A Method of Context-Based Services Discovery in Ubiquitous Environment

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Abstract. Ubiquitous services discovery without users requests (or guidance) is an important issue in ubiquitous environment. The ubiquitous systems mainly gathers the user and services context along with specific interests of users in selection right time the right services required by the user. Many of the existing service discovery schemes use a service matching process in order to offer services of interest to the users. In this work we propose a scheme to acquire the context information using CI-Constructs (Context Information Constructs) and analyze this information into observations from which beliefs are formed. The formed believes along with the users interest the system identify the user required service and guide the user to fetch the service. We propose a C-IOB (Context- Information, Observation and Belief) based service discovery model. With this formulated beliefs the required services will be provided to the users. The method has been tested with a typical ubiquitous museum guide application over different cases. The simulation results are time efficient and quite encouraging.

Keywords: Ubiquitous computing · Ubiquitous application · CI-constructs · Service discovery · Context aware

1 Introduction

Ubiquitous computing applications are heterogeneous both in terms of networking infrastructures and interaction protocols [1]. Because the users' needs change dynamically according to the user context such as position or time, an idea to compose appropriate service elements in the network dynamically based on the user context is a promising approach [2,4], as an alternative approach to the conventional way of providing services, where service providers prepare services perfectly in advance.

1.1 Context Based Services Discovery

Ubiquitous Services discovery [11] provides a mechanism which allows automatic detection of services offered by a node in ubiquitous environment. In other words,

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service discovery is an action of time in finding a service provider for a requested service.

Context-based [6] services that exploit information about user and environment context are becoming one of the core components in ubiquitous computing environments. The environment context information includes physical environment, system context that is being used by user, application context that is used for accessing information and social context of user which includes his/her personal data.

1.2 Some of the Existing Works

A Framework had been suggested in [7] which presents a service discovery for ubiquitous computing environment by using SLP, because the method for DA [12] discovery is based on DHCP [13] and multicast, which is more flexible and scalable architecture than Jini and SLP to extend the scope of service discovery from local to remote. Ubiquitous Service Discovery Framework for Pervasive Computing Environment [8] provides an attractive vision for accessing services anywhere, anytime. Service discovery essentially refers to the discovery of service description. It mainly comprises three components: DS [8], WSS [8] and SAP. In Service Advertisement and Discovery in Mobile Ad hoc Networks [12] the authors presented a Service Advertisement and Discovery (SAD) in Mobile Ad hoc Networks. Service advertisement and discovery is an important component for ad hoc communications and collaboration in ubiquitous computing environments.

2 The C-IOB Model

We have designed a Context-Information, Observation and Belief (C-IOB) model [14] to capture context information and perform the analysis of users in a ubiquitous environment. We discuss the model by describing each of the components of the model.

2.1 Context Information

Context describes own view of a thing or a person. For example user context gives user physical environment, what he/she has, etc. We classify the Context Information into four categories for smooth gathering. The context information is gathered from physical, system, application and social environments. The context information can be divided into four categories:

- **Physical Environment Context:** which includes the context information parameters like location, time, temperature, noise level, pressure, position, orientation, etc.
- **System Context:** gives information on device being used, operating system present in the device, supported network interfaces, output modes of the device, screen characteristics of the device, etc.

- **Application Context:** It includes the type of application, different data types in application, status of the application, resources required by the application, etc.
- **Social Context:** whose parameters include social behavior of user, preferences of the user, social identity, social trust on the user, etc.

2.1.1 Context Information Acquisition Procedure

We introduce a new procedure for acquisition of Context Information (CI) by using CI-constructs. For each type of context information we have designed a separate CI-constructs to collect the complete Context Information.

CI-Constructs

The designed CI-constructs (Context Information-constructs) enable many types of context information acquisition. Each construct is a multiway datastructure with predefined context variables. During the process of acquisition the CI-constructs gathers context information either from the devices or sensors or from the authorised persons. We have designed the following CI constructs by choosing:

a. **CI-What**: this construct asks for context information on something
b. **CI-Who**: introduces a clause of giving information on a person or people
c. **CI-When**: specify the information at or on which
d. **CI-Where**: provides information in or to what place or position
e. **CI-How**: collects information in what way or manner

These constructs in different form collects the all four types of context information. We discuss these constructs in details in the subsection on acquisition procedure.

2.2 Context Information Acquisition

We have designed templates of CI-constructs to suit to collect context information either from the devices or sensors or systems. They are PCI, SCI, ACI and SoCI Constructs to physical, system, application and social context information collection respectively.

2.2.1 Physical Environment Context Information Acquisition

We deploy the PCI-constructs (given in Appendix A) for gathering physical environment context information like location, time, temperature, pressure, etc.

Similarly, we use SCI-constructs to collect system context, ACI-constructs to collect application context and SoCI-constructs to collect user's social context information.

