THE VOCABULARY ONTOLOGY ENGINEERING FOR THE SEMANTIC MODELLING OF HOME SERVICES

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Abstract: With great advance in information technology and broadband networks, the interconnected networked home devices are becoming increasingly popular. Number of heterogeneous networked devices and services which belong to the traditionally separated functional islands such as PC (i.e. Internet), mobile, CE broadcasting, and home automation, not working together can be found in our today's home. Merging of these devices and services would offer home individual residents user-friendly, intelligent, and meaningful interfaces to handle home information and services. The semantic ontology based modelling of home services can enable interoperability of heterogeneous services. The ontology may facilitate clear description on how far each device is suitable for different kinds of information and different interaction demands. This paper is presenting an analysis on the kind of vocabulary ontologies necessary in different functional domains to cope with heterogeneity of service descriptions. The ontology based rich representation of services will facilitate an efficient service discovery, integration and composition.

1 INTRODUCTION

Merging of devices and services from the traditionally separated domains presented in the home would offer home individual residents user-friendly, intelligent, and meaningful interfaces to handle home information and services. To achieve this, the heterogeneous networked services in the home, where a wide variety of heterogeneous networks, devices and software infrastructures, coexist, should be discovered, integrated and composed in a ubiquitous and seamless manner to address the user requirements.

In Amigo project (Georgantas, 2005) we adapt the semantic modelling approach for modelling of the services to enable efficient automated execution of the aforementioned tasks. In service oriented software architectures (TINA, 1997) (WS, 2004), service modelling is usually performed by the operations that a service provides and requires from other services in the architecture. Thus the Amigo services are modelled based on the number of required and provided capabilities. Each capability specifies a number of inputs and outputs. The capabilities along with their inputs and outputs can be used for the service discovery process (i.e. capabilities/requirements matching). Some other properties of the service, often referred as non-functional properties, such as quality of service (QoS), context in which a service is executed, and preferences specified in user profiles may assist to dynamically select the services that best meet the user needs.

In order to allow a rich representation of services and thus facilitate efficient service discovery and composition, functional capabilities, inputs, outputs

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and non-functional attributes of the services can be further semantically annotated using external vocabulary ontologies. The use of ontologies enables computational entities and services to have a common set of concepts and vocabularies for representing knowledge about a domain of interest, while being able to interact with each other. By using such ontologies, the relationships between entities can be more clearly expressed and these allow for better reasoning on their properties. Ontologies are also beneficial for the re-usage of knowledge, as several ontologies from various sources can be integrated to describe the specific domain. Finally, the deployment and customization of such systems as Amigo in any home can be considerably facilitated by using a common set of concepts and vocabularies developed for the networked home environment. The integration of third-party applications and services can be much eased using clear ontology classifications.

This paper elaborates on the vocabulary ontologies for the semantic modelling of home services. In the following, one possible realization of home system is visualized in Section 2. Here the approach and steps have been used to identify the required vocabularies and classifications are outlined. The initial analysis and results for different functional domains (mobile, PC, domotic, CE) are presented in Section 3. Section 4 concludes the paper providing an overview of the current contribution and the future work. As the work on domains analysis and definition of different ontologies is in progress, the objective of this paper is to share and validate the approaches used, to discuss the initial results obtained, and to verify the directions for the future work.

2 SEMANTIC MODELLING OF AMIGO SERVICES

The intensive user research (Rocker, 2005) performed in Amigo project gives some ideas on how the home system could interact with people in a service-rich home environment. Based on this research, a home system (we call it Amigo system) can be visualized as handling a number of separate aspects or application domains of the intelligent home, demonstrating various properties and functionalities that support the persons living in the home.

The Amigo system (in role of supporting gaming and entertainment domain) can start a user's day with playing music from preferred play list, showing the personalized news or general summaries of hot news topics. The content (music, film, TV/radio program or game) can follow the user everywhere in the house or even outside the home area using a mobile or a portable device. It helps to select games to play and supports the usage of various displays in the home environment during the game session. It downloads personal profiles and integrates game devices when friends are coming over to the user's house for interactive multi-player game sessions.

The Amigo system (in role of supporting household task assistance domain) can select the correct settings for home appliances. It may even know how to detect the presence of inappropriate objects inside or near the appliances. It downloads recipes and cooking programs to the kitchen and displays them to facilitate the food preparation procedure.

The Amigo system (in role of supporting ambience assistance domain) can configure the home environment during game sessions, or while the user is watching TV by adapting the light, sound and video features/levels throughout the room. It can adapt the home environment and create an all-surround audio, light and video experience.

