# Context-Based Service Identification in the Museum Environment

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**Abstract.** The substantial growth in technology with multi-featured devices, wireless networks and interacting computing infrastructure has increased the demand of ubiquitous services. A ubiquitous service, unlike other service is decided by the system without user requests or interventions. The system uses different contexts such as user context, device context, network context, and many others to decide accurate services for the user. In this work, we design a technique to identify the required services for the visitors in the museum environment by considering the context of the visitors and their surrounding environment. The technique acquires the required context information and formulates *Composite Context (CC)* which leads to *Essential Context-derived Reasons (ECR)*. We use these *ECR* to identify the visitor's required service. The designed technique has been tested in the museum environment with variety of exhibits and services. The experimental results demonstrate the effectiveness of the technique.

**Keywords:** Context information · Essential Context-derived Reasons · Service identification · Ubiquitous museum-guide services

## 1 Introduction

The technological advancements in the multi-featured handheld devices, wearables, sensors, storage systems, wireless networks, and interacting computing infrastructure have brought Weiser's concept of ubiquitous computing into reality [1]. The notion of ubiquitous computing is to offer ubiquitous services to the users without their requests or interventions. To facilitate such ubiquitous services, context awareness i.e., understanding the situation of the users and their surrounding environment has been recognized as one of the prerequisite requirement [2,3]. The context of the user such as location, time, type of devices, networks and professional qualifications enable the system to anticipate the user's requirements for providing ubiquitous services [4]. Since last two decades, the needs and benefits of ubiquitous services have been explored in various applications such as museum and tourist guides, health care, learning, and several others.


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In the museum environment with large area containing variety of exhibits and several other facilities, it is time consuming and exhausting for the visitors to find suitable services as per their requirements. Also, visitors in the museum have different professional backgrounds and hence they have different perspective towards exhibits. The ubiquitous service is considered to be useful in the museum environment to solve many such purposes. For instance, by means of ubiquitous service the system triggers intuitive services to the visitors based on their change of context, provides exhibit information to the visitors according to their perceptions, provides transparent adaptive services without any location and time constraints, and executes many such tasks. However, from the large number of existing services in the museum environment, the identification of the most relevant service is a challenging task. Thus, according to the visitor's context and his/her service requirements which have been previously analyzed by the system, the system identifies the request without visitor's intervention [5]. The use of context provides a promising way to assist/guide the visitors with relevant ubiquitous services and to enhance the museum visiting experience.

In this work, we propose a technique to identify the required Ubiquitous Museum-guide Services (UMS) by considering the *Context Information (CI)* of the visitors, their surrounding system and physical environment. We acquire the required *CI* and combined them to formulate *Composite Context (CC)* which further leads to *Essential Context-derived Reasons (ECR)*. These *ECR* are used to identify the required service for the visitor. Also, based on the variation in *ECR*, the proposed system decides the suitable service configuration. We demonstrate the application of the proposed technique through different case studies in the museum environment.

The rest of the paper is organized as follows. Section 2 describes some of the related works. The overview of the museum environment is illustrated in Sect. 3. The procedure of context information acquisition and analysis is presented in Sect. 4. The system architecture is discussed in Sect. 5 by describing each module functionality. The application of the proposed technique is described in Sect. 6. We discuss the implementation of the system with experimental results in Sect. 7, followed by the conclusion and future works in Sect. 8.

## 2 Related Work

In the literature, several works have utilized the context information to provide services in the museum environment with different purposes [6–9]. For context-aware mobile applications in the museum, authors in [6] have described the theoretical framework considering different dimensions of the context and discussed the importance of context affecting the visitors and the museum interaction. The context aware museum system iMuseum [7] has proposed to provide customized relic information. They have utilized a 2 sets 3 layers context model based on the ontology and hierarchical model and discussed applications to provide nearby and visitor's interested relic information.

