Implementing a Pervasive Meeting Room: A Model Driven Approach [⋆]

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Abstract. Current pervasive systems are developed ad-hoc or using implementation frameworks. These approaches could be not enough when dealing with large and complex pervasive systems. This paper introduces an implementation of a pervasive system for managing a meeting room. This system has been developed using a model driven method proposed by the authors. The system is specified using PervML, a UML-like modeling language. Then, a set of templates are applied to the specification in order to automatically produce Java code that uses an OSGi-based framework. The final application integrates several technologies like EIB and Web Services. Three different user interfaces are provided for interacting with the system.

1 Introduction

Currently pervasive systems development is a hot topic in computing research. Researchers in this area have developed many software systems which try to achieve the Weiser vision. These systems have been implemented completely ad-hoc or using implementation frameworks that support the specific requirements of this kind of systems. Developing a pervasive system following these approaches is a hard and error-prone task. In order to improve the productivity and reduce the number of errors, we propose to apply the newest trends in software engineering to the pervasive systems field.

Following this idea, we have developed a method that applies the Model Driven Architecture (MDA) [1] and the Software Factories [2] approaches to the development of pervasive systems [3]. These strategies propose to use models for automatically generating the final system, and not only for generating documentation or for guiding the implementation process.

This paper introduces a case of study of a pervasive meeting room that has been developed using our model driven method. The method is based on the specification of the system using PervML, a UML-like language designed for easily describing the functionality of pervasive systems. Then, the PervML specification is automatically translated into Java code. The generated code extends an OSGi-based framework in order to build the final pervasive application.

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The paper is structured as follow: Section 2 briefly introduces the model driven method that is applied in the paper. Section 3 describes the functionality provided by the pervasive system that has been developed for improving a meeting room. Section 4 shows the specification of the pervasive system using the PervML language. Section 5 describes some implementation details, like the hardware and software used for developing the prototype. Finally, Section 6 introduces some conclusions and future lines of research.

2 Method Overview

The proposed method for the development of pervasive systems, which was presented in [3], applies the guidelines defined by the Model Driven Architecture (MDA), that is supported by the Object Management Group (OMG), and the Software Factories, that is supported by Microsoft. Following these guidelines, the method provides (1) a **modeling language (PervML)** for specifying pervasive systems using conceptual primitives suitable for this domain, (2) an **implementation framework** which provides a common architecture for all the systems which are developed using the method, and (3) a **transformation engine** that translates the PervML specifications into Java code.

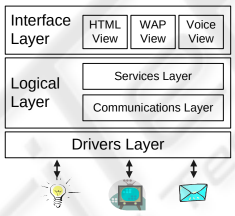


Fig. 1. Framework architecture.

The implementation framework, which is introduced in [4], has been build on top of the OSGi middleware. It provides similar abstract classes to the PervML conceptual primitives (*Service*, *Trigger*, *Interaction*, etc.) in order to facilitate the translation process. Fig. 1 shows the overall framework architecture. This architecture has been designed with the aim of providing facilities for integrating several technologies (EIB networks, web services, etc.) and for supporting multiple user interfaces.

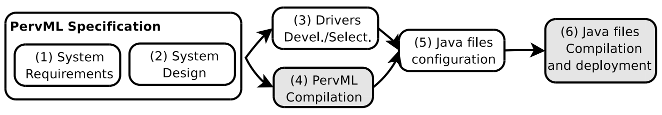

PervML Specification
(1) System Requirements
(2) System Design
(3) Drivers Devel./Select.
(4) PervML Compilation
(5) Java files configuration
(6) Java files Compilation and deployment

Fig. 2. Steps for applying the proposed.