2.3 Observation Formulation

An observation is a summarization of various observed CI parameters of a user in a particular ubiquitous environment. The observation formulation block formulates the observations based on the existing CI of the user. The observation formulator has been designed to formulate all the observation possible, i.e., by taking the given context parameter values in 2s combination, 3s combination till $K_{s^{-1}}$ combination as shown in Algorithm 1. For ex., the context information for a user X gathered through CI-where(x) and CI-when(x) gives the observation: $\{X$ *is CI-where at CI-when*$\}$. Some of the generic observations are listed in Appendix B.

Algorithm 1. Observation Formulation in C-IOB

1: Begin
2: **Input** : K number of context values
3: **Output** : The possible observations
4: Get the Visitor Context Information values
5: We find all the possible unique composition of context information to form observation based on following formula
6: $C_K^n = \frac{n*(n-1)*....(n-k-1)}{1,2,.....,K}$
7: for $i = 1, K$ do
8: for $j = 1, i$
9: $U_{j^i} = CI(i,j) \cup CI(i,j+1) \cup ..... \cup CI(i,j=K)$
10: END

2.4 Belief Formulator

The belief formulator is a component of C-IOB which collects various temporal and symptomatic context information parameters from the environment. For a particular time of the context information corresponding observations are generated. An observation derives an activity of object or a fact from the given context information. The beliefs are deduced based on the new and available observations over a context. A belief qualifies an entity. For example (see Fig. 1), a set of observations may lead to the visitor's planning is to steal an exhibit. The beliefs $B = (b_1, b_2, \ldots, b_n)$. Where b_i is the selected belief from the set of beliefs B which contains b_1 to b_n as literals and variables used to represent various observations on which the belief will be reasoned. Algorithm 2 discusses the belief formulation method. Some examples of beliefs are given in Appendix C.

3 Services Discovery in a Ubiquitous Environment

Services discovery in a ubiquitous environment is the process by which an entity is spontaneously notified of the availability of desirable services or devices in the environment. We discuss the service discovery system by considering the museum environment where ubiquitous guide system is deployed to provide services like exhibit

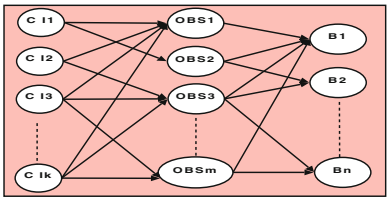


Fig. 1. Formulation of belief from observations and their context information

Algorithm 2. Belief Formulation in C-IOB

1: Begin
2: **Input** : K number of observation values
3: **Output** : The possible beliefs
4: We find all the possible unique composition of observations to form beliefs based on following formula
5: $C_K^n = \frac{n*(n-1)*....(n-k-1)}{1,2,.....,K}$
6: for $i = 1, K$ do
7: for $j = 1, i$
8: $U_{j^i} = O(i,j) \cup O(i,j+1) \cup ..... \cup O(i,j=K)$
9: END

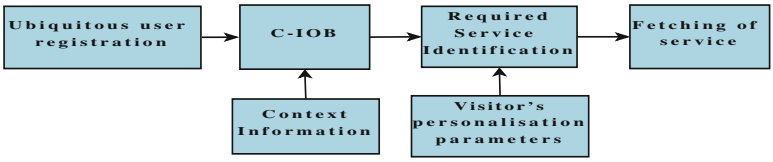


Fig. 2. Service discovery using C-IOB

information, path to exhibit, catering services, etc. The proposed ubiquitous services discovery system is given in Fig. 2. It involves the following components:

3.1 Registration of a Ubiquitous User/Visitor

Registration procedure consists of two main processes. (1) the registration process and the look-up process. Registration is used by services or their operators to provide the required service to the user, and (2). Look-up is used by visitors to find the endpoints of needed services. Different services discovery procedure architectures employ different processes for registration and look-up.

3.2 Identification of Required Service:

Identification of the service mainly depends on the system's lookup status which is offering the service, components of such systems, identifying the suitable

component in the system which provides the required service, type of interface mechanism provided in the service providing entity, types of inputs and outputs of the servicing entity. Also the identification of service depends on the present context of the visitor at which the service has been requested and his/her choice/interest. This identified service must be efficient in all possible ways when compared to other servicing entities in the look-up state. Functioning of the service identification is given in Algorithm 3.

Algorithm 3. Identification of the required service

1: Begin
2: **Input** : Set of beliefs of the visitor and his/her personalised parameters
3: **Output** : Identification of the required service and path to fetch the required service
4: Identify the service based on the visitor's belief B
5: Refine the obtained services by using the visitor's belief.
6: Identify unique highly matched service based on the belief and personalised parameters of the visitor
7: Provide the service URL for fetching the required service
8: Return Service
9: END

Required service identification is done by analyzing the beliefs formed due to the present visitor's context and his/her personalised service requirements. For example, consider a well educated visitor to a museum, the present context information and visitor's personalisation parameters given in Fig. 3 enables in identifying the required service: "provide exhibit's high quality information to the visitor" (Fig. 4).

