Next Generation Context Aware Adaptive Services

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ABSTRACT

Situational information can enrich the interactions between a user and the services they wish to utilize. Such information encompasses details about the user, the physical environment and the computing resources. There are at least three key aspects in addressing this issue. Firstly, it is important to accurately capture or infer the requirements of the users in a timely fashion. Without precise information on what the users are hoping to achieve it is difficult to identify suitable services or sub-services that may fulfill (in part or fully) their information needs. Secondly, the nature of the available services determines the modes in which they may be adapted to the users' needs. Rigid, inflexible services may be difficult to tune to the information requirements of the users. Adaptive services, on the other hand, are well suited to dynamically modifying their behavior, within defined constraints. The third issue to be addressed is the on-the-fly combination of services to meet the users' requirements. This paper argues that current modeling (both of users and services) techniques, adaptive axes and personalization techniques used in current personalized information services, such as Adaptive Hypermedia Systems, may supply the basis for next generation adaptive collaborative services.

1. INTRODUCTION

Current services supporting users often fail to meet the rapidly changing requirements of users as their information requirements are often focused and may be short lived. Collaborative work activities present a challenging *personalization* situation – no longer are we adapting to an individual in a well understood domain, as in personalized eLearning. Rather we are adapting to a group of users involved in a collaborative process. This process, or the desired outcome, may not be as well defined as in the case of a personalized eLearning service. There are, however, a number of potential sources that may be used to acquire this information. The primary source is the users themselves, or more accurately the context information stored about the users. A group of users will bring a wealth of information to any task they are performing. This information combined with some information about the business outcomes they are hoping to achieve form the knowledge basis of the service adaptation and combination. An understanding of the types of information requirements and possible uses of that information are the secondary source of data.

Adaptive services base their adaptivity on user and context information, as well as on an encapsulation of the expertise that support the adaptation. In the case of an eLearning service the personalization of educational material may be based on the learner's learning goals, prior knowledge and learning preferences, i.e. user context information. It is also supported by the expertise of an expert in the knowledge domain and an instructional designer, who has the appropriate pedagogical expertise. Adaptive services should, therefore, be able to accept, and understand, input to their adaptive processes from many sources.

In the case of an adaptive service fulfilling a business requirement, the sources may include context information about the users, information about the environment(s) in which they wish to collaborate, restrictions of the devices they are using and a model of business process, to name a few. These sources of information are not static – users change their goals, sound and lighting aspects of environments change, user may use multiple devices etc. It is unlikely, given the large variance of information sources, that a single adaptive service will be able to fulfill anything more than a few basic information needs of a user.

It is more likely that the fulfillment of such varied requirements will stem from the combination of a number of services. By combining the facilities offered by a number of services in an ad-hoc fashion the information needs of a user or group of users may be met. The services must, however, be combined in a meaningful way, be adaptive to the changing requirements of the users, adapt to the changes of external factors (environment, device etc.) and be fault tolerant.

The three aspects of capturing users' requirements, designing adaptive services and combining those services in a meaningful way present a number of research challenges in the areas of – User Modeling, Context Modeling, Semantic Interoperability, Multi-modal Information Presentation, Service Composition and Self Management of Services.

This paper discusses the research challenges (Section 2) associated with next generation adaptive services, focusing on context information (Section 3) and how it can be used to fuel adaptive services (Section 4) and their composition (Section 5). The case study of services for personalized eLearning (Section 6) is used to illustrate many of these principals in the given domain.

2. RESEARCH CHALLENGES

This section will briefly discuss some of the research challenges faced in trying to realize the view of dynamically adaptive collaborative services.

2.1 User Modeling

The capturing of appropriate user model information is a common issue in personalization systems. What is less common is the reconciliation of multiple user models to form the basis of adaptation. A user model contains explicitly modeled assumptions that represent the characteristics of the user which are pertinent to the system [20]. The system can consult the user model to adapt the performance of the system to each user's characteristics. This view is changed somewhat considering that we are no longer concerned with a single user. The system, also, may not be a single entity, rather a combination of several services. There are several techniques for modeling users and refining this model, including using a stereotype model [27] [23], overlay model [7] or a combination model.