In [10], a context aware framework using mobile agents has been described. They have used location sensing systems to guide the groups of visitors and to

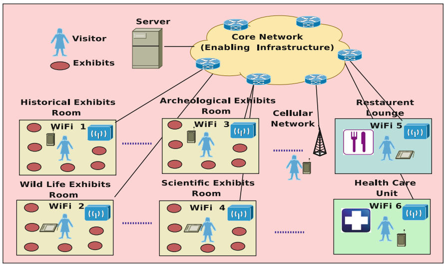


**Fig. 1.** An overview of the museum environment

**Table 1.** Some examples of services in the museum environment

| *Examples of Available Services* |
|---|
| 1. Location of Registration Service; |
| 2. Exhibit Information Service; |
| 3. Path of Next Exhibit of Interests Service; |
| 4. Restaurant Service; |
| 5. Rest Room Facility Service; |
| 6. Transportation Service; |
| 7. Emergency Exit Service; |
| 8. Infant/Child Care Facility Service; |
| 9. Path to Kids Play Area Service; |
| 10. Antique Items Shopping Service; |

provide services on the computers screens that are close to visitors locations. Ubi-Cicero [11], a location aware support with multi-device museum guide services has proposed to provide context dependent museum information and associated games on multiple devices such as mobiles and large screens at nearby locations of the visitors. Authors in [12] has proposed the Context-Information Observation Belief (C-IOB) model with an application of the museum environment in which service requests have been generated based on the acquired context by formulating a set of beliefs combined with the personalization parameters of the visitors. However, unlike other approaches our technique focuses on the identification of the required ubiquitous service in the museum environment without visitor's requests. The proposed system has utilized the record of the set of services in different context availed by the visitors over the past few years. The system correlates and match the context of these services with the formulated context of various combinations of the acquired context to dynamically identify the required services with more accuracy.

## 3 Museum Environment

An overview of the museum environment is depicted in Fig. 1. The museum environment is enriched with many embedded, sensing and intelligent computing devices to acquire the dynamic context of the visitors. The proposed system functions in the museum environment to offer a wide variety of UMS to the visitors, i.e. information regarding the available exhibits, restaurants/food courts, emergency exits, and several others. Some of the examples of available services are given in the Table 1. With the change in service requirements due to the variation of context such as location, time, activity, network, devices, etc., automatically the relevant UMS is triggered to the visitors.

## 4 Context Information Analysis

In this section, we first explain different categories of context information related to the visitor in the museum environment and the procedure to acquire them.

Next, we analyze the context information with various combinations to formulate *CC* and *ECR*.

### 4.1 Context Information *(CI)*

*CI* is the primitive set of information related to the visitor while using UMS. Different *CI* are acquired by considering the visitor and his/her surrounding environment by using a variety of sources such as embedded, sensing and intelligent computing devices, databases [13]. The *CI* of the visitor is classified and considered to be the set of three categories of information which is given as $CI = \{PECI, VCI, SCI\}$. Each one of these categories of *CI* are described as follows:

***Physical Environment Context Information (PECI):*** It specifies the information related to the local surroundings of the visitor. For example, visitor location: geographic location co-ordinates, near or far from the exhibit, specific region; Time: time at which visitor use the service, time duration for which the service is used, etc.

***Visitor's Context Information (VCI):*** It refers to the information specific to the visitors and their present state of operation. For instance, it includes visitor's educational qualifications: professional, college student, preliminary school student; Visitor activity: standing, walking, sitting, etc.

***System Context Information (SCI):*** It provides the information regarding both the device on which the ubiquitous service is running and the network being used by the visitor. For example, it includes the device context such as Type of device: laptop, smart phone, and others; Device battery strength: low, moderate, or high, and network context such as type of network: 2G/3G, WiFi, etc.; network delay: low, moderate, or high.

### 4.2 CI Acquisition

The *CI* of the visitors are acquired from the various sources by adopting the procedure of *CI-Constructs* followed in [14]. The *CI-Constructs* represent the multiway data structure with each construct used to acquire related pre-defined *CI*. Different *CI-Constructs* are utilized to collect the complete set of *CI* in a well-defined manner. Some examples of the *CI-Constructs* are:

- *What*: To collect the information related to an object/entity, e.g., visitors activity, visitors schedule, etc.;
- *When*: To get the information regarding time, instant, duration, day of occurrence of an event/occasion;
- *Where*: To obtain the information about location and place of the visitors;
- *Who*: To acquire the information specific to a person or group;
- *Which*: To collect the information about the devices, networks, etc.;

However, these acquired individual primitive *CI* do not convey the significant information about the visitor's situation [15]. Consequently, *CI* are further combined together in different possible combinations which provide more realistic aspects about the situation of the visitor. We analyzed different *CI* combinations which are formulated as *CC* and further leads to the *ECR*. For the analysis we dynamically designed the definite structures of different combinations depending on the application specific services. The further analysis of *CI* is discussed in the following sections.

