Context Aware Communication Services in "Active Museums"

Sadek Jbara[1], Tsvi Kuflik[1], Pnina Soffer[1] and Oliviero Stock[2]

[1]The University of Haifa, Israel
[2]ITC-irst, Trento, Italy
[1]{tsvikak, spnina}@is.haifa.ac.il, [1]sjbara@cs.haifa.ac.il, [2]stock@itc.it

Abstract

Nowadays, technology enables museums to become "active". Shortly, museum visitors will be equipped with smart personal devices and the museum environment will be able to interact proactively with them, offering them various services. Visitors often tend to visit museums in groups, mainly with family or friends, yet most of today mobile museum guides focus on supporting the individual visitor. Current museum visitor guides and other mobile guides described in the literature sometimes allow interaction between visitors. Such interaction, especially in museums may enhances the overall visit experience. These specific communication services can be abstracted to a general set of context-aware communication services. This paper presents an abstract definition of context-aware communication services for an active museum. The service agent developed in the framework of the PIL project is a prototype system for such general communication services framework. Such framework will ease the development of applications aimed at providing communication services in active environment.

Introduction

The lowering size and costs of computers allow them to become available everywhere. Soon we are going to live in "Active Environments" – instrumented environments [16] that sense and act proactively to support their "inhabitants" in a personalized manner. One kind of service that may be provided to inhabitants of smart environments is communication. Rantanen et al, in the InfoRadar project [18] analyzed the communication needs of active environment inhabitants and suggested a messaging service for smart environments. Their service and research emphasized mainly location- based messaging, where messages can be "posted" by inhabitants of smart environments to each other at specific physical locations. The content of the messages can be enriched by multimedia objects attached to the message. These messages can be accessed remotely by their addressees. The Smart Instant Messenger (SIM) developed by Law et al [13], suggested a generic system which includes messenger mechanism for such environments, based solely on immediate instant messaging (IM) mechanism.

The museum environment is very attractive for experimenting novel technologies, such as active environments. This can be seen from the wide variety of research projects focusing on applying novel technologies in support of visitors to cultural heritage (CH) sites. In Kray and Baus [10], and Raptis et al. [19], the reader can find detailed reviews of such applications. In [10] the authors survey variety of services provided by the systems, including communication services, we focus in this work specifically on communication services and discuss them in greater details. Various museum visitor guides offer different communication services to their users. Analysis of these services leads to the conclusion that the services suggested by the InfoRadar [18] project and SIM [13] for smart environments are all relevant to the museum environment, as well as a few more. Moreover, there may be additional context aware services that can be offered to "Active Museum" visitors, beyond communication services.

Reviewing the literature reveals a large variety of similar communication services, each tailored to a specific situation and using specific terminology. Furthermore, these services are embedded in the application they serve and developed separately for each application. We suggest that communication services can be abstracted and defined as a service layer for active museums, where application developers will be able to choose and tailor the communication services to their own application. This paper provides a first step towards a context aware communication service middleware in an "active museum".

The rest of the paper is structured as follows: The next section describes the background and related work on communication services provided by mobile guides in various museums and cultural heritage applications; In the third section we define the user context to be used by context aware communication services in an active museum; In the fourth section we generalized various communication services and their use of context; In the fifth section we describe the system built within the PIL project, planned to be integrated with a communication service middleware; Conclusions and future work are presented in the last section.

Intra-Group Communication Support in Museum Visitors' Guides

Museum visitors' guides have evolved from providing information about the exhibits on demand to personalized, location-aware systems that at best are able to provide a coherent presentation during the visit (see for instance [21]). The next step is to take into account the small group (e.g. a family or a group of friends) that the visitor may be part of, and facilitate interaction among members to stimulate further interest, since this is the most common form of museum visit [4].

What we discuss in this paper is an initial step toward better facilitating the ambitious goal of having technology stimulating conversation about the museum contents within the group, during and after the visit, by enabling the visitors to communicate throughout the visit. In fact, according to [14] conversation is a key factor for enhancing learning in particular and the museum experience in general. Specifically regarding communication services, it is worth mentioning that some experimental museum visitor's guide systems were already extended to also provide means of communication among visitors. In this section we review these systems and identify their common characteristics.