Amigo system cannot depend on the availability of any specific set or types of devices in handling these aspects. In order to support this, we need to introduce an engineer role into the Amigo system that supports higher level Amigo applications and hides the necessary underlying technologies. Examples of the support for this role can range from controlling specific appliances to downloading content to a PDA device. This "Engineer" role is handled by the Amigo Intelligent services, and a number of other services that are dynamically registered using the service discovery functionality of various appliances located in the Amigo house and composed by the Amigo system when necessary.

The aforementioned scenes have been analysed to gather the requirements for various domain ontologies and vocabularies to cope with the heterogeneity of services descriptions (i.e. capabilities, inputs, outputs) and address the requirement specifications. As an example: "John and Robert start to play an interactive multi-player adventure game in John's living room. The Amigo system adjusts the ambience for the game experience by controlling the lights and sound. Robert notices that it is late so he has to leave, but he continues to play the game under way..." Some examples of the

vocabularies related to the various Amigo domains in this scene are:

From positional information and/or gesture recognition output Amigo User Interfaces detect that John and Robert want to play. Upon activation of the game, the system queries the capabilities for *PositionControlInput* User Interface Services provided by the Amigo User interface. When controlling the ambience in a room the Amigo system queries services providing the domotic domain *ControlLight* and *LightDetectors* capabilities available in the context of that room. TV monitor, when plugged in, provides CE domain capability of *DigitalMediaRenderer* for *AVStream*.

To be able to support the continuation of the gaming session, John's Amigo system checks the *DeviceContext* of Roberts PDA to match a most suitable mobile client technology provided by game console and uses the PDA's *ContentDownload* capability to load a game into it.

Other supporting services that are not that visible in the example above are seamlessly involved. For example, context management service will be used to provide user location. The Amigo system may ask the User modelling and profiling service for relevant user context and preferences about favorite adventure game to be automatically downloaded.

Different levels of ontologies (see Figure 1) can be envisaged to model the entire Amigo home environment appropriately in order to address the service/application developer's and user's requirements for efficient service discovery, composition and invocation.

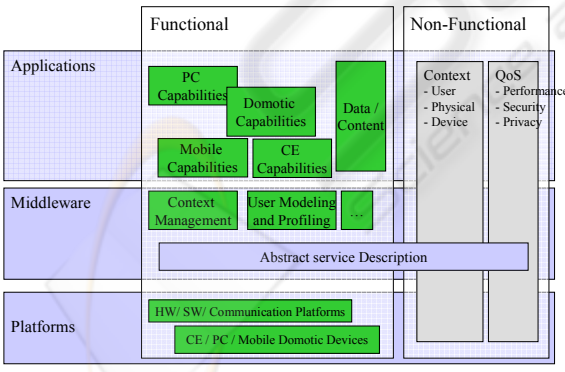

Figure 1: Different levels of services and ontologies.

To verify and validate this approach, the following iterative steps have been used in order to identify the required vocabularies and classifications on which the ontologies will be based (Noy, 2001):

Step 1: We gathered Amigo requirements for the various domain ontologies. Some domain-specific examples, based on user scenarios that can help to determine what types of information are required and what types of query support the ontology should provide have been identified.

As an example, the mobile domain information and services are useful in such cases as communication (call, SMS), notification (alerts about some events in the home), and entertainment on the way. Examples of mobile platforms used in home are a mobile phone, PDA, laptop, etc.

The PC domain is related to the "classical" view that we have about computers. Personal computers, Web cameras, peripherals such as printers, scanners, etc, are included in this domain. The role of PC domain is mainly related to storing, accessing and processing information.

Analysis of the CE domain concerns audio, video and other entertainment devices presented in the home. The interaction of home individuals with this domain mainly takes place during their leisure time, thus making the CE domain a very attractive, actively utilized and potentially profitable one. Plenty of CE devices such as HiFi systems, TV screens, video consoles, sound speakers, etc, can be found in our homes. Especially the entertainment content that is displayed and exchanged between those CE devices is quite attractive and important from the user's point of view. This content includes songs, films, still photos, etc, and can be seen as indispensable attribute of the CE domain. In addition, a many of the data linked to this content (such as size, bit rate, and parental permissions) can affect the user's experience directly or indirectly.

The domotic domain is related to identifying the requirements of home automation devices to Amigo system. Some examples of such devices could be a lighting system, a washing machine, a gas sensor, etc. Energy cost savings, security of persons and goods, comfort improvement are some of the benefits of home automation. The role of domotic domain is quite critical as it is also associated with home care and safety. Safety and security of persons and goods is increased with functions such as detection of fire or gas leakage, tele-transmission of alarm, or detection of intrusion.