Context Information	Context Information at Particular instant	Observation	Belief	Personalisation parameters	Service
Location	at (x1, y1)	Visitor is at (x1, y1) at time t1	Visitor is spending more time near exhibit	History – Visitor is visiting museum for first time	Provide high level exhibit information at his/her understanding level
Time	t1				
Position	Turning towards	Visitor turning towards exhibit and moving slowly	Visitor is near Exhibit E1 and he is turning towards it	Interest – He/she is interested in science related exhibits	
Acceleration	Moving slowly				
Exhibit Sensor	ON	Exhibit sensor is ON and Visitor is using PDA	Visitor is using PDA and moving slowly	Personal profile – He/she is a well educated person	
Visitor Device	Laptop/PDA/ Cellphone				
Visitor Preference	Interests	Visitor interest is identified through his profile and visitor is moving in north-east direction	Visitor level is decided using his interest and movement is towards north-east direction	Preference – Understanding level is high so needs more information about exhibits	
Mobility of Visitor	Mobile/Stationary				
Direction	North/South/ East/West				

Fig. 3. Exhibit information service discovery using C-IOB model

Beliefs	Services	URL/Path
Visitor is spending more time Visitor is looking for more information	Provide exhibit information of his/her understanding level	infodb@iob.pet.ece.iisc.ernet.in
Temperature is high in museum Humidity and noise level is increasing	Provide Emergency fire exit path and call the fire extinguisher	emergency@iob.pet.ece.iisc.ernet.in
Visitor is away from exhibit Visitor is looking for service	Provide basic amenity services like path to rest rooms, etc.	basic amenity@iob.pet.ece.iisc.ernet.in
Visitor is on the move Visitor is not near to any exhibit in museum	Provide path to next exhibit according to visitor preference	Pathtoexhibit@iob.pet.ece.iisc.ernet.in
Visitor is away from exhibit Visitor preference says its his/her lunch time	Provide path to nearest restaurant and reserve a seat	pathtorestaurant@iob.pet.ece.iisc.ernet.in

Fig. 4. Service identification based on beliefs

3.3 Fetching the Required Service

Once the service required has been identified, it had to be fetched from the service providing entity. The service fetched will be based on the context, availability of the service in look-up table and current status of the service providing entity.

4 Implementation of Services Discovery System in a Ubiquitous Guide System for a Museum

The working of system is explained with an example of a Ubiquitous guide for museum application. Consider that a visitor enters the museum. The context information module collects the physical environment, system, application and social context information of the visitor's periodically. These collected context information is the input to observation formulation module where it forms different observations based on different context information. Depending on the observations formulated, the belief formulator module formulates belief based on which required services are provided to the visitor in museum.

4.1 Case Study: Services Discovery by Ubiquitous Guide in a Museum

Figure 5 illustrates all the services provided by the ubiquitous guide system in a museum. We discuss a couple of case studies for explanation of system functioning.

Case 1: Path to next exhibit service
Consider that visitor is at exhibit E_x at time t_i mins. Let us assume that according to a visitor profile calendar gives less time to spend in museum and the visitor has to visit many exhibits in the museum as per his/her interest. In such a scenario, the ubiquitous guide system comes into picture. Initially the ubiquitous guide system identifies all the exhibits and their locations in the museum as per visitor's interest. Based on the believes formulated the system is aware that the visitor has less time to visit the museum. Then based on the belief it has to take a decision of how the visitor must move on an optimal path to cover all the exhibits of his/her interest and then the system provides path to the next nearby interested exhibit soon after the visitor finishes watching the current exhibit.

Case 2: Catering and reservation services
Assume that a visitor is in a museum, and time is mid-day and the beliefs formulated suggest that "visitor needs the catering service", so the system provides the catering service. To provide the catering service to the visitor, system must know the visitor preferred dishes, which is determined from the visitor profile. Once his/her preferred dishes are determined, then the system starts searching for the nearby restaurants where these dishes are available. Once the search is complete, the system decides the best restaurant where visitor preferred dishes are available according to the visitor preference and also system reserves a table in the restaurant for the visitor to have lunch. After completing these procedures, the system informs the visitor.

Case 3: Fire emergency exit service
If there is any fire emergency in a museum or in such public places, people are more distracted due to the situation. In such a scenario the system guides the visitors to the emergency exit based on beliefs. The occurrence of fire emergency alarm can be determined by different context information such as room temperature, humidity, noise level in a room. The corresponding observations for this context informations: sudden increase in room temperature, increase in humidity level and noise level is high; leads to the belief that there is some fire disaster. Once this belief has been formulated, then the system decides that the visitor needs emergency fire exit service and it provides the path to emergency exit as well as it informs the fire extinguisher service to control the fire.