A first example is the "guidebook" system, developed for the Exploratorium in San Francisco [5]. The guidebook prototype provides two communication functionalities, named *rememberer* and *communicator*. The first provides the visitors with means to build a record of their experiences which they can consult during and after their visit, while the last helps visitors communicate by electronic bulletin boards for individual exhibits, instant-messaging, and/or beaming information between handheld devices. The researchers concluded that their remembering service may have value for personal and social uses. They also concluded that people seem to enjoy helping each other and discussing the exhibits, and this seemed to encourage additional interaction with the exhibits.

A second example is the MUSE project [6] which uses the WHYRE system [1]. By using the WHYRE system, the visitors can mark the currently displayed screen or can use a built-in camera in order to take a picture of what they are looking at. The effect of these operations is to update a visit memory album. Furthermore, at any time, either during or at the end of the visit, the visitors can modify the memory album by deleting some selected items, re-ordering them, or including comments and annotations. The final album can be saved on the CD, which represents the "memory" of the on-site visit.

A similar service is provided in practice by ESPRO [http://www.espro.com/], a company producing audio guides that allow its users to mark artwork of interest and select later on objects to be printed at the museum shop.

A third example is Campiello system [7], which aimed to encourage the creation of connected communities in cultural towns. Where visitors can use a form paper which uses a paper based interface technology to add information to their personal diary by storing comments about the data from the information space during the visit, these pages can be printed or faxed to be processed later. Furthermore, people can post their paper forms to large screen, and they can view together the newest input to the system by drifting off the old comments from the screen, to ensure that the comments on display are always recent and timely, similarly to "Post-its" expiry time characteristic.

A fourth example is MOMO system [9] which provides social interaction between visitors by allowing visitors to communicate and send messages to other visitors, and to see the names of visitors that already visited specific artwork, in order to share similar interests. The authors claim that the messaging feature is the main point of the social interaction because it allows visitors to communicate and to interact with the rest of the museum visitors, either by sending messages individually or by sending the same message to all the members of a group. Thus it becomes extremely easy to share ideas and opinions or just to keep in touch with other people.

A fifth example is the CyberGuide [15], a mobile context aware tour guide that allows its user to leave messages to exhibit owners and to send report about his/her location to some central service that others can access.

A sixth example is the Hippie system [17], allowing its users to take notes and annotate visited exhibits in order to store personal explanations or bookmarks available during the visit, and to send SMS-like messages that can be directed to a dedicated addressee such as family or group members, in the museum, or to enter a full e-mail address to contact a remote user.

There are two other systems whose main goal is encouraging communication among group members by using functionalities that are not regarded as communication services in our view:

One is the SottoVoce system [8], which supports synchronized sharing of descriptive audio content between pairs of visitors. The SottoVoce guidebook can be used for three kinds of intra-group activities: (1) a shared listening, which allows paired companions to listen to each other, (2) a following service, that allows one person to follow the other's activity, and (3) checking in, which allows the visitors to elicit information about their companion's state, to find out whether their companion was listening to descriptions of specific objects, and to monitor others.

The second AgentSalon system [22] supports face-to-face discussions and exchange of knowledge by attaching a virtual personal agent to each visitor that accompanies him/her during the visit, on a personal device. When a visitor reaches an information kiosk the agent can migrate from the visitor's mobile device to the kiosk's large screen and then inter-agent communication starts, aimed to encourage inter-user face to face communication.

In our own PIL system [12], which provides intra-group context-aware communication services we have gone further. The system provides communication and alerting services for both individuals and groups. The interaction between visitors through the PIL guide is done mainly by messages. Such messages can be delivered immediately or when certain conditions are satisfied, like, for instance, the location of the visitor in case of posting a note or, in case of system's alerting service the time remaining to the end of the visit. A notable aspect is that the message takes into account information the system has about the sender and the addressee, integrating the message with contextual information useful for the receiver.