Fig. 2 shows the steps that should follow a development team. The grey bubbles are automatically carried out. Next we briefly introduce each step:

1. The **system analyst specifies the system requirements** using the *service* conceptual primitive. The system analyst uses three kind of PervML models in order to describe (1) the kind of services available on the system, (2) the number of services which are availables in every location and (3) how they interact when some condition holds.
2. The **system architect selects the kind and number of devices or software systems** that are more suitable in order to provide the services specified by the analyst. The selection could have into account economical reasons or constraints in the system physical environment. The system architect uses other three PervML models for describing (1) the kind of devices or software systems that are used for providing the system services, (2) the specific elements that are going to implement every service and (3) the actions that the device or software systems must carry out for providing every service operation.
3. An **OSGi developer implements the drivers for managing the devices or software systems** which were selected by the system architect. These drivers provides access from the OSGi-based framework to the devices or external software systems. They must be developed by hand, since they deal with technology-dependent issues. If any device or external software system was used in a previous system, the same driver can be reused.
4. The **transformation engine is applied to the PervML specification**. Many Java files and other resources (Manifest files, etc.) are automatically generated as a result of this action.
5. The **Java files are configured in order to use the selected drivers**. This configuration only implies to set up the drivers identifiers.
6. Finally, **the generated files are compiled, packaged into bundles (JAR files) and deployed** in the OSGi server with the implementation framework and the drivers.

The proposed method is focused on the development of the software system that is part of the pervasive system. The physical installation of devices, networks, etc. is out of the scope of this work.

3 Case of Study: The Pervasive Meetings Room

The case of study which is shown in this paper aims to improve the functionality provided by a meeting room. This section briefly describes the functional requirements that must be fulfilled by the pervasive system.

The meeting room, which is shown in Fig. 3 provides two kind of lighting services: the main lighting service, which covers all the room, and an specific service for lighting a projector screen. Users must be able to switch these lighting services manually using some kind of device. When anybody is near the screen, the intensity of the specific lighting must be decreased in order to provide a better visibility. Moreover, a security system must record what happens in the room if anybody is there when the security is activated.

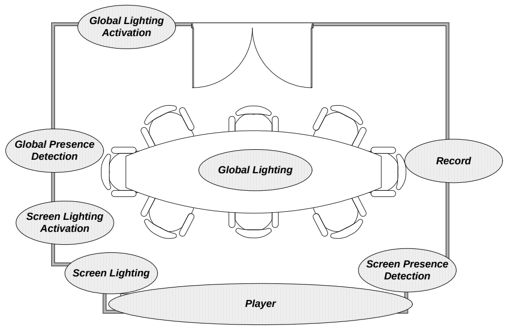

Global Lighting Activation
Global Presence Detection
Global Lighting
Record
Screen Lighting Activation
Screen Lighting
Screen Presence Detection
Player

Fig. 3. The meeting room plan.

4 System Description using PervML

Perv-ML is a language designed with the aim of providing to the pervasive system developers with a set of constructs that allow to precisely describe the pervasive system. Perv-ML promotes the separation of roles where developers can be categorized as analysts and architects. Systems analysts capture system requirements and describe the pervasive system at a high level of abstraction using the service metaphor as the main conceptual primitive. System architects specify what devices and/or existing software systems realize system services. Next we give a more detailed description of the language and how it is applied to the meeting room case of study.

4.1 The Analyst View: Specifying System Requirements

The goal of the pervasive system analyst is to capture the system requirements using high level of abstraction primitives. PervML considers that a pervasive system provides services to the users in an environment. In the **PervML Analyst View**, the analyst describes the pervasive system using the *service* metaphor as the main conceptual primitive. This view is composed by three models which are shown in Fig. 4.

The system analyst uses the **Services Model** for describing the kinds of services that are provided in the pervasive system. The diagram which represents the Services Model in Fig. 4 shows that the meeting room provides services for controlling the lightings, for detecting presence, for recording video, etc. Additionally to the information shown in Fig. 4, the description of a kind of service includes (1) **pre and post conditions** (which are expressed using the Object Constraint Language (OCL)) for every operation, (2) a **Protocol State Machine** which indicates the operations that can be invoked in a specific moment, and (2) **triggers** which allow specifying the proactive behaviour of the services.

