

A Study of Contextualized-services of Digitalized Museum with Context-Awareness System

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Abstract

As a new type of service model, contextualized-services has been paid a multi-partite attention both domestically and internationally. Contextualized-services will be the demand of future museum in order to suit the development in a new era. In this study, we mix together the relevant studies to expound relevant concepts and their meanings, and analyze - from three dimensions of user, museum and knowledge - the demand of contextualized-services. Based on the factors of context-data collecting, context-computing, context-model building and context-model assessing, the article analyzes the building process of context-awareness model, and sets up, focusing user as a core, a service framework of digitalized museum's contextualized-services, that composes of the modules like context-awareness, resources integration, technical support and scene service. The article also discusses the problems involved in contextualized-services and then puts forward relevant solutions. Furthermore, raising up the strategy about perfecting the construction of museum's experience-available scenes, and by this way, to create a better immersive experience of museum visiting for visitors. The study also discusses the problems involved in contextualized-services and then puts forward relevant solutions. Furthermore, raising up the strategy about perfecting the construction of museum's experience-available scenes, and by this way, to create a better immersive experience of museum visiting for visitors.

1. Introduction

Context, also called circumstances or preceding-and-following texts, means any information used to define the status of an entity, such as the entity's location, time, surroundings, activities, and trends. It is also all information describing the features and status of a physical entity and of a virtual one. By utilizing information, we can offer services and data that are suitable to user's current situation. Such an offer is called context-awareness service.

With its awareness of the information about a context into which a user is invoked, such as who, where, when, what etc., the context-awareness service (contextualize-services) can automatically recognize, understand and explore the user's demand, and then establish a kind of adaptive adjustment mechanism to enhance the accuracy and dependability of service. Functions like these are the critical supporting conducts or methods to enhance the system's effectiveness and quality (Yang et al., 2007).

Under the condition of user's ever-moving, a "context" - into which a user involves — will present some dynamic features like different period, different location and different work. And consequently, his demands of service are ever-changing. And consequently more, about offering individualized service based on user's context change, the study has substantially achieved some results, both domestically and internationally.

Reviewing the current situation of the majority of China's modern museums, what a sense we can make is still of a "relic stock-house", old-fashioned and uninteresting. Due to monotonous scene-constructing, they are unable to satisfy the various demands of experience by today's visitor. Thus, the quality-raising and upgrading of museums are urgent in the aspect of scene-rebuilding.

Based on the scene theory, new research perspectives are possible to be set up for building a museum-scene with experiencing style, and also to carry out multi-dimensional and comprehensive analysis or probe into this issue. Relying on the doctrine of scene-perception, this paper explores the multi-interactions among context-awareness, contextualized-services in digitalized museums and constructing cultural environment. The paper also analyzes and illustrates how a museum can approach its user-centered goals of individualized recommendation and contextualized scene-switching, so that enabling a museum to create a better immersive experience for its visitors.

2. Literatures Review

2.1 Research on museums and their scene-building

According to the redefinition by The International Association of Museums (TIAM) in 1989, museum means a kind of non-profit public organization that is - with its main functions of collecting, preserving, studying and exhibiting physical and/or intangible heritage those are possessed by the whole society - established for the purposes of serving all people, and of improving society's development, community's harmony and nation's opening. It also is for non-profit, study, education and services (Chen Guoning. 2017).

At present, promoted by the ever-development of tourism industry, functions like tourism, leisure, and entertainment of museum have become increasingly prominent. A resource for cultural tourism, museums are also in lockstep with the development trend of cultural tourism. Between museums and tourism, the relevance will inevitably get closer as society and tourism continue to flourish. Some studies, from the R&D perspectives on tourism products offered by museum, have been conducted and achieved a certain level by domestic academics.

Xuhong Kong and Hongshi Sun (2003) noted that, from the perspective of the product, our museum tourism products are facing both problems of incomplete levels and of over-dating tendency. So, they suggest then upgrading the public image of institutions who run their business of museum tourism, to perfect the rank system of museum tourism products, and to strengthen the solution of polishing the consonance among museum tourism products of all.

Ying Li (2004) analyzed the current R&D situation of museum tourism products in China. About the states of incongruity in quantity and quality of museum development, and of mismatch between the methods of promotion and propaganda for products and, on the other side, the demand on the market, Li suggested a set of development tactics such as paying attention to consumer demand, balancing the sorts spreading of different museums, introducing the necessary concepts of marketing, improving the methods of exhibiting and so on. 1916, with his researching perspective of museum audience, Mr. Gilman selected audiences' visiting experience at Museum of Fine Arts Boston, U.S. as a case for his relevant research (Marchetti E. 2013).

According to museologist John H. Falk (1992), the audience's tour at museum means a multi-interactive visiting experience which mixes personal emotional factors, historical background and his/her experience of human-computer interaction there. By classifying museum-audiences' types and levels, Siyi Wang studied - from perspectives of behavioral patterns, doctrine adopting and emotional precepting - audience's activities at museum. Also, Wang (2016) suggested that museum should highly think of audience's experiencing perception and emotional satisfaction.

On the studies of museum curation and to which the related design, Kenneth Hudson of UK analyzed, from a standpoint of media studies, the museum's information-disseminating practices involved in museum's exhibition design. It is emphasized by Hudson that museum's exhibition should be people-oriented with adaptable functions (Landau et al., 1980).

At an academic seminar on The Theory & Practice of Museum's Exhibition Planning, Chen Chen cleared up the system of exhibition's curatorial processing and the components relative to exhibiting management under the project oriented. He suggested museum curation should develop a core standard-operating-procedure (SOP)

for meeting the demands, from ever-advancing epoch to exhibition's curatorial planning of museum (Chen, Chen, 2019).

In the field of research on museum's function, Aiko Hashimura of Japan argued that, at the same time of implementing museum's educational function, education should be combined with recreation. Also, museums should advocate experienceable and appreciable education (Cun et al., 2011).