The examples described above combine some means of communication as part of the application, assuming and concluding that this may improve the overall museum visit experience. Communication services are offered also in other "active environment" applications outside the museum.

One example is a Smart Instant Messenger (SIM), Law et al [13], suggested a generic system which provides an instant messenger mechanism for such environments. The SIM system enables communication between visitors by SMS-like messaging mechanism, provided by its *Instant Message* component that provides the basic message exchange functions.

A different example is the InfoRadar project [18] which is one of the set of examples for smart systems in the domain of cultural heritage, but not museum-specific. It provided public and private location-based messaging and a novel radar interface for accessing messages, where nearby messages can be tracked in the mobile device on a map. Such messages have an expiry time and visibility, and can be viewed remotely if the recipient is unlikely to visit the location of the message. The InfoRadar package contains a compact-size digital camera that can be connected via infrared to the InfoRadar main device and allows the user to attach a picture to a message being composed.

Another example also in the domain of CH is the "Guide" project [2] developed in the city of Lancaster, UK, that provided an electronic handheld guide enabling visitors to Lancaster to access information about the city, to create tailored tours of the city, to access interactive services, to send and receive messages to/from their companions, to let other members of their group know their location and to leave virtual stick-on notes at specific locations in the city so they can share their experiences with other tourists.

Table 1. Communication services provided by mobile guides in CH environments

Systems Group	System	SMS	Post-It	Memories
Museums Guides	Campiello		X	X
	MUSE			X
	MOMO	X		
	Exploratorium	X		X
	PIL	X	X	
	CyberGuide		X	
	HIPPIE	X		X
Guides	GUIDE	X	X	
	InfoRadar		X	

All the above described communication services in the domain of CH and especially the museum domain, can be categorized into three main types of services, namely SMS, Post-it, and Memories, as summarized in Table 1.

As can be seen from the table, intra-group communication is highly popular (in a form of SMS

or Post it), while "memories" seems to be a bit less popular.

However, the wealth and usefulness of these services calls for a more systematic approach for applying them then the ad-hoc approach taken by the current applications.

Visitor Context in "Active Museum"

The above survey of the museum visitors guide research literature reveals a variety of services implemented that can be categorized as "communication services". We can see that the communication services provided by these systems share basic characteristics, and can be mapped to a general communication service.

[3] in such an environment, enhanced by attributes that are used specifically by communication services. In other words, the characteristics related to the first observation are: (1) the information the user is exposed to during the visit (exhibits and presentations) which is part of the user's environment, (2) Temporal information, and (3) The fact that visitors tend to visit museums in groups, which leads us to consider the social context of the visitor. These characteristics have to be enhanced by the communication related attributes.

Our definition of a user's context in an "active museum" considers some attributes already defined for general cultural heritage applications [20], and