There are a number of implicit approaches that may be used in acquiring and refining the user model. These include –

- The observation of the user's direct-manipulative interaction with the software system.
- The analysis of the information which the user retrieves from a database or repository [22].
- The system can also explicitly ask the user for information [23] employing mechanisms such as questionnaires.

The reconciliation of the user information with other models in the system impacts upon the context information stored about those models and how interoperable the information in those models is.

2.2 Context Modeling and Semantic Interoperability

Context refers to information that relates to a situation. This typically includes information about the user, environment and potentially the task they wish to achieve. It is important that this information can be gathered (see *User Modeling* above) and shared. The sharing of such information also presents research challenges. Traditionally when interconnecting information systems of different parties, design time solutions (e.g. handcrafting of gateways) have been used to bridge semantic differences that may exist in the information of both parties. Increasingly due to the rapidly changing nature of relationships between parties (e.g. in the B2B area), a solution that allows for semantic interoperability to be achieved at runtime through the dynamic brokering of meaning and the dynamic translation of dialogue between parties is needed. This need for semantic interoperability or shared understanding is particularly visible in the ad-hoc combination of services to fulfill the requirements of a group of users.

2.3 Multi-modal Information Presentation

Multi-modal information presentation involves adapting the material delivered to a device to the characteristics of that specific device. For example, PDAs typically have much less screen real estate than desktop PCs. In this case it may be necessary to modify the content to ensure it renders correctly on the target device. In broad environmental situations users may be using a heterogeneous set of devices to view the same content over time. In these situations equivalent renderings of the content should retain the key features of interest to the users to facilitate effective discussion of that material.

2.4 Service Composition and Self Management of Services

Service Composition is the orchestration of a number of existing services to provide a richer composite service assembled to meet some user requirements. The current major interest in service composition, however, stems from the emergence of web services and the possibility of composing them to provide value-added services over the WWW. Service composition techniques typically involve expressing elemental services and composite services, the latter being compositions of elemental services and other composite services. The definition of composite services requires the expression of the flow of control and information between the elemental services. One of the challenges of combining services in an ad-hoc fashion is that of reliability.

3. DEFINING CONTEXT

Much debate has occurred and is still taking place about the meaning of both context and context-aware computing. Therefore one of the first steps in producing a context management system is to determine what information constitutes context.

Schilit and Theimer, the pioneers of context-aware computing, regard context to be location, identities of nearby people and objects, and changes to those objects. They consider where you are, whom you are with, and what resources are nearby to be the important aspects of context. Abowd et. al.'s more recent classification of context [1] expands the Schilit et al definition. They define context as:

"…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 application themselves."

This means that any information that depicts the situation of a user can be entitled context. The temperature, the presence of another person and the devices a user has at hand are some examples. When humans talk directly to one another they are able to use implicit information about the situation, i.e. context, to enhance the conversational bandwidth. Unfortunately this implicit information does not transfer naturally to human-computer dialogue [17]. The concept behind context-aware computing is to exploit the progress in sensing and mechanisms for observing the environment to systematically collect implicit context [3].

Context information can be formed into an abstract model of all the actors in a smart space system. A system is context-aware if it uses the context information in the abstract model to provide relevant information and/or services to the user. Context-aware systems can make more informed decisions about information to be presented to users and how to react to commands received from users. According to Schilit and Theimer context-aware computing is any system that "adapts according to its location of use, the collection of nearby people and objects, as well as changes to those over time" [29].

Context is effective only when shared [34]. To ensure context is shared, context must first be gathered and managed by a context-aware system. This implies that the context-aware system must understand what context is before it can go about seeking and categorizing this information. Schilit et. al. propose the following classification of context information: [29]

- **Computing Context** - network connectivity, bandwidth, and nearby resources such as printers, displays, or workstations.
- **User Context** - the user's profile, location, nearby people, and current social situation.
- **Physical Context** - lighting, noise level, traffic conditions, temperature.

These forms of context information may be utilized in an immediate, just in time, way or may be processed from a historical perspective. Historical context information is where computing, user and physical contexts are stored across a time span. Potential uses for this stored information would be to establish patterns of smart space usage.