American Stephen E. Weil (2016) said that the mission of museum has been realistically shifted to carry out propaganda and some social missions from education, collection, preservation and exhibition. With the current performance relating to museum's basic exhibition, Jixiang Shan (2015), former curator of the Imperial Palace, Beijing, studied museum's unique nature, social image and right guidance. And then, based on museum's function of exhibition, she put forward some exhibiting ideas expected to be attractive to visitors.

2.2 Context-Awareness Recommending System and Context-Awareness Services

In the aspect of theoretical research on the context-awareness services, the foreign studies mainly concentrate on the matters of context taking, context modeling combined with system framework building, context-awareness applicating, context-awareness recommending system and so on. Plenty achievements of such theoretical research can be seen now. Their findings include that, of context-awareness services, one of the main challenges is how to exactly take and characterize the dynamic contextual information collected by users of context-awareness services system. However, user's attention points properly release a real-time picture of dynamic contextual information.

Context-awareness services have been extensively applied in many areas such as e-commerce, mobile computing, information retrieval and information recommendation. Satoh I (2015) pointed out that there was a big difference between the research at laboratory level of context-awareness services and its application in a real-world. He further pointed out, and made his analysis then, that there was a number of common issues facing those context-awareness services in a real-world. Thus, after exploring the experiences collected from context-aware service experiments in a real-world like museum, he raised up his solution tailored for such situation.

Kim et al., (2010) put forward a new type of individualized recommendation system which - by gathering contextual data such as the user's location, identity and category of demands - increases both satisfaction degree and accuracy rating of advertising services. Created by Kim et al., (2010) a prototype system called NAMA is able to, based on information about context around user, description of user, recommend individualized information for user's online shoppers (Kwon et al., 2005).

Hong et al., sliced context-awareness system to layers of the basic research, the network, the middleware, the application and the user's infrastructure. And by this way, they brought up a solution of using context history - which is based on context-awareness computation - to provide a framework of individualized information services and building up a relevant prototype system (Hong et al., 2009). On the other hand, Kim et al., (2014) applied context-awareness and individualized recommendations for a system of individualized health service and, consequently, realized the combination of collaborative filtering and context-awareness.

Both context-awareness recommendation methods and systems and, on the other hand, context-awareness retrieval have been deeply studied by several academics. Adomavicius et al., (2005) for example, detailly expounded the principles and methods of a multi-dimensional recommendation system containing contextual information. They suggested introducing a joint-recommendation algorithm aligned with context and developed an experimental prototype system for movie recommendation.

Proposed by Su et al., (2010) a music recommendation system called "uMender" is able to comprehensively utilize contextual information, music content and relevant users rating. Under its analysis on two-levels music clustering, content and characteristic, the uMender can divide users into different groups according to the similarity of the context, as well as recommend music that appropriates both targeted listeners and the listeners' status.

Based on geographic location, Lee et al., (2006) suggested a system of hotel recommendation. By creating a decision tree, the system scores targeted hotels and offers useful information services to tourists who are in specialized geographic contexts. While Gavalas et al., (2011) used traveler's personal information - combining with contextual information (user's location, local time, local weather conditions, sites visited already etc.) - provided recommendations after a collaborative filtering algorithm. Yap et al., (2007) argued that user's context was an important attribute characteristic when describing user's interest models. by creating a network model named "Bayesian", user's real context and his/her preference can be predicted in dynamic way. Thus, the accuracy of recommendation services can be improved in a complex context of mobile network.

Based on fuzzy sets, Madkour et al., (2012) proposed a model of context-awareness retrieval. It takes into account the influences from both functional context-information (including user's identity, time and location, current activities, etc.) and non-functional context-information (including user's preferences, experiences,

emotions, culture, society, etc.). So, it is available for the model to select the necessary services and sort them into order. Moreover, the model is used to deal with incomplete and uncertain situational information.

Hence, we can see that context information is a crucial component for ensuring the quality of individualized retrieval in a mobile environment. However, various applications must take into account various context factors.

2.3 Research on the Scenes Construction of Museum Based on Contextual Awareness

Dey (2000) views context as all information describing conditional feature of an entity. Within big data environment, a user's context can reflect the user's various needs in various time, space and user's behavioral status. One of the pioneers creating the concept "context-awareness", Schilit et al., (1994) argued that context-awareness emphasized both device's perception on changings of contextual information and the feedback from the system.

Context awareness is a process that, with a variety of devices or technologies, collects and analyzes context-information, and being utilized in the fields of advertising, e-commerce, tourism, and resource retrieval. It can be used by museums to completely sense visitors' demands, and then offer specialized and knowledgeable contextual services.

Every scene is a unique area where information-medium and physical environment interact with each other. That is something like a novel method of multi-connection and value exchange. With the popularity of smart mobile devices, more frequently users interact with their surroundings, and more attention is paid to service experience. So, the contextual services have been more attached importance to. Titled *The Coming of a Scenarios Era*, the book clearly points out that a scenario composes of both harder factors like space, environment, social atmosphere, experience and softer factors like cultural atmosphere and construction of relevant resources (Xie Bin. 2018).

Contextualized-services system cannot be efficiently running, unless it consecutively suits contextual elements by context switching and resources reallocating. Targeting specific topics or user groups and perceiving real-time context in which the user is involved, the system can automatically recognize or discover user's needs. Then, by based on the context of user's needs and that of task operating, and by integrating resources and combining services in a focus-oriented way, the system actively offers services so that a variety of scenario options are available for user (Zeng, Jianxun. 2018).

Contextualized services is necessary for museum to follow up the new trend of the time. It sharply shows an integrated development with space, resources and services, and also determines the value of why a museum should survive any more. In this new era under user-commanding, context is ubiquitous and variative. Therefore, a no-gap connection between user's empathy-experience and context should be a new implication created by a digitalized museum.