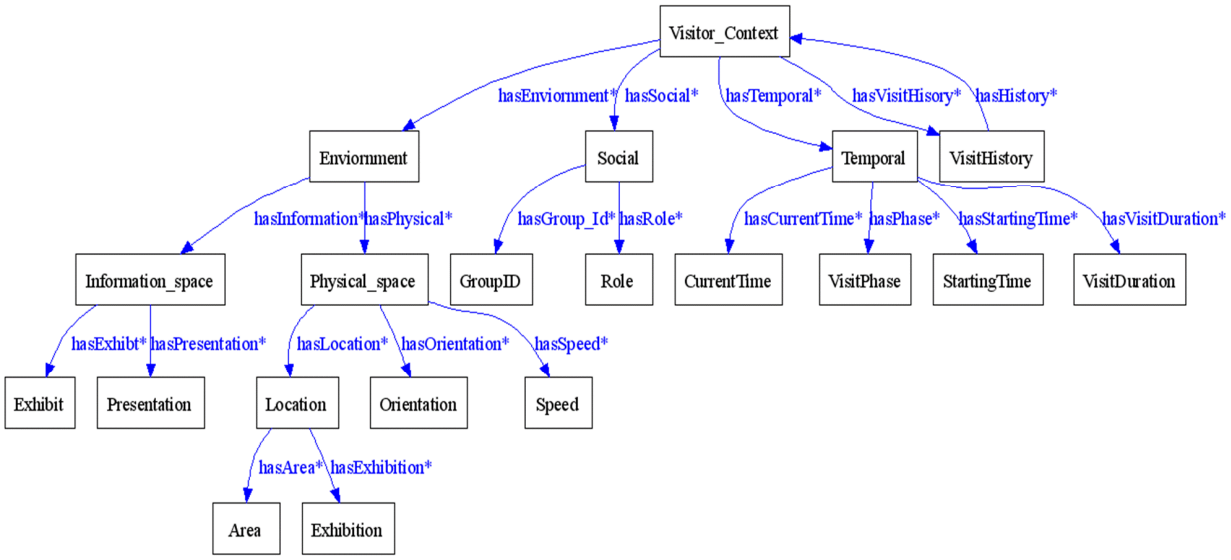

Figure 1. Visitor context model in "Active Museum".

A key issue for a generalized communication service layer in an active museum is a generic definition of the visitor's context that will support it.

Dey et al [3] define context in general as: *"Context is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves".*

This definition is generic, and it needs to be operationalized in the museum environment so that the relevant information considered as context can be identified.

Defining the visitor context in the museum that is relevant for communication services, we must include a general user's context definition following

enhanced by additional museums relevant user's context attributes, as illustrated by figure 1.

The visitor context in "Active museum" includes:

- Environmental space, including:
  - Physical space: represents the current user's position and orientation related to a space model
    - Position: represents a pair of parent area and child area. For example, an exhibition is a parent area, while each sub area of it, namely "island", is regarded as a child.
    - Orientation: refers to the current geographical direction the mobile device (user) is pointing at.
    - Speed: the user's speed of movement.

- Information space: represents the current level-of information (hierarchy) explicitly requested by the user. For instance, exhibit level of information, which provides the user the list of presentations about this exhibit, or the current presentation that the user requested to see from this list.

- Temporal: represented by temporal information about the visit like duration, starting time and current time, and by segmenting the visit into phases like for instance the portion of time allocated for the first and last phases, this may be relevant for communication services or other services (e.g., the "Please Don't Miss" system's recommendations service provided by PIL system as described below).
- Visit history: this attribute represents the history at a given moment. It aggregates each of the other context attributes from the start of the visit. In other words it represents a sequence of user's "*contexts*" and their change events.
- Social context:
  - Intra-group relations: represents a pair of group name and role in the group.

The above definition of context represented as key-value model. As defined in [23], a key-value model of user context is represented as a sequence of pairs of keys (attributes) and values.
Our model represents each key by a leaf of the context model (Figure 1.) and its value may be changed continuously (like speed and time) or discretely like area and exhibit. In other words if the context model have n leaves, then the user context will be described by the sequence of pairs: $\{Attr_1:Val_1, Attr_2:Val_2, \ldots, Attr_n:Val_n\}$.

For example, key-value pairs for location may consist of the attributes and values that describes this location like: {Location: - *Exhibition*:*Phoenicians*, *Area*:*ReligionAndCult*}.
Possible change of user context if the user changes his area but still in the same exhibition can be for example:
{*Exhibition*:*Phoenicians*,*Area*:*MaritimeCommerce*}
to {*Exhibition*:*Phoenicians*,*Area*:*EverydayPottery*}.
These attributes (the leaves of the model in Figure 1.) and their values can be used as condition for delivery, and/or for enhancing the service content. The usage of such attributes and values by the communication services will be described later.

The above definition of context attributes provides a basis for a generic definition of a communication service layer that can be used by application developers. Furthermore, this generic definition of user's context will be an essential part of the context aware communication service middleware in "active museum".

Generalizing Communication Services in Active Museum

We may generalize means of communications that usually have different names and attributes (as reviewed in Section 2) so that every subset of communication services will be an instance of the generalized service. For example, instant message, inter-visitor, intra-group, and "interaction between visitors" may simply called Immediate Message; email-folders, remembering, annotation, picture taking and user to themselves messages may be called Memories; while attaching a note to some artifact, posting virtual note and location based messages may be called Conditional Messages.