### 4.3 Composite Context (CC)

The individual *CI* in different combinations will lead to define high level *CC* which are more realistically useful for identifying the required services. The *CI* are combined together in the combinations of two's, three's, four's and so on, which result into comprehensive number of *CC*. On matching with the definite structures of combinations of *CI* the appropriate valid *CC* can be obtained. Consider the case, if for the visitor the museum environment the system has acquired 8 context parameters from the different categories of *CI* such as:

*PECI* = {*Visitor/Device Location, Time of Service, Time Duration*};

*VCI* = {*Visitor Activity, Educational Qualifications*};

*SCI* = {*Type of Device, Battery Strength, Access Network Delay*};

For instance, two's combinations of *CI* using these 8 context parameters results into total of 28 ($^8C_2$) combinations of *CC*. However, based on the definite structures of *CI* combinations the system formulates 25 valid *CC*. Likewise, three's, four's and other possible *CI* combinations results into total 247 *CC*, among which 60 valid *CC* are formulated. The examples of *CC* formation from the two's and three's *CI* combinations are depicted in the Fig. 2. The procedure of *CC* formulation is given in Algorithm 1.

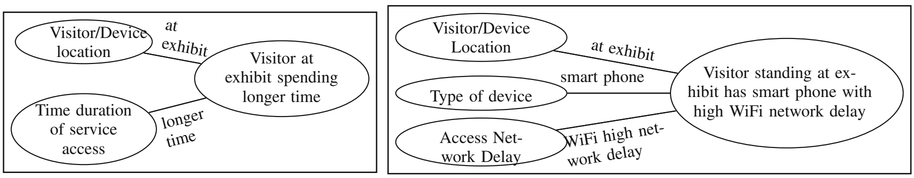


**Fig. 2.** Examples of *CC* formation

### 4.4 Essential Context-Derived Reasons (ECR)

The *ECR* are deduced over the different combinations of the *CC*. The formulated *ECR* realizes the visitor's service requirement and enables the system to accurately identify the required service. For instance, suppose that at particular

**Algorithm 1.** Algorithm for *CC* formulation

**Input:** *CI parameters*; **Output:** A set of 'm' formulated *CC*;
**while** *Change in CI observed* **do**
  Acquire *CI*={*PECI, VCI, SCI*} using associated *CI-Constructs* respectively;
  Get total 'n' number of *CI*;
  Initialize y=1 (* y = number of valid cc *);
  **for** $x = 2$ *to* $n$ **do**
    Generate *'k'* combinations of *CI* such that $k = \frac{n*(n-1)*\cdots*(n-r-1)}{1*2*\cdots*r}$ with $r$=$x$;
    **for** $i = 1$ *to* $k$ **do**
      **for** $j = i$ *to* $k$ **do**
        **if** *Matched with CI Combinations in the Context Structures Storage* **then**
          Formulate valid $cc_y$ = *CI(i,j+1)* $\cup \cdots \cup$ *CI(i,j=k)* with 'r' combinations of the *CI*;
          y=y+1;
  Obtain a set of valid *CC*;

instant the system obtains 60 *CC* (mentioned in the previous section). These *CC* are further combined in two's, three's, four's, and all possible combinations which results into enormous number of *ECR*. However, on matching with the definite structures of combinations of *CC* the system obtains 400 valid *ECR*. These exhaustive set of formulated *ECR* provides more realistic information about the visitor's service requirement. The examples of *ECR* formulation with two's and three's combinations of *CC* are depicted in Fig. 3. The procedure of *ECR* formulation is given in Algorithm 2.