3. Demand Analysis of Contextualized-Services in Digitalized Museum

3.1 User Dimension

In an era under user-commanding, context is ubiquitous and variative. Of services operation, the environment and performance style are paid attention more when users obtain the knowledges they need. Aside from knowledge based-on visual perception such text, photograph and video etc., user expects more that he/she can — via scenarios-show of knowledge and experiences of sense organs - experience knowledge itself not only, but also the knowledge-services.

Era is going ahead with information inflation. Be parallel with that, the user's personal demand of information has become more individualized. So, the museum should base on user-involved context and explore user's demand trend, in order to provide services of precise knowledge-searching and individualized information-recommending.

Along with the faster paces of life and learning is quickening, it is a remarkable characteristic of fragmented behaviors when user run an on-line access, while the contextualized-services is able to — by completely activating human senses for perceiving a plenty of contents contained by information — help user to improve their obtain information, with higher efficiency and quality. Meanwhile, for the goal of meeting user's demand of "being on the scene, a museum should:

- provide contextualized-services in a way that is effective, convenient and focalized;
- if user needs, provide a simulative contextualized-experience and/or a context running with automated processes;

- to users from institutes of education and scientific research, provide contexts of virtual-but-simulative laboratory, scientific researches coordinating and scientific data sharing etc. Therefore, fully playing museum's advantage of data resources and fully utilizing user's demand on science-intensive findings;
- to students from primary and secondary schools, provide contexts of practices participating, community activities and on-line classroom of science teaching, as well as meet their demands like study, social interaction, entertainment, innovation and more;
- general users, provide contextualized-services of comfortable entertainment spaces, visiting routes in individualized and customized.

Users focus more on experience when learning new information, while experience is one of the components of contextualized-services which is beneficial not only to improve the development of contextualized-services but thus gain user's appreciation, and to be used as a guide the creation and reconstruction of contexts and/or scenarios.

Users experience means an all-round perception of museum environment, resources and services. It mainly appeared in the aspects of user's satisfaction-degree, effectiveness of scenarios construction, as well as appeared in the whole process of service running. Thus, a comprehensive contextualized service-platform should be developed by museums for its users. So, the platform should be linked, in a way of no-gap, with context such as "empathy-style" one that user being involved in and bring a perfect-service experience to the user.

Scenarios in museum should have self-adaptive ability in order to depend on the changing of user's demand, fully utilize its equipment, services and resources to create an individualized contextualized service. And such services should enable users, either online or offline, to actively obtain information and to have a strong sense of identity and belonging. Thus, the museum truly achieves its goal of taking the users as the core.

3.2 Museum dimension

According to the Chicago School of Urban Studies, of a place or space to attract people, the reason is not - although emphasized by classic theories - local economic factors, but what the culture and lifestyle can be offered by that city or place (Wu Jun. 2014). In the scene of museum, within a given space of museum, a specialized scene normally composes of exhibits furnishing, cultural facilities, services offering, crowds of visitor, ongoing activities as well as derived cultural products and so on.

Fostered by various scenes, the scene values as a whole create the museum's distinctive value orientation that attracts more visitors with same value concept to come and watch and then creating a "customer stickiness". That means visitors who gather here for their variety forms of cultural consuming and participation. Further, all of these will boost cultural production and consumption in various forms and contents, which ultimately push the museum to get better.

As a new window of information, context not only offers a fresh method of information consumption, but also reduces the distances among users, museums and services for preserving intangible cultural heritage; and moreover, realizes a mutual-perception of people-and-museum, people-and-services, people-and-knowledge. Dominated by users, this is an era of seizing context. For library and museum, there would be neither an ongoing power for growing up, nor a further room for sustainable development, unless contextualized services as a commanding point.

3.3 Dimension of intangible cultural heritage

The EU regards the digitalization of cultural heritage as a key-of-the-key factor for their sustainable development of society and economy. Fundraised by program Horizon 2020, EU raised up a project named Virtual Multi-Operated Museums (VMOM) (Ioannides et al., 2018). It is - under the general background of EU's policies and practices on digital cultural heritage - a major action of coordinating plus supporting in the field of virtual museum. In this project, a group of world-class leading experts outline their declaration and roadmap about higher-graded policy, strategy planning and MR technology utilizing in a ground-breaking method (Ioannides et al., 2018). Of this project, the goal is to foster, in southern European nations, a trend of evidence-based growth and development that has been affected by virtual museums.

Traditional knowledge is mainly based on collection of findings as well as the interactions between human and environment. This knowledge includes various kinds of knowledge about traditional surviving skills, such as tools and skills for hunting and agriculture, midwifery, ethnobotany and ecology, traditional medicine, celestial navigation, ethnoastronomy and climatology. Such knowledge has been either handed down from one generation to the next, or inserted into story, folktale, ballad, ceremony, song and law. Important to the surviving

of relevant ethnic group surviving, this knowledge may be beneficial to human beings in many aspects of our daily life, because the knowledge fosters a unique idea of common existence.

However, with a trend of increasing richness of intangible cultural heritages' kinds and former, information overload has become a tough challenge. For this reason, digitalized museums should strengthen its supply and service of cultural heritages by offering contextualized-services. It is difficult to raise the user's interest in knowledge if relying on traditional showing methods like texts, images and videos, and difficult too, to bring user a perfect experience. But, on the other hand, knowledge contained in a context becomes richer more and more, and with contextualized services, we can offer a better show of the multi-dimensional scenarios of knowledge.

Based on scene, the services of knowledge offering might help readers and/or visitors to improve their memory and comprehension of knowledge. Thus, knowledge is no longer of abstract notions, but being presents in the form of interactive scenarios. By recreating a historical scene, for instance, readers will be available to participate in it and to be a witness of history.