All the above-mentioned services have the following common features:

1. Information to be sent, text and/or multimedia
2. Sender
3. Recipient (may be the same person, or more than other)
4. A set of contextual (and possibly other) conditions that may apply for the delivery, like when and where to deliver it, expiration time etc'.

This abstract commonality is illustrated by Figure 2.

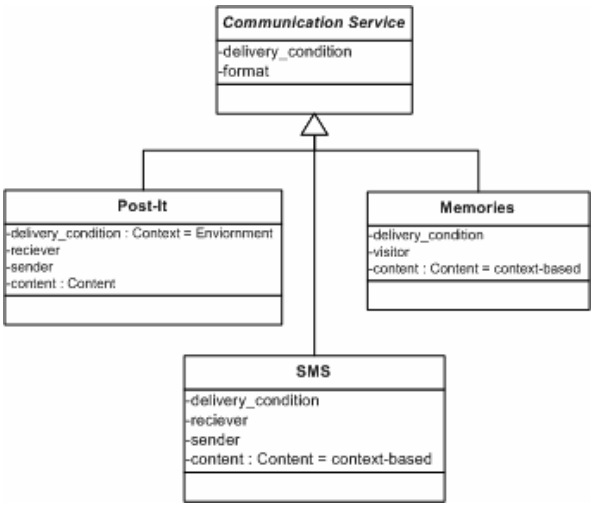

Figure 2. Communication services abstraction

The above abstraction shows that a communication service can be specialized into one of three classes; each one represents a subset of communication services. These classes are characterized by their attributes and constraints on the values of these attributes (see Figure 2). Such service may provide a selection of content which may include text, audio, pictures, video and their combination, a definition of source and a set of contextual conditions for the delivery. The contextual information may include current and future location of sender and receiver as well as timing information.

It may be used by different attributes of different classes of services. For instance, the Post-it uses an environmental context attribute for the delivery condition and textual content; in contrast, a SMS service has no conditions for the delivery and the same content format as a Post-It, while the delivered content can be changed to fit the sender's context and content.

The above can be implemented as a general communication service in any environment, in an abstract layer above some communication infrastructure, so application developers may select specific services to be used, as needed for their application.

The PIL Museum Visitor's Guide system

The PIL museum visitor's guide [12] was developed for demonstrating and experimenting individual museum visit support, inter-group communication and to some extends group-visit support. Figure 3 presents the core parts of our museum visitor's guide multi-agent system. Several components interact by exchanging messages through channels; this kind of architecture is very effective to experiment with flexible systems (for detailed description of the underlying technology see [11]). The system contains a user-modeling component that keeps track of visitor's preferences based on their behavior, a spatial information broker which reports visitor's position periodically, integrating positioning information from different sources (IR and WiFi), and a presentation composer which provides presentations to the visitor, based on current location and taking into account visitor's inferred preferences. The novel addition is the service agent that provides communication and alerting services for both individuals and groups. This component keeps track of the context of the individual visitors and abstracts the information to an overall group state.

Regarding communication services, the initiator of messages may be the individual visitor or the system. Messages can be addressed to a specific visitor, to a group or to everybody. Messages can be delivered immediately or when certain conditions are satisfied.

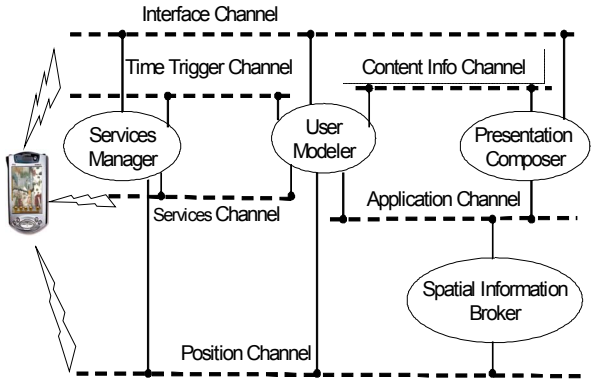

Figure 3. PIL museum visitors guide architecture.