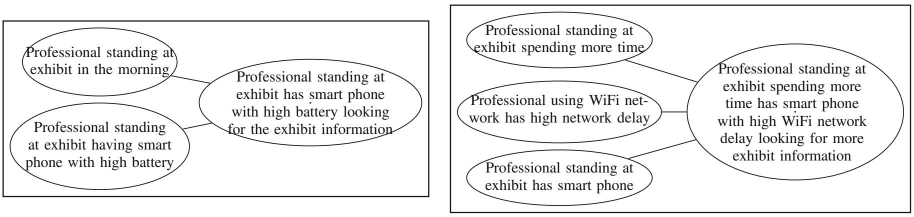


**Fig. 3.** Examples of *ECR* formation

## 5 UMS Identification System

The *UMS Identification System* identifies the required services for visitors in the museum environment without their requests. Figure 4 illustrates the architecture of the *UMS Identification System*. It consists of three modules: (1) *Context Analyzer Module* (2) *Service Identification Module* and (3) *UMS Identification Main Module*. The functionality of each module is discussed as follows.

**Algorithm 2.** Algorithm for *ECR* formulation

**Input:** 'm' number of *CC*; **Output:** A set of 'n' valid *ECR*;
**while** *Change in CC observed* **do**
  Obtain 'm' number of *CC*;
  Initialize y=1 (* y = number of valid ecr *);
  **for** $x = 2$ *to* $m$ **do**
    Generate *'k'* combinations of *CC* such that $k = \frac{m*(m-1)*\cdots*(m-r-1)}{1*2*\cdots*r}$ with $r{=}x$;
    **for** $i = 1$ *to* $k$ **do**
      **for** $j = i$ *to* $k$ **do**
        **if** *Matched with CC Combinations in the Context Structures Storage* **then**
          Deduce valid $ecr_y = CC(i,j{+}1) \cup \cdots \cup CC(i,j{=}k)$ with 'r' combinations of the *CC*;
          y=y+1;
  Obtain a set of valid formulated *ECR*;

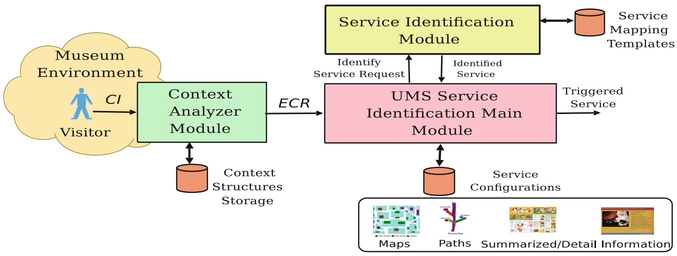


**Fig. 4.** Ubiquitous museum-guide service identification system architecture

***Context Analyzer Module***
It is responsible for formulating the *ECR* from the acquired *CI*. As and when the acquired *CI* instances are concurred with the available structures of combinations in the *Context Structures Storage*, accordingly it formulates an exhaustive set of *ECR*. Further, it sends the formulated *ECR* to the *UMS Identification Main Module*.

***Context Structures Storage***
A persistent storage in the form of the *Context Structures* is used to store dynamically designed definite structures of *CI* combinations based on the application specific services. These predefined structures of different combinations of *CI* enable the system to yield more realistic *CC* and further *ECR* respectively.

***Service Mapping Templates***
A dynamic storage of service mapping templates is maintained by the system. The system designs and stores the templates based on the set of services in different contexts availed by the visitors over the past few years. The implicit information contained in the templates are potentially found useful to identify the service. Formally, templates define two tuple hypothetical information $\langle ECR,\ s_j \rangle$ as given in the Table 2, that maps a set of *ECR* to a specific category of the service. A particular template can be chosen using the set of formulated *ECR* to obtain the related service.