Step 2: The numerous available sources of information that may provide classifications and ontologies have been considered (FIPA, 2001, FIPAAV, 2001, OMA, 2005, CCPP, 2004, TvAnytime, MPEG7, 2004, MPEG21, 2002, Shimizu, 2005, UPnP, 2003, DLNA, 2005). The above enumerated sources provide suitable information to model device capabilities to be useful in adaptation of content information to particular

device mode, however they lack in providing service functional descriptions that would allow the automatic selection of particular devices based on the services available, through the service capability matching. Moreover, most of information is mobile domain oriented and might give only some ideas for service modelling in other domains. As regarding to domotic domain, due to the great heterogeneity of devices that can be found in the domain, there is no available classification covering the entire home automation world. Therefore the Amigo classifications can be a starting point in modelling of domotic information.

Step 3: Here some draft lists of information (i.e. vocabularies) for different domains based on various sources enumerated have been created

Step 4: Analysis and classifications. In this step we analyse and filter the lists obtained from step 3 against the requirements from step 1 to identify information needed to support the Amigo scenarios. We are in the process of identifying the required ontologies and relations between them for describing the information of a particular domain. The preliminary taxonomies and class hierarchies for the ontology are initially defined and presented in the following.

3 ANALYSIS AND CLASSIFICATIONS

The following set of taxonomies for different functional domains (mobile, PC, domotic, CE) can be identified for further analysis:

- Taxonomy for the typical functional capabilities of devices, provided as software services
- Taxonomy of functional capabilities of software services which provide the intelligence support in the home
- Taxonomy for devices and platforms that can be used to define device context and facilitate the adaptive service discovery
- Taxonomy of content including multimedia content

When classifying the functional capabilities, we focus on those capabilities of devices and services that can be used for service discovery and further service composition in Amigo. The various aspects identified in the example are reflected in the classification. Most of the analysed capabilities are closely associated with the control of devices discoverable in Amigo home (the engineering aspect), but classifications that help modelling of services associated with higher level aspects supported by Amigo home (e.g. gaming and entertainment domain support) are also analysed.

Figure 2 gives an idea of functional capabilities class hierarchies in Amigo. The high level *FunctionalCapability* of services found in Amigo home can be described using three application domains presented in Amigo home. These are *ExtendedHomeSupport, HomeCareAndSafetySupport,* and *HomeInformationAndEntertainment*. Naturally this level of hierarchy can be easily extended if services supporting other application domains functionality will be developed in the future. Accordingly lower level class hierarchies present the capabilities of the services from four functional domains (mobile, PC, domotic, CE) and intelligent user services which support at least one of the above enumerated application domains. In essence, the communication with users (*UserComminication*) by calling and messaging is an inherent capability of the mobile domain. In the PC domain which is much overlapped with mobile domain, this may additionally involve means for user *AudioVideoCommunication* through the *Videoconference. MultimediaApplicationSupport* may be described by capabilities providing control to AV devices in home, and *GameApplicationSupport* by support for game downloading and user communities (not presented in the picture). *IntelligentHomeSupport* can be viewed as the glue, expanding through all application domains and described by a number of services, which capabilities support *UserIntefaceServices* with devices (GUI, speech, gesture services), provide *IntelligentSoftwareSupport* through e.g. *ContextManagement*, *UserModellingAndProfilling*, and other intelligent services and control home devices (*HomeDeviceControl*). The Functional Capability class hierarchies can be easily extended by service developers with respect to application domains possibly present in any future homes and also with respect to particular domain of interest. For example, *HomeInformationAndEntertainment* can be further extended by *VideoApplicationSupport*, *MusicNewsApplicationSuppport*, etc. Accordingly *HomeCareAndSafetySupport* will be further extended in our future work with services capabilities specific to devices from domotic domain such as e.g. *ControlLight*, *ControlBlinds, ControlTemperature*, etc.

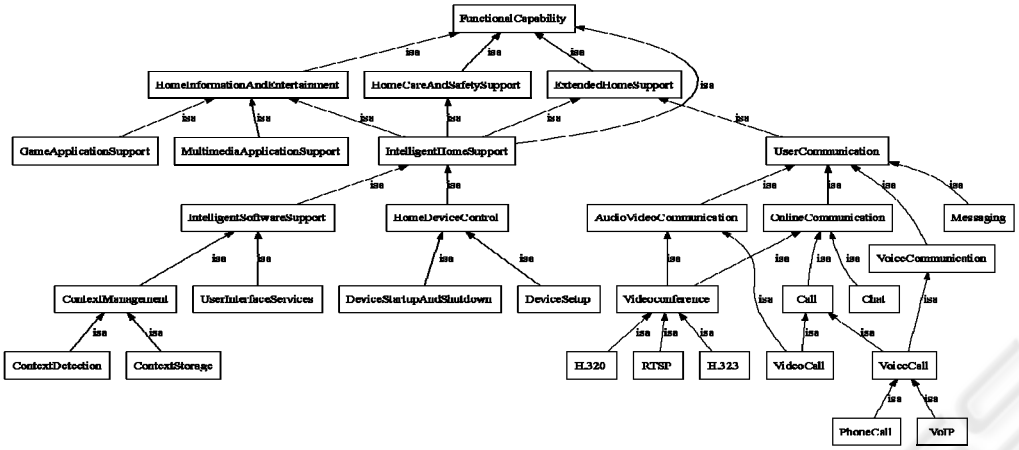

Figure 2: Partial class hierarchies of functional capabilities.