4. CONTEXT AWARE ADAPTIVE SERVICES

Users are very much 'in control' of the current generation of applications (requiring the user to initiate almost all action), there is the danger that users could start to feel helpless and out of control of systems and services that begin to make decisions on their own because they have more information than the user does. This is a key lesson that was learned in the field of intelligent tutoring systems (ITS). After the ITS had gathered the information required (user context) it produced and delivered a personalized course to the learner. The learner, however, was rarely given the ability to adjust the delivered course or ask the ITS to rebuild the personalized offering based on new information.

With context-aware systems, services may exist that can adapt and need less explicit input from the user. For example, many devices could use context information to perform tasks such as turning on and off depending on whether they are (or are likely to be) used, using a discreet mode depending on situation, sharing a controlled amount of information with other services with the user's authorization, adapting information output based on terminal types, etc.

For services to provide support for these capabilities it is imperative that the behavior of their features is adaptable. In this way a service may offer the user only select features depending on the circumstances. The user's attention, therefore, is not cluttered by extraneous features that they do not require to fulfill their goals. If the services make good decisions, based on the information available to them, the user will perceive a better result and be more productive. Conversely a single service may not have the features required to fully facilitate the user in their task. In this situation it would be desirable to be able to combine services, or individual features of services, into a new service to fulfill the user's requirements. This ad-hoc composition of services presents a number of research challenges.

5. ADAPTIVE SERVICE COMPOSITION

Service Composition is the orchestration of a number of existing services to provide a richer composite service, assembled to meet some user requirements. The current major interest in service composition, however, stems from the emergence of web services and the possibility of composing them to provide value-added services over the WWW. Service composition techniques typically involve expressing elemental services and composite services, the latter being compositions of elemental services and other composite services. The definition of composite services requires the expression of the flow of control and information between the elemental services. Techniques for this draw heavily on business process modeling and languages for enactable work flows. Service composition also overlaps with software engineering in the assembly of systems from pre-existing software components. Architectural Description Languages (ADL) address system assembly by assuming components offer well-defined services which are composed to meet system requirements. ADLs address static aspects of such composition, including the use of connectors to express the positioning of protocol or data transformation functions between services.

In context aware environments users (or more likely their agents) will be faced with a changing array of local services, plus varying access to remote web-based services, as users move between environments. The task of orchestrating these services to meet the needs of whatever tasks the user currently wishes to undertake therefore requires adaptive service composition, utilizing appropriate context information and services, i.e. the rapid composition and re-composition of services. The problem of how to dynamically compose services, that are context aware, with little a priori knowledge is therefore analogous to the problem of web service composition.

Chakraborty and Joshi [11] define a difference between *proactive* and *reactive* composition of services. Proactive composition is performed off-line for deployment on stable, always-up, resource rich platforms. Reactive composition assembles compound services, created on the fly under the auspices of some composition manager, often optimizing for real-time parameters, e.g. available network bandwidth. With the introduction of context into this situation one can envisage a combination of reactive and proactive techniques being utilized, i.e. where possible a compound service will be assembled proactively leaving *holes* to be filled reactively later. This approach is analogous to the candidacy/abstraction model implemented in Conlan et al [15], where content holes in a personalized eLearning offering are filled at real-time with the most appropriate candidate. The candidate selection is based on context information about the learner. Real-time selection of appropriate candidates allows the service to utilize the most current information. This approach conforms to the *optional-composite* [11] view of services where not all components need to be in place for service operation.

6. CASE STUDY – ADAPTIVE SERVICES FOR eLEARNING

Course Management Systems (CMS), such as Blackboard [6] and WebCT [33] in the eLearning domain are typically monolithic systems with a fixed (i.e. non-extensible) set of features. This has led to individual CMS vendors attempting to differentiate their products from their competition by promoting and developing some features of their product. The downside of this approach is that certain features of the product may be weak by comparison. For example, a CMS may have strong learner management facilities, good content management, but have poor learner collaboration tools.