**Table 2.** Examples of service mapping templates

| *ECR* | *Exhibit information service in different categories ($s_j$)* |
|---|---|
| {*Professional scientist standing at the exhibit spending longer time,*<br>*Professional looking towards exhibit waiting for the information,*<br>*Professional standing at exhibit with smart phone waiting for the information,*<br>$\cdots$, *Professional looking at exhibit has smart phone with high battery,*<br>*Professional standing at the exhibit has smart phone with high WiFi network delay*} | $s_1$: At higher level for professionals with summarized information; |
| {*College student standing at the exhibit spending longer time,*<br>*College student looking at exhibit has smart phone with high battery,*<br>*Student looking towards exhibit waiting for the information,*<br>$\cdots$, *Student standing at exhibit with smart phone,*<br>*College student standing at the exhibit has smart phone with high battery and low WiFi network delay*} | $s_2$: At average level for college student with detail information; |
| {*Preliminary school kid standing at the exhibit spending longer time,*<br>*Preliminary school kid looking towards exhibit waiting for information,*<br>$\cdots$, *Kid standing at the exhibit with smart phone waiting for the information,*<br>*Preliminary school kid looking at the exhibit has smart phone with high battery,*<br>*Kid standing at the exhibit has smart phone with high battery and high WiFi network delay*} | $s_3$: At lower level for elementary school kids with summarized information; |

***Service Identification Module***

It identifies the visitor's required service according to the formulated *ECR*. The *Service Identification Module* correlates the formulated set of *ECR* with the information available in the *Service Mapping Templates*. Depending on the matched template it obtains the mapping of $ECR \longmapsto s_j$, i.e., a set of formulated *ECR* associated against the available service. Further, it sends the identified service to the *UMS Identification Main Module*. The working of the *Service Identification Module* is explained in Algorithm 3.

**Algorithm 3.** *Working of Service Identification Module*

**Input:** A set of formulated *ECR*; A set of different categories of services $S = \{s_1, s_2, \cdots, s_k\}$;
**Output:** Identified Service $s_j \in S$;
**while** *Visitor is interacting with the system* **do**
  Get a set of formulated *ECR* from the *UMS Identification Main Module*;
  Correlate the formulated *ECR* and match $\langle ECR,\ s_j\rangle$ in the *Service Mapping Templates*;
  Map the $ECR \longmapsto s_j$ in the template and select the relevant $s_j$;
  Send the identified $s_j$ to the *UMS Identification Main Module*;

***UMS Identification Main Module***

It acts as an intermediary module of the system. Based on the dynamic variations in the *CI*, it obtains a set of *ECR* from the *Context Analyzer Module*. It forwards *ECR* to the *Service Identification Module* and gets the identified service. Finally, according to the requirements, it fetches the *URL* of the relevant configuration of the identified service from the *Service Configurations Database* and triggers the required service. Algorithm 4 explains the working of the *UMS Identification Main Module*.

***Service Configurations***

The *Service Configurations Database* consists of the *URLs* of the transcoding proxy servers providing different configuration of the services. Several proxy servers are

**Algorithm 4.** Working of the *UMS Identification Main Module*

**Input:** A set of formulated *ECR*; Identified Service $s_j$; **Output:** Triggered $s_j$;
**while** *Visitor is interacting with the system* **do**
  **if** *Change in the CI is Observed* **then**
    Obtain a set of *ECR* from the *Context Analyzer Module*;
    Forward the formulated *ECR* to the *Service Identification Module*;
    Get the identified service $s_j$ from the *Service Identification Module*;
    Select the relevant configuration of the $s_j$ with service lookup in the *Service Configurations Database*;
    Trigger the relevant configuration of $s_j$ to the visitor;

distributed in the museum environment to provide the variety of service configurations such as filtered information at summarized and detailed levels, different adaptable formats, different modalities, and many other forms [16]. Also, periodically the *Service Configurations Database* is updated subject to service availability. Table 3 indicates some of the configurations of available services in the museum environment.

## 6 Application of Proposed Technique in the Museum Environment

We demonstrate the application of the proposed technique with different case studies in the museum environment. As and when their will be change of *CI* accordingly *ECR* are formulated. The following cases demonstrate the decision of the system to identify the visitor's required services depending on a set of formulated *ECR*.

***Case 1: Exhibit information service.*** When a professional scientist is standing at the exhibit, he is spending longer time waiting for the exhibit information, and has a smart phone with high battery and high network delay. The system maps these formulated set of *ECR* to the exhibit information service at a professional level. Due to high network delay, according to the requirement the system provides the relevant service configuration containing the summarized exhibit information with the necessary details based on the knowledge level of scientist.