Scene can shorten the gap between readers and knowledge of cultural heritage. Under this service, knowledge performance becomes concrete from abstract, and approachable even touchable. In an individual scene made by digitalized museum, user can concentrate his attention on what he is learning or watching, and more easily understand and deeply remember this knowledge of cultural heritage then. Also, a scene can simultaneously display not only text, images, audio, video, but also the contents in the formers like three dimension (3D), augmented reality (AR), virtual reality (VR), real objects, plots and more.

Smoothly switching of multi-scenes, dynamically interacting between human and scene, all of these are able to present, in a vivid and brilliant way, knowledge resources of cultural heritage no matter how vast and complex they are.

4. Context-Awareness Model Construction for Contextualized-Services Users

4.1 Context data collection

Of the contextualized services by digitalized museum, the characteristics include regarding user as a core, regarding demands as an orientation, pursuing the more convenient and higher efficiency. According to both the demands of contextualized-services and the characteristics of digitalized museums, this paper creates, based on ontology-based, a data model of context-awareness.

In this model, C_i is the first-level ontology and regarding user as a core, while the second-level ontology composes of self-context X_i , physics-context Y_i and information-context Z_i . The model makes a label-set of context attribute for the second-level ontology. And the label set comprises specifically detailed numerical values of the labels. (see Figure 1)

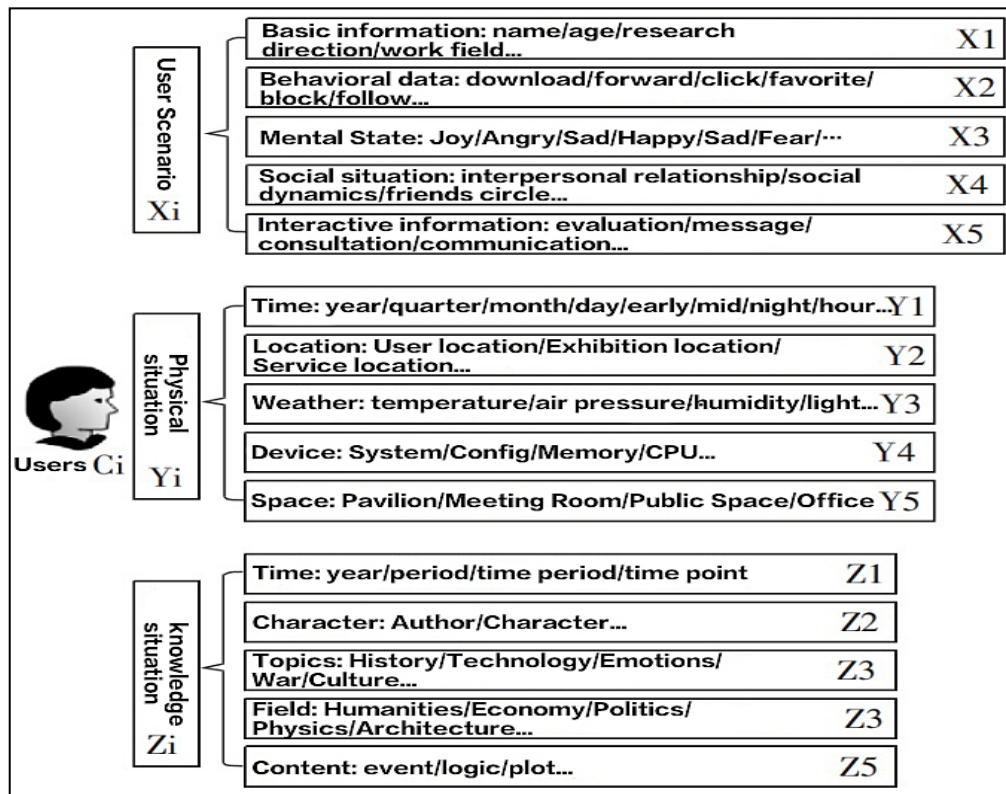


Fig. 1 Ontology-based reader context-data model

Of the context in which user is involved, the ontological attributes include basic information, behavioral information, psychological state, social context, interactive information and more. Among them, the basic information can be collected from user's museum-registration and relevant demographic data, while the behavioral data - extracted from user's web-crawling or back-end database - can be used to describe user's behavioral habit and preference of exhibition visiting.

Mental state can reflect user's psychological changes caused by different contexts, circumstances and contents of information. Depending on such kinds of changes, museums can provide a user with its contextualized-services suitable for this user's current mental state.

Data of mental state can be gathered from questionnaires, online feedback, and from utilizing log collection and web crawlers to collect user's comments, etc. Relying on text-sentiment analysis or the Big-Five Personalities, we are able to obtain the psychological characteristics of user in various contexts.

Social circumstances reflect the characteristics of user's interpersonal relationship and social demands when he is in different contexts. Social platforms can be used to collect user's social data. User's social information can be collected through his web-crawlers, his smart-mobile terminals, etc. By relying on users' social contexts and excavating the characteristics of users' social demands, we can help digitalize museums to provide social context services to user.

Gathered from the interactions among users, the data can be used to assess and compare the qualities of different services, so that we can adjust and improve service method as well as optimize the model of contextualized awareness.

Ontologies of physical scenes contain attributes of time, location, weather, space and equipment. In this expression, "time" means a specific period during which a user is in library or museum and obtain the service there. So, the word "time" here, reflects user's preference or normal practice on timing. After knowing the user's location and, further, knowing his demand preference at different locations where he is, we can provide a contextualized service matching that location.

User's scene-experiencing is affected by various weather factors, such as temperature, air pressure, illumination and others. Thus, the model in Figure 1 should, in accordance with weather changing, adjust its method of contextualized service.

It is also necessary to contextualized-service that museum should — relying on the space where the user is there and what equipment he is using — offer a correct contextualized-service matching the exact space and equipment. For the services contextualized by a digitalized museum, the goal is rightly of providing appropriate contextualized service by using appropriate equipment at appropriate scene.