A general context-aware communication service should support communication with various addressees, based on contextual conditions (and as a result, offering a variety of services).

For initial demonstration of the above, the services include context-aware immediate message (SMS-like) and context-aware virtual "post-it". The messages are sent either among visitors or by the system to the visitors. A visitor may send immediate messages or may leave a virtual "post-it" to colleagues at a certain point. The message is being contextualized by the system using the sender's and receiver's contexts (e.g., if the receiver has already been to the place, the system notifies the sender about that). The visitor may also send a message suggesting visiting cafeteria specific exhibit (or avoiding one, or taking a break, scheduling the visit, etc.).

These messages make use of the defined user's context real-time values. Let us take as an example an "SMS" service: Assume a message with the content "you must see this", sent from a specific location, regarding a specific object in the museum. The receiver's message content is dependent upon the sender's context, since rather than receiving the word "this", the receiver gets a description of the specific object following the sender's context; this message is delivered immediately. Differently from the previous case, similar content, e.g., "you must see this presentation" can be left as a "Post-it" message that is virtually attached to the specific object and the term "this" in this example not related to "this" object but

to a presentation that describes it. In this case the service uses the receiver's context as a delivery condition, by checking if the receiver's context matches the sender's context when attaching the "Post it" note. Furthermore, the system uses extra contextual information for delivery or rejection of such service, e.g., whether the receiver has seen the "this" presentation in the past (which is part of his visit history contextual attributes).

Another set of services is time based alerting. Usually, visitors have limited time for their visit. We are experimenting with services that help visitors get the most from their time by exploiting the group dimension. Visitors do not want to miss the most important exhibits in a museum, and the system can keep track on the visit time and alert them as their visit is about to end, so they will not miss the major attractions they have not seen yet. This kind of service considers two aspects of visitor's context: the history of the visit and the time phase.

Context-aware communication services were integrated into the system so they do not interfere with normal use of the guide (the application). This means, for instance, that communication activities are available to the visitor only when no multimedia presentation is being played (e.g. only when moving around/approaching an exhibit or between presentations in a certain position). Furthermore, the service agent uses the information broadcasted from the underlying communication infrastructure and does not affect the interaction between the communication infrastructure and other modules, or the exchanging of the information between the modules.

The service agent is a prototype for a middleware layer of communication services. This layer will use the current infrastructure for filtering and delivering communication services where each kind of communication service will be handled and delivered based on a separate gateway (channel). Every visitor's context attribute (based on the extendable context model described above) will be broadcasted on its unique channel and will easily be used by the different services.

The middleware layer will have an interface (API) that can be easily configured by application developers, who may want to develop new applications that use context-aware communication services. Such applications would be instances of various communication services, using different contextual attributes for the content or the delivery of messages.

As an example, assume the developer chooses to develop an application that uses specific SMS messages. The developer will use a specific SMS module to define the general properties of SMS messages and specific structure for each kind of message. Any message structure consists of properties and conditions, for example whether to enhance the delivered content or not and by what (e.g for "come here" content the receiver will get an image of "here" or directions of how to get "here"), whether to regard history or not (for message rejection), and if the message is personalized or directed for all.

A specific application that can be considered is providing a message of "*Let's meet in the cafeteria*", to be sent to visitors equipped with mobile guides in the museum, where this message will be sent from a person to his group members that have not visited the cafeteria yet. The received message's content will include a picture of the cafeteria and directions of how to get there.

First, the developer have to add this location value, its id, and other related information (picture, explanations etc.) to the museum hierarchical data file (to be used by the system for enhancing the message content). Then to edit the communication service configuration file according to the requirements of such message (see Figure 4.). Specifically, it indicates that the message does not contains free text, that the delivery conditions relate to the receiver's social context (groupId) and to his history, and that the message content relates to a specific location (cafeteria) and should include an image and directions.