***Case 2: Path to next exhibit of interests service.*** When the visitor standing at the exhibit and has spent adequate time, also visitor is looking at other exhibits with the constraint of limited available time, and has a smart phone with moderate battery and low WiFi network delay. Using these set of *ECR* the system identifies service as the path to next exhibit of interests. With limited available time and low network delay, the system provides the detailed information containing map and optimal paths to the exhibits of visitor's interests.

***Case 3: Restaurant information service.*** During the afternoon around 1:00 pm, when the visitor has spent adequate time in the museum, sitting on the bench using a laptop with high battery and low WiFi network delay waiting for

**Table 3.** Examples of configurations of services

| Available Services | Configurations of the Services ($s_j$) | URLs |
|---|---|---|
| Exhibit information service | At higher level I for professionals with summarized/detail information; | exhiinfo_l1@pet.iisc.in |
| | At average level II for students with summarized/detail information; | exhiinfo_l2@pet.iisc.in |
| | At lower level III for preliminary school kids with summarized/detail information; | exhiinfo_l3@pet.iisc.in |
| Path to next exhibit of interests service | Paths to different exhibits with summarized/detail information; | exhipath_l1@pet.iisc.in |
| | Optimal path to visitor interested exhibits with summarized/detail information; | exhipath_l2@pet.iisc.in |
| | Shortest path for visitor in hurry with summarized/detail information; | exhipath_l3@pet.iisc.in |
| Restaurant service | Breakfast menu with summarized/detail information of path and seat availability status; | restser_l1@pet.iisc.in |
| | Lunch menu with summarized/detail information of path to reach and seat availability status; | restser_l2@pet.iisc.in |
| | Snacks menu with summarized/detail information of path to reach and seat availability status; | restser_l3@pet.iisc.in |
| Emergency exit service | Optimal route to emergency exits, location of fire extinguishers, etc. with summarized/detail information; | emerexi_l1@pet.iisc.in |
| | Shortest route to emergency exits, emergency contact numbers, ambulance facility for critical conditions with summarized/detail information; | emerexi_l2@pet.iisc.in |
| Transportation facility service | Information regarding different types of transports with summarized/detail information of routes; | transinfo_l1@pet.iisc.in |
| | Transportation routes according to the budget with summarized/detail information; | transinfo_l2@pet.iisc.in |

the information. The system maps these set of *ECR* and identifies the restaurant service. Based on the visitor's requirements determined from the *ECR*, the system provides the relevant configuration of the restaurant service containing summarized information of lunch menu along with the path to reach the restaurant.

Figure 5 depicts the various sequences of events taken place in the museum environment and accordingly the visitor's required services triggered by the system.

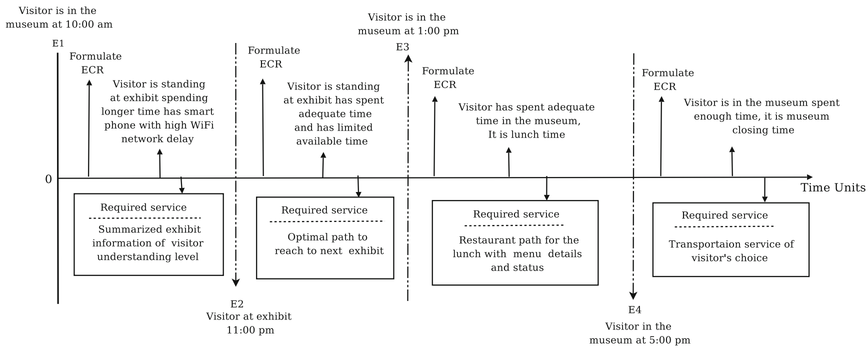


**Fig. 5.** Event sequence diagram of different cases

## 7 System Implementation

To explain the functioning of the system, the museum environment is considered with three to four WiFi units and one 2G/3G network unit. Different visitors are considered according to their educational qualifications. On registration for each visitors unique-Id has been assigned. We have considered ten different services depending on the generally used services in the museum environment. A context structure storage has been fed with the definite structures of different combinations of *CI* to formulate the *ECR* depending on the application specific services. Based on the set of services in different contexts availed by the visitors over the past few years, the service mapping templates are created and maintained by the system. Additionally, we have taken the services in different configurations to offer the visitor's required service.