Ontologies of knowledge-context can be broken down into the attributes of time, character, subject, domain and content. We can collect some knowledge-contexts and then label them. Of a knowledge-context, an accurate

depicting and/or describing can swiftly provide the knowledgeable contents aligned with user's expectation. The more accurate labelling a knowledge-context, the more accurate a contextualized-service system can distinguish and pick up the targeted knowledge.

Of digitalized museum's contextualized-service, the main function is to offer user a scene-service that is convenient, fast and smart, and then presenting the appropriate knowledge, via a proper scene, to a right user.

4.2 Contextual Computing

After classifying the labels of users' context-attributes, a number of group context-models can be set up, so each group can be offered the contextualized-services tailored for them, while the museum can increase its effectiveness of system's response. Although the items of contextualized-services can be offered by individualized-context in an individualized and accurate way, yet if the individual context-data is collected in an incompletely and imperfectly way, then a context-building is unable to meet the true demand of user.

Based on both segmentation of user-group and drawing specific group's context-preference, new users will be recommended - referring to similar existing user-groups - the individualized-context. Clustering or segmentation is a type of unsupervised learning method that usually uses algorithms like K-means and DBSCAN etc. We can also select Euclidean distance, cosine similarity and so on to measure the distance between one group and another.

Regarding the deficiency of user-context label, Bayesian formula $P(B_i|A) = \frac{P(B_i) P(A|B_j)}{P(B_i) P(A|B_j)}$ can be used to solve this problem. For the purpose of contextualized services, in this formula:

- ① $P(B_i)$ means the probability of context- B_i ,
- ② $P(A|B_j)$ means the probability of context- A when context- B_j existing, and
- ③ $P(B_i|A)$ means the probability of context- B_i when context- A existing.

With this formula, we can figure out the context- B 's probability possessed by a user if he has context- A 's characters. When a user has context- A but no context- B 's data, we can use probability estimation to fill the absent context-label. On the other hand, we can also determine whether the user's context-attribute label is appropriate.

Association Rules can reflect the interdependence and association between one object and others. Thus, Apriori algorithm is used frequently. With Association Rules, the relevance among multi-contexts can be explored. By this way, we can set up a scene involving multi-elements, increase the stickiness of contextualized-services and completely activate the user's initiative of obtaining services.

The most of user's context-data, when being collected, is in the form of text. Thus, the label of context-attribute can be obtained by data mining. When a text-mining occurs on context-data, the frequency analysis based on TF-IDF can be used to determine the frequency of context-labels, while LDA is used to extract a topicalized-context (topic-context, in short).

Topic-context is the most attended context by user, so that receiving more weight when selecting context-label. User's context-preference may change over time, but the topic-context is the primary factor able to reflect the user's context-preference. Thus, by extracting the user's topic-context, we may rapidly grasp the direction of the user's dynamic context-changing.

Before grasp the main trend of user's context-preference, we should completely know and/or understand what the topic-contexts this user enjoys. Therefore, even if there are very subtle changes in user's context-preference, the contextualized-services offered by us will not — as long as grasping user's context-preference in a systematic way — diverge from the user's expectations.

4.3 Scenario modeling

Context modeling is based on the labelling processes on user's context, physical context and knowledge context. A Label presents its characteristics of short-text and semantization. With shorter language or character, label can be used to express complex context-data and be easy for computer's reading and human's understanding. Thus, we can increase both the processing efficiency and the recognitional capacity on context-data.

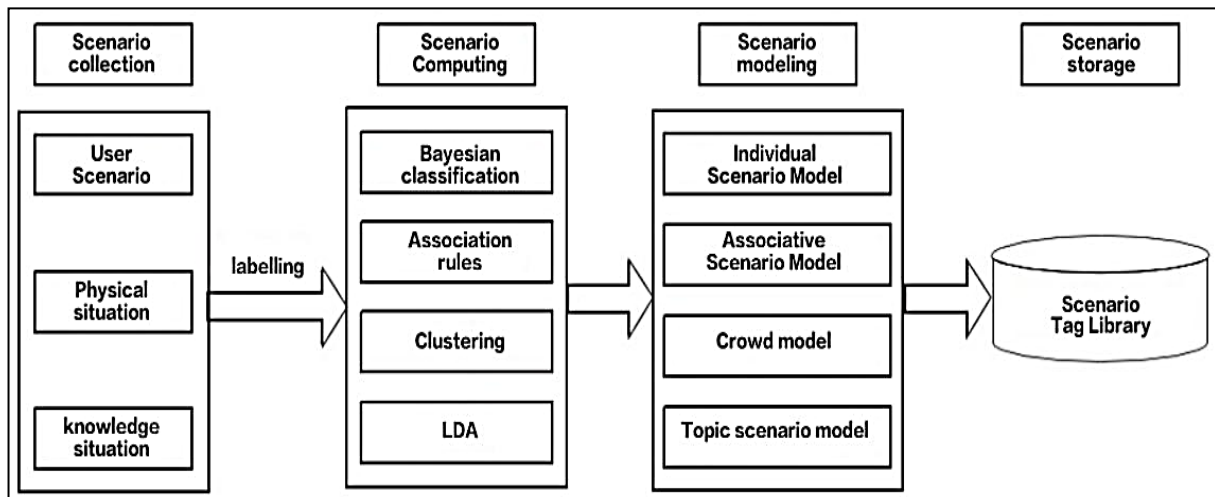


Fig. 2 The building process of context-awareness model

Following the course of labeling, we can use Bayesian classification, association rules, clustering, and LDA to process and build models such as:

- individual scenario-model - can swiftly create labels for user's context-attributes, and be used to explore user's context-characteristics or demand preferences;
- associative scenario-model - can be used to the association among different context-labels, then simultaneously meeting demands of associated-contexts when offering relevant contextualized-services;
- crow context-model - can gather up individual labels and from which drawing a number of group-contexts, then utilizing these group-contexts to explore their context-characteristics or demand preferences;
- topic scenario-model - is used to rapidly draw user's context under specific subject (i.e., subject-context). It can explore the contextual factors behind user's demand preferences. By this way, we are able to rapidly grasp user's main context-preferences and further, knowing the dynamic changing of such preferences.