As previously mentioned, the device capability profiles provide background for the devices and platform taxonomy. A common problem with the various standards considered is that they mostly describe only the variable set of capabilities of a device leaving out the standard set of capabilities for the underlying platform technology. We think that such assumptions should be explicit. As an example, a partial draft of low level ontology based on mobile platform taxonomy is illustrated in Figure 3.

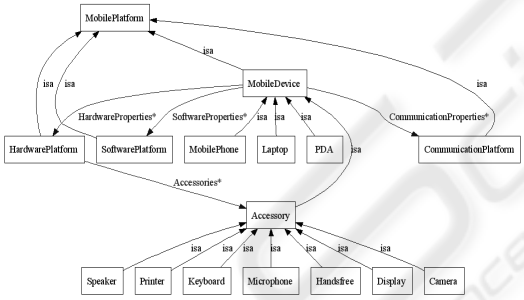

Figure 3: A mobile platform Taxonomy.

The proposed taxonomy is based on various device property descriptions but is more generic in order to cover also implicit information left out of those classifications. Again, each class in this taxonomy is a specialisation of its parent classes. For clarity, the taxonomy is restricted to three levels in which the first level defines a role of the platform, the second is a sub-classification of platforms provided in this role and the third level is usually a specific technology with possibly several instances. The vocabulary can describe for example the communication properties of a mobile platform, or classes of mobile devices with typical platform properties. A mobile phone model can be specified as an individual of class *MobilePhone* with specific properties. Similar ontologies can be created for the devices and platforms from other functional domain (PC, domotic, CE). The integration of those is part of our future work.

The taxonomy for content is related to input and output information provided by services and can be used for the purpose of service selection/matching. The types of content in mobile domain are related to CE domain. Typical to these domains is that many applications are fixed in device but others, like Java games, are downloaded as content to device. Typical application data e.g. in mobile and PC domains is related to contact and calendar information:

MobileContent
- Application
  - Game / Calendar / Phonebook / CameraImaging
  - EmailClient
- ApplicationData
  - Bookmark / CalendarEntry / ContactInformation
- Media
  - Audio / Image / Video / Text
  - Stream / Still

QoS aspects in the service discovery may rise some questions related to the format of used multimedia content in particular situation/context, i.e., which format for this content is the best suitable for the current state of the network. Furthermore, some capabilities of content-related services may only apply to certain content formats or media. Thus some explicit relation to these ontologies is necessary. Device capabilities in CE are essentially described by the way in which they behave in relation to content. It is not our purpose to define a content description language but rather to provide a bounded taxonomy that will enable the modelling of capabilities under the *MultimediaApplicationSupport* class presented above. Therefore, after analysing the

aforementioned classifications and scenario requirements, an essential classification may be:

MultimediaContentType
- ContentSize / Bitrate / NumberOfChannels
- Resolution
  - SpatialResolution / TemporalResolution
- MediaFormat
  - AudioFormat
    - ADPCM / CS-ACELP / G.711 / MP3 / OGG / PCM / WAV / Mono-Stereo
  - ImageFormat
    - BMP / GIF / JPEG / TIFF
  - TextFormat
    - Plain / RTF
  - VideoFormat
    - AVI / DivX / MPEG2 / MPEG4 / WMV / XVid /

A separate taxonomy for QoS characteristics is also considered, but not yet elaborated, for mobile and PC domains. This taxonomy is related mostly to service usability because of restrictions of mobile devices, selection of most suitable communication channels, and determination whether a specific content can be presented on a particular device.

4 CONCLUSION

This paper has presented the requirements analysis and the initial results on ontology vocabularies and classifications modelling for the services and devices capabilities from four functional domains (mobile, PC, domotic, CE) presented in the home environment.

In our future work we are planning to iteratively refine and extend the existing classifications with generic services and devices capabilities found from four functional domains and also with services capabilities developed in duration of Amigo project towards the support of the demonstrations for three application domains of Home Information and Entertainment, Home Care and Safety, and Extended Home. Special attention will be paid to the description of domotic devices and services with their possible integration with domotic information on devices states and events as most critical ones in developing of services for the Home Care and Safety application domain.

It is also planned to elaborate the ontology on QoS related aspects that will contain the devices related capabilities and the content related information (the initial results are presented in this research), and also network related QoS parameters which would allow to tackle the interoperability issues between different QoS schemas (e.g. UPnP and RSVP) presented around the home.

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