This problem may be tackled by separating the individual features into discrete services, allowing the customer to assemble a conglomerate CMS with the features they desire. There are, therefore, some complimentary research themes between this approach in the eLearning domain and the challenge of dynamic assembly of personalized services for business. The key element missing from the current eLearning research is the dynamic assembly of the services. This issue, however, is analogous to the inner workings of adaptive hypermedia systems and may be resolved by applying some of the research themes addressed in personalized content assembly and delivery to automated service combination.

The research goal of our group was to develop a framework for dynamically composing eLearning services that combine the attractive features of the modern re-usability approaches to eLearning with the power of adaptive hypermedia systems based on the open standards of bodies such as ADL [4], AICC

[5] and IMS [21]. It was clear for us that the target framework should keep the winning features of the re-usability approach allowing teachers to structure a course according to their specific needs while also helping them to re-use existing relevant learning content instead of creating everything from scratch. At the same time, we want to enable the teachers to create adaptive courses and re-use not just files, but any interactive and collaborative learning activities. The framework in which the courses are delivered should also support the addition of auxiliary services, such as learner context services, collaboration tools and assessment services.

The first key feature of our solution, implemented as part of the EASEL IST Project [18], was to separate the course management system from the content. In our vision, the course management system is not a storage for all educational content to be delivered (as it is today), but a portal that provides a structured access to educational content without storing it. The content itself comes directly from different content services that are independent from any portal and generally reside on different servers distributed over multiple locations. Portals are maintained by course providers while content services are maintained by content providers. Many portals can use the same content service in very different circumstances.

The second key feature was to separate content specification from the real content. In the current model the search for the relevant content starts with some kind of content specification in terms of duration, pedagogical type, covered topics, etc. The teachers then attempt to find the desired content in a repository by issuing a formal search query in terms of content metadata. Finally, the relevant content is manually selected, copied, and integrated into the course. In our model, the teacher is able to stop at the stage of desired material specification allowing the portal to resolve this specification at runtime by automatically finding or generating relevant content.

The abstraction of the real content and the learning concepts is a key feature that supports the runtime selection of the most appropriate material. From the perspective of service composition this may be represented by the abstraction of the business goals and the actual services used to fulfill them, allowing for the dynamic selection and substitution of services. In both of these domains the issue of semantic interoperability comes into play. The abstract language describing the process and the metadata employed to describe the services need to be interoperable. This does not necessarily mean that they need to be identical, only that there needs to be some mechanism for mapping between the vocabularies used in each.

The services delivered to the user will be adapted based on the context information available to those services. This information may include pertinent details about the learner's learning experiences, including their content display preferences, learning style and prior knowledge. It is the role of the adaptive services, and the adaptive service composition environment, to take account of this information when adjusting their delivery of learning content and services. Context information about the physical environment and surroundings of the learner may also be considered important. For example, if the learner is engaged in a learning experience on a PDA it may be inappropriate to deliver a high quality video stream as the terminal device may not be capable of rendering that content to a sufficient standard. If the learner is situated in a library it may not be appropriate to delivery audio content to them. By utilizing abstraction techniques the learner's needs may be fulfilled with different types of learning material selected based on their requirements and the current situation.

This approach potentially facilitates the separation of responsibility for the personalized learning experience to many services. For example, one service may be responsible for producing a personalized course outline, expressed in terms of the learning concepts to be taught, based on the learner's prior knowledge. This personalized course model may be taken by a service responsible for selecting appropriate learning material candidates from the repositories available. A third service may be responsible for the delivery of an appropriate candidate for the current physical environment as well as monitoring learner feedback. The separation of responsibilities enables individual services to specialize rather than attempting (unsuccessfully) to be many things to many learners.

7. CONCLUSION

This paper has examined the area of context information and how it may be applied to adaptive service composition. Namely, it has looked at how context is defined, gathered and may be utilized by adaptive information services. A case study of context usage in adaptive eLearning was also discussed.

The principle of adaptive service composition was also covered, arguing the benefits of many discrete services combined, possibly at runtime, to fulfill the learner's requirements. Monolithic CMSs invariably lead to user (tutor or learner) dissatisfaction with some features. By combining appropriate context information about the learner with the facilities offered by many discrete services the learner's needs may be addressed in a truly personalized manner.

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