After analyzing and processing these context-labels and models, we can save them in order to paste and use at any time. (see, Figure 2).

4.4 Model Evaluation

For building up a model of user's context-awareness, it is necessary to measure the label- effectiveness - that is to say, measuring the accuracy of context-awareness model - of user's context-awareness after it is created. Another measure is on the label's accuracy rate, for which sample-survey can be used. Within a sample that is under surveying,

- the label's accuracy rate of each ontology is P_i (the ratio of the number of accurate labels to the total number of labels), therefore,

- the average correct rate of sample labels is $\bar{P} = \frac{1}{n} \sum P_i$, and $\sigma^2 = \frac{1}{n-1} \sum (P_i - \bar{P})^2$

- the variance is $\sigma^2 = \frac{1}{n-1} \sum (P_i - \bar{P})^2$.

Thus, the higher average correct rate plus the lower variance, means the better effect of a context-awareness model's building.

For measuring the effectiveness of conjunctive-contexts model, we can use the lift degree (i.e., $\text{lift}(A, B) = \frac{P(A \cap B)}{P(A) P(B)}$) to make a correlation measuring on those extracted conjunctive-contexts. In this case,

- if context-A and context-B are independent to each other, then $P(A \cup B) = P(A) P(B)$, i.e., the degree of lifting is 1;
- if the degree of lifting is less than 1, then there is a negative correlation between context-A and context-B. On the contrary,
- if the degree of lifting is more than 1, then there is a positive correlation between context-A and context-B.

Additionally, we can use the measurement of X2 chi-square as well as the Kulc measurement, which is raised by Kulczynski's Kulc, one of the Polish mathematicians. Before assessing a crowd context-model, we need to measure the accuracy of individual user's group-category classifying to which he belongs. Different users should be located into relevant groups, and then we should make a judgment of the effectiveness of cluster depending on such group. To do that, measurements like accuracy degree, recall rate and silhouette coefficient can be used.

5. Discussion

For upgrading the contextualized-services by digitalized museum, scene-awareness should be integrated - in an organic way — into the course of contextualized-services, and therefore, creating an “ecology” of user ⇌ demand ⇌ scene. That means, with a scene to know user's demand. It is true that user's demand creates his scene, while a scene maps the user's context.

On the other hand, with the module of context-aware, the module of resource integration, module of middleware and the module of contextualized-services, this paper build up a service system framework for digitalized museums (see Figure 3).

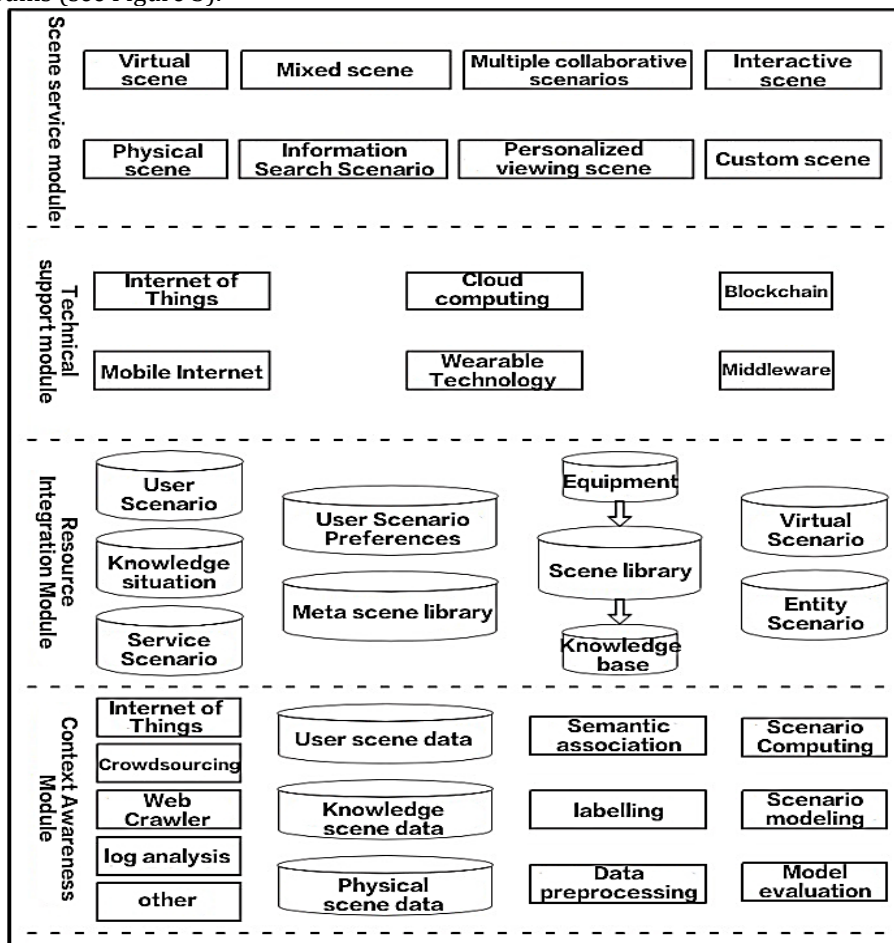


Fig. 3 Scenario-based service architecture of Digital Museum based on context awareness

5.1 Module of Context-Awareness

For gathering context data, methods and techniques include Internet-of-Things, crowdsourcing, web crawler, log analysis, etc. The main techniques of Internet-of-Things can be broken down into sensor, monitor, GPS, RFID, etc.

These techniques are not only used to gather user's context data, but also to provide a set of contextualized services that is of all directions, three-dimensional interconnection and perceptible as well.

