Towards Model-based Development of Context-aware Augmented Reality Applications

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Abstract

Augmented Reality (AR) is a technique that enables users to interact with their physical environment through the overlay of digital information. With the spread of AR applications in various domains (e.g. product design, manufacturing or maintenance) and the introduction of concepts such as Pervasive Augmented Reality (PAR), the aspect *context-awareness* started to play an important role. By sensing the user's current context and adapting the AR application accordingly, an adequate user experience can be achieved. Due to the complex structure and composition of AR applications, their development is a challenging task. Although, context-awareness for AR systems was addressed to some extent, a systematic method for development of context-aware AR applications is not fully covered yet. Therefore, in this paper, we identify the main challenges for development of context-aware AR applications and sketch our solution idea for a model-based development framework.

1 Introduction

Augmented Reality (AR) is a user interface metaphor, which allows for interweaving digital data with physical spaces. AR relies on the concept of overlaying digital data onto the physical world, typically in form of graphical augmentations in real-time [1]. With the spread and increasing usage of Augmented Reality (AR) techniques in different domains, the need for context-awareness in AR was underlined in previous work [2]. However, due to the complex structure (tasks, scenes) and composition (interrelations between real and virtual information objects) of AR applications [3], the development of context-aware AR applications is a challenging task. While context-aware AR applications were introduced for specific application domains, e.g. maintenance [5], a systematic method for supporting the efficient development of context-aware AR applications is not fully covered yet. Therefore, in this paper, we discuss the main challenges in developing context-aware AR applications and sketch a first solution idea for a model-based development framework for context-aware augmented reality applications.

2 Challenges

Based on IBM's MAPE-K architecture (shown in Figure 1) which can be seen as an architectural framework for self-adaptive and context-aware systems and relying on our previous work in the area of UI adaptation for web and mobile apps [4], we identified the following main challenges for development of context-aware AR applications:

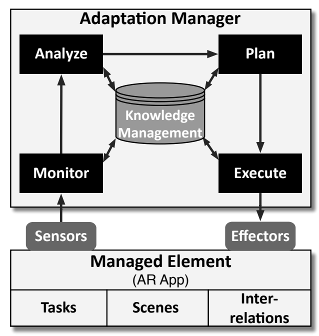

Figure 1: Challenges for context-aware AR.

(C1) Context Monitoring. First of all, context monitoring, represented as the *Monitor* activity in Figure 1, is an important prerequisite for enabling context-aware applications in general. An important challenge in this regard is to continuously observe the context-of-use of an AR application through various sensors. The context-of-use can be described through different characteristics regarding user (physical, emotional, preferences etc.), platform (Hololens, Handheld, etc.), and environment (real vs. virtual environmental information). Due to the rich context dimension which is spanning over the real world and virtual objects, it is a complex task to track and relate the relevant context information to each other. The mixture of real (position, posture, emotion, etc.) and virtual (coordinates, view angle, walk-through, etc.) context information additionally increases the aspect of context management compared to classical context-aware applications like in the web or mobile context.

(C2) Decision Making. Based on the collected context information, a decision making process is performed to analyze and decide whether conditions and constraints are fulfilled to trigger specific adaptation operations on the *Managed Element* which in our case is an AR application. For this purpose, the decision making process makes use of the activities *Analyze* and *Plan*. In general, an important challenge is to cope with conflicting adaptation rules which aim at different adaptation goals. This problem is even more emphasized in the case of AR applications as we need to ensure a consistent display between the real world entities and virtual overlay information. For the decision making step it is also important to decide about a reasoning technique like rule-based or learning-based to provide a performant and scalable solution.

(C3) Adaptation. The key responsibility of the *Adaptation Manager* is to execute the adaptation operations conform to the previously described steps (see *Execute* activity in Figure 1). As AR applications consist of a complex structure and composition, an extremely high number of various adaptations is possible. The adaptations should cover text, symbols, 2D images and videos, as well as 3D models and animations. In this regard, many adaptation combinations and modality changes increase the complexity of the adaptation process.

(C4) Knowledge Management. During the adaptation process of a context-aware AR application, the responsible sub-components of the *Adaptation Manager* can store various information (e.g. context information, executed adaptation operations, etc.) in the *Knowledge Management* component. This component is not only responsible for storing all these kinds of information, but can also be used to improve the adaptation process based on previous information about context and pursued adaptations. Considering the complexity of AR applications, the design and implementation of a suitable *Knowledge Management* component is a challenging task where special focus on data management, update policy etc. is required.

3 Solution Idea

To address the previously introduced challenges, we combine our previous work on model-driven development of adaptive UIs for web and mobile apps [4] with an existing method for structured design of AR UIs [3]. As shown in Figure 2, our solution concept addresses three different aspects: *AR UI*, *Context*, and *Adaptation*. Regarding the *AR UI* aspect, shown in the leftmost column in Figure 2, we rely on the approach and the *SSIML/AR* language of Vitzhum [3]. *SSIML/AR (Scene Structure and Integration Modeling / Augmented Reality)* is a visual modeling language which provides model elements for modeling virtual objects and groups in a virtual scene. Additionally, the relations between application classes and the 3D scene can also be specified. Using *SSIML/AR*, an abstract specification of the user interface of the AR application is created. This *Abstract AR UI Model* is the input for the *AR UI Generator*, which generates the *Final AR UI*. In order to support the creation of context-aware AR apps, we complement the development method with two additional aspects, namely the *Context* and *Adaptation*, originally presented in [4]. The *Context* aspect serves to characterize the dynamically changing context-of-use parameters by providing an abstract specification in terms of a *Context Model*. Based on the *Context Model*, the *Context Service Generator* generates the *Context Service* which monitors context information like brightness, acceleration or noise level. The *Adaptation* aspect addresses the specification of the adaptation logic in terms of abstract AR UI adaptation rules represented as the *Adaptation Model*. The specified AR UI adaptation rules reference the *Context Model* to define the context constraints for triggering adaptation rules and they also reference the *Abstract AR UI Model* to define which AR UI elements are scope of a UI adaptation change. The *Adaptation Model* is the input for the *Adaptation Service Generator* which generates an *Adaptation Service*. At runtime, the *Adaptation Service* monitors the context information provided by the *Context Service* and adapts the *Final AR UI*.

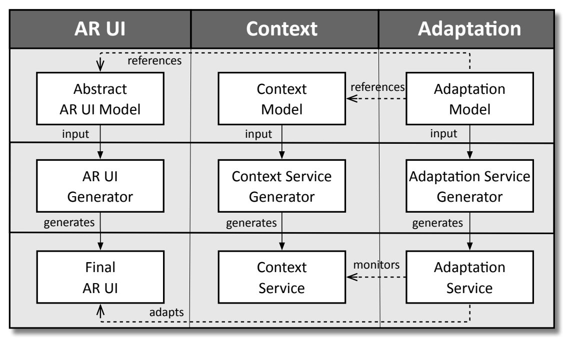

Figure 2: Solution Idea for Context-aware AR.

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