### 7.1 Results and Discussion

We have conducted series of experiments in the museum environment for different visitors with their variety of acquired *CI*. We have periodically collected *CI* of the visitors consisting of eight different context parameters based on which

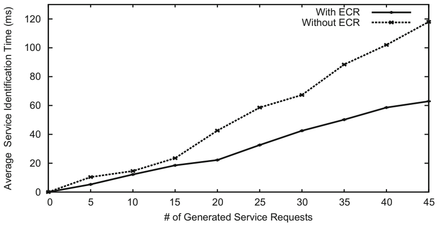


**Fig. 6.** Average service identification time vs. number of generated service requests

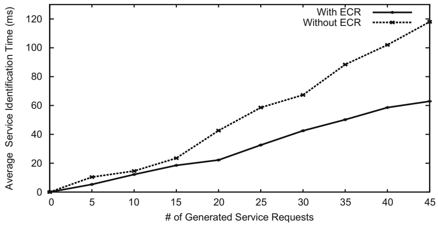


**Fig. 7.** Precision of the identified service with and without considering ECR

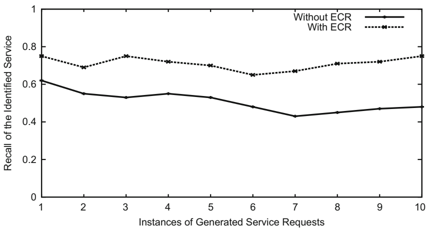


**Fig. 8.** Recall of the identified service with and without considering ECR

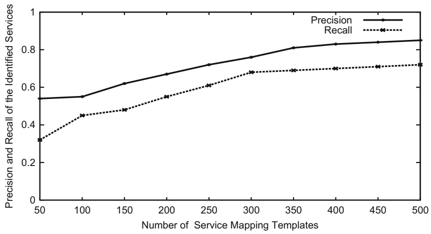


**Fig. 9.** Precision and recall of the identified service with available templates

*ECR* are formulated. We have measured the system performance by considering the service identification time, precision and recall of the identified services. During the experiments we found that using an exhaustive set of formulated *ECR*, the system is able to correlate and match quickly with the information in the service mapping templates. Accordingly, using formulated *ECR* the average time required to identify the service is reduced as shown in the Fig. 6 when compared to without *ECR*, i.e. without analyzing different combinations of *CC*.

Further, the system performance is measured by considering the precision and recall of the identified services based on the *ECR*. Precision determines fraction of the identified relevant services among total services retrieved by the system. Recall denotes fraction of the identified services which are expected to be relevant visitor's required services. Precision and Recall are given by Eqs. 1 and 2.

$$Precision = \frac{\mid \{Identified\ Services \bigcap Retrieved\ Services\} \mid}{\mid \{Retrieved\ Services\} \mid}; \tag{1}$$

$$Recall = \frac{\mid \{Identified\ Services \bigcap Retrieved\ Services\} \mid}{\mid \{Identified\ Services\} \mid}; \tag{2}$$

As indicated in the Fig. 7 for several instance of generated service requests using an exhaustive set of *ECR*, the system identified more relevent set of services among the existing services. This indicates that, *ECR* enables the system to accurately decide the required services and hence improves the precision. Also, as shown in the Fig. 8, the recall of services are improved using the *ECR* with identified the most relevent services.

Also, we have measured the precision and recall of the identified service depending on the number of service mapping templates. As shown in the Fig. 9 with more number of available service mapping templates based on the *ECR* the system retrieves more relevant services and improves the precision and recall of the identified service.