For instance, the sensors can perceive factors like temperature, humidity, air pressure and illumination, then running its middleware of device to adjust the factors automatically. The monitor gathers data about the user's behavior, space, surrounding environment, social relations and other information. GPS can be used to pick up the context of user's location, and then offer services based on his location.

Crowd-sourcing is applied for collecting and labelling the data of knowledge-context. Scene's synchronic factors - such as components for design, track of thinking and service plan - can be obtained through the operation of crowdsourcing.

Web crawler can be used to draw the data of user's social affairs, discussion record, scoring evaluation, reading records etc. and then, finding user's emotional feature, social relation and reading preferences. All of the information is useful to provide the user with a set of individualized contextualized services.

Technique of log collection can utilize the data-backup of a system platform to extract the information of system performances on each time span, and then reflect on the platform's data change. Such techniques are also useful to collect information like dynamics of user's behavior, data flow, network attack, processes of various events and processes of business.

For collecting context data, other methods include online surveys by questionnaire, interview, scene simulation etc. The data collected from different sources is necessary to be normalized so that it is easier for being analyzed and processed, and meanwhile removing away the false data, noisy data and redundant data.

The collected data cannot directly reflect the user's contextual feature. To solve this challenge, it is necessary to do both data conversion and semantic analysis. Further, exploring user's context-semanteme and carry out a label processing.

By context computing, context modeling, model assessing and data saving, a context-awareness is able to conduct its computing work in accordance with a given logical structure, and then increasing the efficiency of system.

5.2 Module for Resources Integrating

With the module of resource integrating, a digitalized museum may effectively integrate its collected resources of cultural heritage, its facilities for space managing and its resources of users, and then creating basic conditions for running its contextualized services.

By using the context-data of user's context, of knowledge context and of physical context, a digitalized museum may explore user's scene-preference and refine a meta-scene. Meta-scene (or, scene-of-scene) is not only a logic-setting on the basic structure and content of a scene, but also a scene's basic units composing of scene-elements, as well as the basic components for building a scene.

It, a meta-scene, may be diffused and evolved into different scenes, so that we can make a scene to be more adaptable and expandable. After matching user's context-demands with meta-scene, museums can construct scene-contents aligning with user's demand and preference. Furthermore, with the smart facilities of digitalized museum and the facilities applying for user's mobile terminal and client-terminal, museum can integrate and meet user's demands of knowledge, then deliver him either a virtual or a physical scene service.

5.3 Module of Technical Support

Contextualized services of digitalized museum need supporting technologies like the Internet of Things, cloud computing, blockchain, mobile Internet, wearable technology and middleware. By using the technology of Internet of Things, museums provide contextualized services which are omnidirectional, stereoscopically interconnectional and perceivable. With sensors, monitors, RFID and others, museums can gather user's context, then its facilities and objects will have perceptive function and offer a better contextual experience to user.

In the time of big data, the function of mobile devices is insufficient to carry out computing work under big data. Thus, complex data can be sent to cloud platform; and using server to complete a quick computation of high concurrency then send the results, via cloud transport, to mobile client, and by this way to increase the effectiveness of service. Meanwhile, by using Hadoop for distributing storage and management, we can increase both acquisition efficiency and sharing degree of resources.

Blockchain has its characteristics like decentralization, point-to-point transmission, asymmetric digital encryption, collaborative maintenance, anti-tampering, anonymity etc. So, it plays an important role in protecting cultural heritage copyrights and in information sharing. Also, blockchain can offer decentralized resources management. Based on the permanent storage of resources and the function of quick extracting,

blockchain can effectively address the issues - existing in the process of sharing museum's resources —of storage securing, confidence lack, intellectual property protecting and others.

In this mobile Internet era, museums can utilize user's mobile terminal equipment to collect his diverse context-information, and further, utilize such information to broaden the scope of contextualized-services.

Wearable technology can make a virtual scene to build scenes that is more convincing and perceptible to user. With this technology, user users can perceive a variety of screen scenes, but he does not have to attend the site in person. Thus, when a museum offers its a full range of contextualized-services on the one hand, it can also collect more context-data from user, detect user's demand and increase the service-stickiness on targeted user on the other hand.

Middleware is a kind of independent software system or service program. It has a standardized program interface and agreement and is able to ensure that digital museum's application software runs on various hardware and OS-platforms. Supported by middleware, the service software of museums becomes stabler and more applicative. Even if the underlying hardware and system have changed; as long as no change occurring in standardized interface which is defined by middleware, then the applicative software does not need to be altered.

5.4 Module of Scene-Service

Museum's modules of scene-services cover a spectrum from virtual scene, physical scene, hybrid scene, scene of information search, scene of individualized reading, scene of multi-element cooperating, interactive scene to customized scene and so on.

Virtual scene provides a virtual scene-service via facilities like the hall of virtual scene, smart wearable devices, mobile smart terminal etc. For example, with virtual reality, augmented reality and others, this service is designed to present knowledge and service items, then meet user's demand when he is under a ubiquitous wireless scene-service. Physical scene means, within a museum building, providing a layout of various material objects and creating various scenes, so that enabling users to enjoy their higher-quality experience of scene-service, and even offering a scene-service that is genuine and perceptible. Hybrid scenes harmoniously mixing physical scenes with virtual scene.

Scene of information search can utilize user's scene-information to deliver him an accurate and quick recommendation of information retrieval. Thus, if a challenge of serious information overload happening, user's information retrieval can approach - by methods like text, voice-command, graphics and so on - to the associated knowledge he needs.

Based on a scene of multi-element cooperating, a module can perceive a multi-dimensional context where the user is in. Combining this "perceive" with a retrieval object submitted by user, that should be visitable and browsable, although the user is incapable to describe clearly his retrieval target, yet the system can deduce what the user's retrieval purpose is and his real expectation is; and then not only offering the retrieval items matching user's demand but also visualizing the items with a multi-dimensional scene.

