (2012), "A serious game model for Cultural Heritage", ACM Journal on Computing and Cultural Heritage, Vol5., No4., Aricle 17.

[9] Riding, R., & Cheema, I. (1991). Cognitive styles - An overview and integration. Educational Psychology, 11(3-4), 193-215.

[10] Not E., Petrelli D., How Can Personalization Shape Social Action in Cultural Spaces?, in Väänänen-Vainio-Mattila K., Häkkilä J., Cassinelli A., Müller J., Rukzio E., Schmidt A. (eds.), Proceedings of "Experiencing Interactivity in Public Spaces (EIPS)", workshop at CHI'13, 2013, pp. 82-86, Paris, April 28, 2013.

[11] Stoica A., Avouris N., (2010), An architecture to support personalized interaction across multiple digitally augmented spaces, Int. J. on Artificial Intelligence Tools, vol. 19, 2, pp. 137-158.

[12] Azuma R. T. 1997. A Survey of Augmented Reality. In Proceedings of the PRESENCE: Teleoperators and Virtual Environments 6, 4(August), 355–385.

[13] Barberis C., A. Bottino, G. Malnati, P. Montuschi (2014). Experiencing indoor navigation on mobile devices. In: IT PROFESSIONAL, vol. 16 n. 1, pp. 50-57. - ISSN 1520-9202.

[14] Manesis, T., & Avouris, N. (2005, September). Survey of position location techniques in mobile systems. In Proceedings of the 7th international conference on Human computer interaction with mobile devices & services (pp. 291-294). ACM.

[15] Stock, O., Zancanaro, M., Busetta, P., Callaway, C.,Krueger, A., Kruppa, M., Kuflik, T., Not E., Rocchi, C. (2007) Adaptive, intelligent presentation of information for the museum visitor in PEACH.UMUAI,17(3)257-304.

[16] Not E.,Petrelli D., Balancing Adaptivity and Customisation: In Search of Sustainable Personalisation in Cultural Heritage, Proceedings of the 22nd Conference in User Modelling, Adaptation and Personalization, UMAP 2014,pp. 405-410.

[17] Vlahakis, V., N. Ioannidis, J. Karigiannis, M. Tsotros, M. Gounaris, D. Stricker, T. Gleue, P. Daehne, and L. Almeida, (2002), Archeoguide: an augmented reality guide for archaeological sites, IEEE Computer Graphics and Applications 5 (2002): 52-60.

[18] Carmagnola, F., Cena, F., Console, L., Cortassa, O., Gena, C., Goy, A., Torre, I., Toso, A. And Vernero, F.: 2008, Tag-based user modeling for social multi-device adaptive guides. User Modeling and User-Adapted Interaction 18(5), 497-538.

[19] van Hage, W., Stash, N., Wang, Y., & Aroyo, L. (2010). Finding your way through the rijksmuseum with an adaptive mobile museum guide. The Semantic Web: Research and Applications, 46-59.

[20] Pujol, L., Roussou, M., Poulou, S., Balet, O., Vayanou, M., & Ioannidis, Y. (2012). Personalizing interactive digital storytelling in archaeological museums: the CHESS project. In 40th Annual Conference of Computer Applications and Quantitative Methods in Archaeology. Amsterdam University Press.

[21] Brusilovsky, P., Kobsa, A., and Nejdl, W. (2007). The Adaptive Web: Methods and Strategies of Web Personalization. Springer,Heidelberg.

[22] Martins, A. C., Faria, L., Vaz de Carvalho, C., and Carrapatoso, E. (2008). User Modeling in Adaptive Hypermedia Educational Systems. Educational Technology and Society 11, 1, 194-207.

[23] Jin, X., Zhou, Y., Mobasher, B. 2005. Task-Oriented Web User Modeling for Recommendation. In Proceedings of the Conference on User Modeling (Edinburgh, Scotland, UK, July 23-29, 2005) UM '05. Springer, Heidelberg, 109-118.

[24] Kulkarni, C.E., and Klemmer, S.R. 2011. Automatically Adapting Web Pages to Heterogeneous Devices. CHI EA'11, ACM, New York, NY, 1573-1578.

[25] Cheverst, K., Davies, N., Mitchell, K., and Smith, P. 2000. Providing Tailored (context-aware) Information to City Visitors. In Proceedings of Adaptive Hypermedia and Adaptive Web-based Systems (Trento, Italy, August 28-30, 2000). AH'00. Springer, Heidelberg, 73-85.

[26] Avouris, N. M., & Yiannoutsou, N. (2012). A Review of Mobile Location-based Games for Learning across Physical and Virtual Spaces. J. UCS, 18(15), 2120-2142.

[27] Mobasher, B., 2007. Data Mining for Web Personalization. In The Adaptive Web, Brusilovsky, P., Kobsa, A., and Nejdl, W., Eds. 4321, Springer, Heidelberg, Germany, 90-135.

[28] Pierrakos, D. Paliouras, G., Papatheodorou, C., and Spyropoulos, C. 2003. Web Usage Mining as a Tool for Personalization: A Survey. J. User Modeling and User-Adapted Interaction 13, 4, 311-372.

[29] Carroll, J., Dickinson, I., Dollin, C., Reynolds, D., Seaborne, A. and Wilkinson, K. (2004), "Jena: implementing the semantic web recommendations", WWW 2004, pp. 74-83.

[30] Fidas, C., Hussmann, H., Belk, M., Samaras, G. (2015). iHIP: Towards a user centric individual human interaction proof framework. In Proceedings of the ACM SIGCHI Extended Abstracts on Human Factors in Computing Systems (CHI 2015), ACM Press, 2235-2240.