## 8 Conclusion and Future Works

This paper has presented a novel technique to identify the ubiquitous museum-guide services for the visitors in the museum environment without their requests. The proposed system has identified the required services based on the acquired context by formulating an exhaustive set of *ECR*. The formulated *ECR* were correlated and matched on to the service mapping templates which were potentially found useful to identify the ubiquitous services. The experimental results have shown that by considering the an exhaustive set of formulated *ECR* the precision and recall of the identified service has improved. In addition to the museum environment, the proposed technique can also be applied in several applications such as tourist guides, smart homes, ubiquitous commerce and like others. In future works, we are intended to consider the certainty of the required service according to dynamic variation in the context information. Also, we incorporate the visitor's personal interests to identify the required service as per individual requirements. Additionally, we emphasize on the design of content adaptation mechanism to provide the optimal services to the visitors.

## References

1. Weiser, M.: The computer of the 21st century. In: ACM SIGMOBILE Mobile Computing and Communications, pp. 3–11, July 1999
2. Dey, A.K.: Dey.: understanding and using context. Pers. Ubiquit. Comput. **5**(1), 4–7 (2001)
3. Geihs, K., Wagner, M.: Context-awareness for self-adaptive applications in ubiquitous computing environments. In: Vinh, P.C., Hung, N.M., Tung, N.T., Suzuki, J. (eds.) ICCASA 2012. LNICST, vol. 109, pp. 108–120. Springer, Heidelberg (2013)
4. Zhou, L., Naixue, X., Shu, L., Vasilakos, A., Yeo, S.S.: Context-aware middleware for multimedia services in heterogeneous networks. IEEE Intell. Syst. **25**(2), 40–47 (2010)
5. Chen, N., Chen, A.: Integrating context-aware computing in decision support system. In: Proceedings of the International MultiConference of Engineers and Computer Scientists (IMECS), vol. I, March 2010
6. Raptis, D., Tselios, N., Avouris, N.: Context-based design of mobile applications for museums: a survey of existing practices. In: Proceedings of the 7th International Conference on MobileHCI, pp. 153–160. ACM (2005)
7. Yu, Z., Zhou, X., Yu, Z., Park, J.H., Ma, J.: iMuseum: a scalable context-aware intelligent museum system. Comput. Commun. **31**(18), 4376–4382 (2008)
8. Abowd, G.D., Atkeson, C.G., Hong, J., Long, S., Kooper, R., Pinkerton, M.: Cyberguide: A mobile contextaware tour guide. Wireless Netw. **3**(5), 421–433 (1997)

9. Oppermann, R., Specht, M., Jaceniak, I.: Hippie: a nomadic information system. In: Gellersen, H.-W. (ed.) HUC 1999. LNCS, vol. 1707, pp. 330–333. Springer, Heidelberg (1999)
10. Satoh, I.: Context-aware deployment of services in public spaces. In: Brinkschulte, U., Givargis, T., Russo, S. (eds.) SEUS 2008. LNCS, vol. 5287, pp. 221–232. Springer, Heidelberg (2008)
11. Ghiani, G., Patern, F., Santoro, C., Spano, L.D.: UbiCicero: a location-aware, multi-device museum guide. Interact. Comput. **21**(4), 288–303 (2009)
12. Venkataram, P., Bharath, M.: Context based service discovery for ubiquitous applications. In: International Conference on Information Networking (ICOIN), pp. 311–316, January 2011
13. Baldauf, M., Dustdar, S., Rosenberg, F.: A survey on context-aware systems. Int. J. Ad Hoc Ubiquitous Comput. **2**(4), 263–277 (2007)
14. Venkataram, P., Bharath, M.: A method of context-based services discovery in ubiquitous environment. In: Vinh, P.C., Alagar, V., Vassev, E., Khare, A. (eds.) ICCASA 2013. LNICST, vol. 128, pp. 260–270. Springer, Heidelberg (2014)
15. Buchholz, T., Krause, M., Linnhoff-Popien, C., Schiffers, M.: CoCo: dynamic composition of context information. In: The First Annual International Conference on Mobile and Ubiquitous Systems: Networking and Services, MOBIQUITOUS, pp. 335–343, August 2004
16. Berhe, G., Brunie, L., Pierson, J.M.: Modeling service-based multimedia content adaptation in pervasive computing. In: Proceedings of the 1st Conference on Computing Frontiers, pp. 60–69 (2004)