Mobile visual search, for instance, can use the scene-information such as an archaeologist's location and working time, plus the visual features of culture-relic image, to precisely match the informational resources with this relic. Under this service, the archaeologist's working efficiency can be increased.

At the same time, depending on user's scene-feature, a museum may offer individualized reading-scene that is tailored to his demand. Digitalized museum supports simultaneous online interaction of multi-users who are in separated scenes. This interaction is often seen in a scene of multi-parts coordinating for the purposes of learning, exchanging and watching. By utilizing interactive scenes to operate the interactions of person-with-person and person-with-museum, the museum can offer its services like exchanging, consulting, navigation, assessment and feedback.

Depending on the user's subjective or objective needs, a customized scene-service may self-define a scene mode, then using this scene to autonomously establish a scene's content, structure and theme for the targeted user.

6. Conclusion and future work

Context-Awareness Service has the characters of intelligence, proactivity, contextual self-adaptability and others. By following the changes of user's dynamic context, it can offer suitable learning resources and individualized services, and even effectively support a user running his mobile and ubiquitous learning

activities. Consequently, both domestical and international research have achieved some outcomes, and also it is applied in the fields more and more.

In the field of scene-services and/or contextualized-services by digitalized museum, how to utilize - driven by user's dynamics, multi-dimensions of services and the scene-sensitivity - the contextual information to offer suitable services. This issue has been concerned more and more by the industrial community, while the application - of context-awareness services in a digitalized scene - has made progress to a certain degree.

However, in the sector of museums, there are still some lacks current theoretical discussion and practical application. Things like mechanization and operation of context-awareness services, construction and administration of context-awareness services based on the scenes in digitalized museum, all of this systematical research should be strengthened furthermore.

Thus, we should completely and deeply study the theory of context-aware information services that is scene-based and applied in a digitalized museum. Also, we should construct an organized model and system of services, should develop a more appropriate platform of service, and should make digitalized scene-services become more real-time, more individualized and more dynamic, in order to effectively improve the quality of customer service.

Additionally, it is a complex systematic engineering to effectively implement context-aware services. Apart from constructing an appropriate service system, service platform and guarantee mechanism, there are a number of issues that are worth discussing furthermore.

6.1 User's Experience and User's Behavior of Services Accepting

User's mobility is not only the core challenge to context-awareness service, but also makes user inevitably be in a complex situation. Therefore, how to intensify user's vivid experience when he is receiving information services via mobile devices, and how to increase user's recognition of context-awareness service, such issues should be paid attention in further study.

Context-awareness service is a new model of services offering. The key to this model's success is the user's behavior of accepting the model and ongoing using it. Users' recognition of context-awareness services and acceptance will directly influence the development of operating services, and also will be a major criterion and/or standard of success or failure to assess the construction of context-awareness services.

Of context-awareness services by digitalized museum, the model is not immutable. Depending on the museum's real situation and based on improving physical scene, the museum should focus on strengthening the construction of virtual scenes, and then ensure the combination of fabrication and reality as well as achieves multifunctional services. Contextualized services should be able to offer users its services that must be of complete coverage, multilayered inter-connection and be touchable and perceptible. Thereby the museum plays its roles of disseminating our culture, view of value, concepts of innovation and our thinking methods, also presents the value of digitalized museum existing.

6.2 Semantic Gap between the Collection and Acquisition of User's Cognitive Psychological Data

Digitalized museum's contextualized-services need - based on user's scene-information - knowing his context-preference and demand of scene-services. However, user's scene-information is not after all a complete exploration of user's true intention. That means, user's scene-information is only an indirect appearance of his in-mind demands, but not spell out his true expectation in complete.

There is a plenty of context-semanteme in the scene where the user is. Exploring the scene that can release the point a user's attention paying to, is the crucial factor to command the description of a relevant scene. With human-operated computer systems, we can systematically dig out the gap between the context-semanteme in the scene where the user is and his expression of demand. This gap can be named of "contextual semanteme-gap". Things expressing different contexts are given different semantemes. Unless digging out context-semanteme, impossible is it to truly understand the user's contextualized demands, and impossible to align the contraction of scene with user's demands and expectation.

In order to more rightly establish a fine connection between the fundamental semanteme of a context itself and the surface semanteme that a user wants to spell out, it is necessary to create a set of semanteme-labels covering different fundamental context-substance or explore the connection between the semantemes of fundamental context and that of surface demand. In the practice, it is necessary for us to continuously optimize and improve the all of these and narrow the "contextual semanteme-gap" as much as possible. By doing these, the context-semantemes may approach a true expression of user's demands and his internal expectation.

6.3 Protection to User's Personal Information

As digitalized museums need collecting user's context-data overall, it is inevitable to involve the issue of user's informational privacy. At a very opened and shared environment in digitalized museum, the protection of user's personal information must be paid a heavy attention. That is to say, a digitalized museum should implement its protection to user-data in the aspects of collection, transmission, storage, application and so on.

Protection in data-collection: first, before collecting context-data from users, the museum should explain what data will be collected and for what purpose these data will be used and must be given consent from user. Second, collected data should be necessary and without irrelevant data and should not violate user's privacy.

Protection in data-transmission: during the course of data transferring, encryption technology can be applied to the security of user information transmission, and meanwhile using internal network or local area network, as far as possible, to transmit such data.

Protection in data-storage: it is necessary to implement data-desensitization, setting firewall and permission-control against visitor's accessing, and meanwhile avoiding centralized data storage but adopting dispersed storage.

Protection in data-application: when analyzing and using user's context-data, it is necessary to enforce security management in order to secure the proper use of these data, prevent the data from the leakage caused by museum's staff.

In summary, protection the security of user's personal information and/or his information privacy is bound to become the key factor of fostering up the museum's credit and public image. Also is it a good attitude of holding commitment to users.

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