Finally, at the application level, the developer uses the middleware's API to send the message, while he/she needs just to allow the user to select/view the content of the message while the delivery is

```
<CommunicationServices>

<SMS>
<structure MsgId="1" freeText="false">
<deliveryContext Social="groupId" History="true" />
<content Environment="location" Location="cafeteria"
Image="location" Direction="full"/>
</structure>
</SMS>

…

</Memo>

</CommunicationServices>
```

Figure 4. Communication services configuration

performed by the middle layer, according to the message type. In other words, the content of the message to be sent, (for example the text "come here") is selected by the user while the mechanism implementing the actual delivery according to the type of the message (SMS in this case) is determined by the application developer, using the service's API. The middleware will be responsible for tracking both sender's and receivers' states, guarantee the delivery of the service based on the delivery context, and change the message content based on its defined structure (see Figure 4.). Moreover, such kinds of structures are extendable and can cover various message contents. One can simply note that such configuration file can include different structures for each kind of communication service (SMS, Post-it and Memories).

Conclusions and Future Work

Communication services are very helpful for enriching museum visit experience, as they enable inter-group communication that in turn encourages interaction. Such services are already experimented in different systems, as was shown by the systems reviewed.

The communication services implemented so far in active museums are only a small fraction of possible services. Despite the wide range of communication services provided by the various systems discussed, we can clearly see that these services share common features. Some can use the same user context attributes for the delivery condition, while other services may use contextual information in their content. This fact motivated us to provide a generic definition of the user's context attributes in an "active museum".

The abstract view of such heterogeneity of communication services simplifies the definition of such services. We believe that abstracting the commonality of the used services into elementary service attributes such as content, condition, and others, is a major step toward providing architecture for a communication service framework in the museum.

Such framework will ease the developments of communication services and will be placed on top of the communication infrastructure, behave as a middleware layer between the application and the infrastructure, and will be used by the application developers to define and use specific services as they need.

Toward the next part of this work our aim is to provide architecture and implementation for the above described middleware layer, using multi-agent communication infrastructure.

We plan to show that our framework can provide means to use and configure different communication services with different characteristics by creating different applications that uses our framework.

Acknowledgments

PIL was developed as part of the collaboration between ITC/irst and the University of Haifa and experimentation is conducted at the Hecht museum at the University of Haifa.

References

[1] Cinotti T. Nagaraj R. Giuseppe Mincolelli, Giuseppe Raffa, Luca Roffia, Fabio Sforza: WHYRE: A Context-Aware Wearable Computer for Museums and Archaeological Sites. In Proceedings of 8th International Symposium on Wearable Computers (ISWC 2004) pp. 174-175.

[2] Davies N. Cheverst K. Mitchell K. Efrat A. Using and determining location in a context-sensitive tour guide. Computer 34, 8, (Aug. 2001), pp.35-41. (http://www.comp.lancs.cs.uk/~km/papers/IEEE_Computer_Special_Issue.pdf).

[3] Dey A.K. Abowd G.D. Towards a Better Understanding of Context and Context-Awareness. GVU Technical Report GIT-GVU-99-22, College of Computing, Georgia Institute of Technology. (ftp://ftp.cc.gatech.edu/pub/gvu/tr/1999/99-22.pdf).

[4] Falk H. Dierking L. The Museum Experience. Whalesback Books Washington (1992).

[5] Fleck M. Frid M. Kindberg T O'Brien-Strain E. Rajani R. and Spasojevic M. From Informing to Remembering: Ubiquitous Systems in Interactive Museums, Pervasive computing, 1, 2, (April – June, 2002), pp. 13-21.

[6] Garzotto F. Cinotti T. Pigozzi M. "Designing multi-channel web frameworks for cultural tourism applications: the MUSE case study", Selected Papers from Museums and the Web 2003, Toronto Archives & Museums Informatics pp. 239-354 (http://www.archimuse.com/mw2003/papers/garzotto/garzoto.html).

[7] Grasso A. Koch M. Snowdon D. Campiello – New user interface approaches for community networks. In Proceedings at Workshop Designing Across Borders: The Community Design of Community Networks at CSCW'98(seattle,WA)(http://www.scn.org/tech/the_network/Projects/CSCW-PDC-ws-98/grasso-el-al-pp.html).