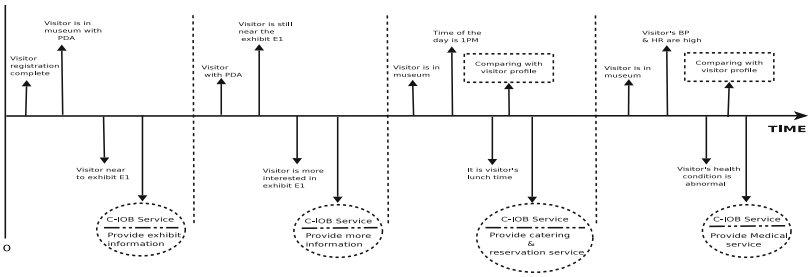


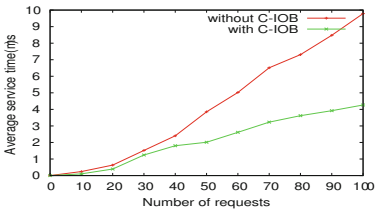
Fig. 5. Providing different services based on context

5 Results

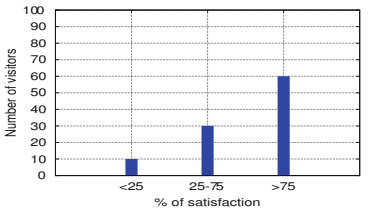
The designed services discovery system is tested with the Ubiquitous museum guide system. With the results obtained, we can conclude that more than 75 % of visitors are satisfied with the services provided, which is performance measure of the C-IOB based services discovery system in a ubiquitous environment.

From the statistics given, we can conclude that as the number of requests increases, the time taken to service the requests by C-IOB based service discovery

system is less when compared to traditional service discovery system, which makes the system efficient and to perform well in real time environment.



(a) Average service time taken to number of requests from visitor



(b) Average visitor satisfaction to the number of requests from visitor

6 Conclusion

C-IOB based services discovery is a new concept in discovering the required services for the ubiquitous computing users. The C-IOB model proposes to exploit useful contextual information within ubiquitous computing environments to discover the most appropriate and relevant services for the requesting user. The key feature of the C-IOB model is that context information is used not only to select the most appropriate service instance, but also to improve the dissemination of service requests across heterogeneous ubiquitous environments, thus minimizing the resource consumption.

Appendix

A CI-Constructs

See Fig. 6.

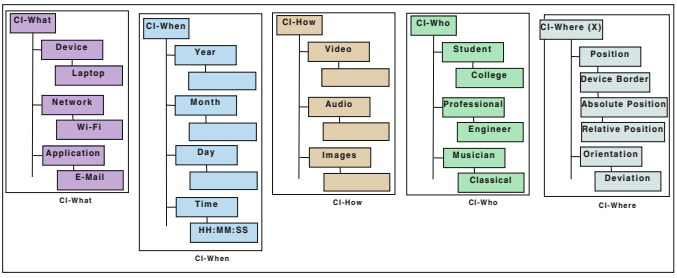


Fig. 6. Context Information(CI)-constructs

B Observations

See Fig. 7.

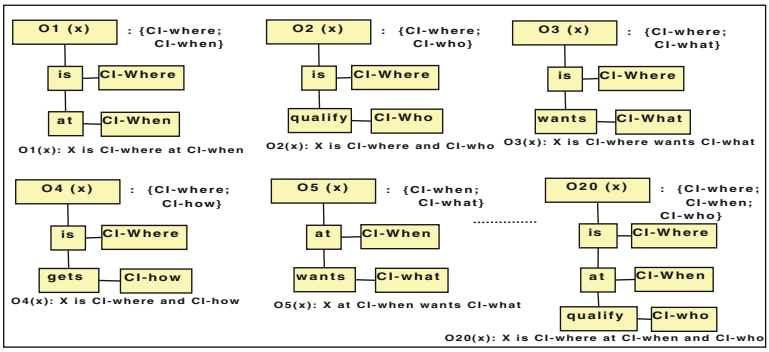
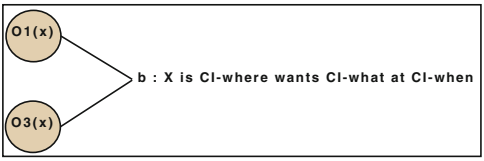


Fig. 7. Formulation of observations from Context Information-constructs

C Beliefs

Consider observations $O_1(x)$ and $O_3(x)$ of Appendix B. From those observations the formulated belief is:



In the museum environment if CI-where = near the exhibit wants CI-what = path to next similar exhibit at CI-when = after 5 min.

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