[8] Grinter R. E. Aoki P. M. Hurst A. Szymanski M. H. Thornton J. D. and Woodruff A. Revisiting the visit: Understanding how technology can shape the museum visit. In Proceedings of ACM Conference on Computer Supported Cooperative Work, New Orleans, Louisiana, USA, (2002) pp. 146 – 155.

[9] Jaén J. Mocholí J. Esteve J. Bosch V. Canós J. MoMo: Enabling Social Multimedia Experiences in Hybrid Museums by (Politechnic University of Valencia, Spain) in International Workshop of Re-Thinking Technology in Museums:Towards a New Understanding of People's Experience in Museums, Limerick (Ireland), (29th-30th June 2005) pp. 245 - 251.

[10] Kray C. Baus J. A survey of mobile guides. In Proceedings at Workshop HCI in mobile guides (in conjunction with Mobile HCI 2003), Udine, Italy.

[11] Kuflik, T., Albertini, A., Busetta, P., Rocchi, C., Stock, O. and Zancanaro M. An Agent-Based Architecture for Museum Visitor's Guide Systems - IFITT's Global Travel & Tourism Technology and eBusiness Forum (ENTER 2006), January 2006, Lausanne, CH.

[12] Kuflik T. Sheidin J. Jbara S. Goren-Bar D. Soffer P. Stock O. Zancanaro M. Supporting small groups in the museum by context-aware communication services In Proceedings of the 12th international conference on Intelligent user interfaces 2007, Honolulu, Hawaii, USA (January 28 - 31, 2007) pp. 305-308.

[13] Law C. Zhang X. Chan S. Wang C., "Smart Instant Messenger in Pervasive Computing Environments" The First International Conference on Grid and Pervasive Computing (GPC2006), May 3-5, 2006, Taichung City, Taiwan. Informatics, Toronto, (2003), pp. 239-254.

[14] Leinhardt G. Knutson K. Listening in on Museum Conversations, AltaMira Press, 2004.

[15] Long S. Kooper R. Abowd G. D. and Atkeson C. G. Rapid prototyping of mobile context-aware applications: the Cyberguide case study. In Proceedings of First International Symposium on Handheld and Ubiquitous Computing, HUC'99, (1999), pp. 52-66.

[16] McCarthy J. Active environments: Sensing and responding to groups of people. Journal of Personal and Ubiquitous Computing (CHI 2000), Vol. 5, No. 1, (January 2001) pp. 51-52. Available at http://www.inf.ethz.ch/vs/events/dag2001/.

[17] Oppermann R. and Specht M. A Nomadic Information System for Adaptive Exhibition Guidance. In Bearman, D. a Trant, J.(eds.) Cultural Heritage Informatics 1999:selecte papers from ICHIM 99, pp. 103-110.

[18] Rantanen M. Oulasvirta A. Blom J. Tiitta S. Mäntylä M. InfoRadar: Group and Public Messaging in the Mobile Context. In Proceedings of NordiCHI, Tampere, Finland, ACM Press (2004), pp. 131-140.

[19] Raptis D. Tselios N. Avouris N. Context-based design of mobile applications for museums: a survey of existing practices. In Proceedings of Mobile HCI (2005) pp. 153-160.

[20] Roffia L., "Context Related Information Sharing and Retrieval in Mobile Cultural Heritage Applications", PhD Thesis, University of Bologna, Italy, 2004.

[21] Stock O. and Zancanaro M. (eds.) PEACH: Intelligent Interfaces for Museum Visits. Cognitive Technologies Series, Springer, Berlin, (2007).

[22] Sumi Y. Mase K. In: Interface Agents that facilitate knowledge interactions between community members. Springer-Verlag (Cognitive Technologies series) (2004) 405–427.

[23] Thomas S. and Claudia L-P: *A Context Modeling Survey*. Workshop on Advanced Context Modelling, Reasoning and Management as part of UbiComp 2004 - Nottingham/England, September 2004