The system analyst uses the **Structural Model** to indicate the instances of every kind of service which are provided by the system. The services are represented as components whereas the kind of service that they provide is depicted as an interface (using the lollipop notation). Dependency relationships between components can be included in order to specify that one component uses the functionality provided by another. In

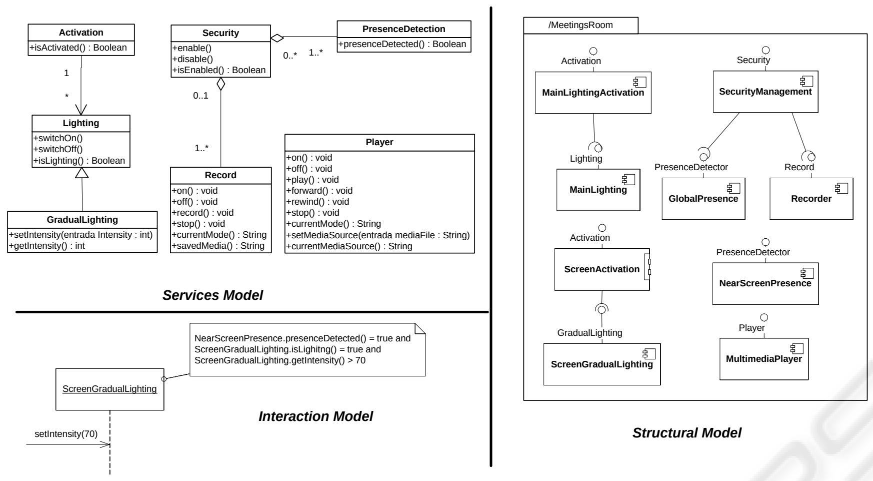


Fig. 4. The models that are used in the Analyst View.

our case, the `SecurityManagement` component that provides the *Security* kind of service uses the functionality provided by the `GlobalPresence` and the `Recorder` components.

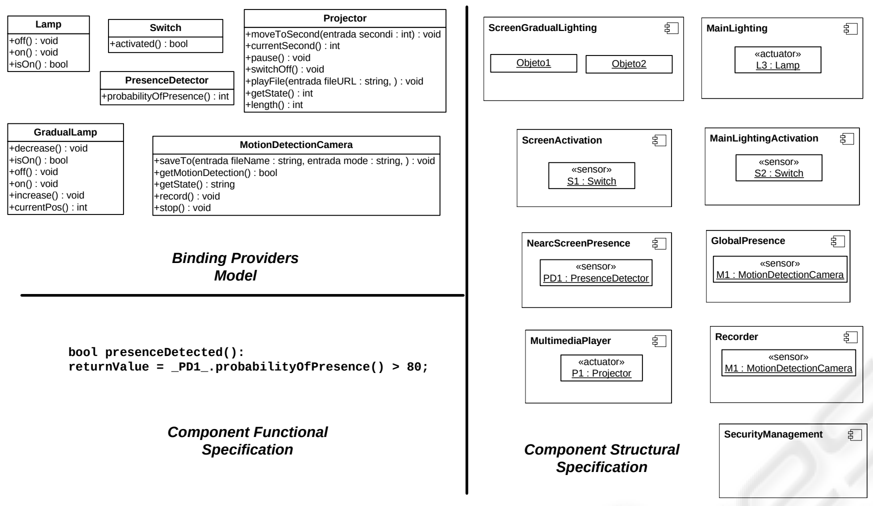
The system analyst uses the **Interaction Model** for describing the actions that are carried out in the system when some condition holds. This model is composed by a set of UML 2.0 sequence diagrams. Fig. 4 shows the interaction that is in charge of decreasing the light intensity when anybody is near the screen.

4.2 The Architect View: Designing the System

In order to provide a complete specification, an abstract description is not enough. The devices and software systems that conform the pervasive systems are key elements, since they are the final suppliers of the system functionality. We call **binding providers** to these elements (devices and software systems), because they bind the pervasive system with its physical or logical environment.

In the **PervML Architect View**, the architect specifies what kind of devices and software systems are used in the system, which elements implement every service and how these elements provide the service. The system architect decisions must take into account issues like the project budget, device availability, the physical environment structure, etc.

The system architect uses the **Binding Providers Model** to describe the different kind of devices or software system that are used in the pervasive system. Fig. 5 shows the Binding Providers Model for our meeting room. For instance, the diagram specifies that the *PresenceDetector* sensor provides an operation which returns the probability that anybody is detected in a location. It is important to note that this model describes the functionality provided by a kind of device or software system, but it is not tighted



```
bool presenceDetected():
returnValue = _PD1_.probabilityOfPresence() > 80;
```

Fig. 5. The models that are used in the Architect View.

to any specific item. For instance, the *Lamp* described in the model could be finally implemented as an EIB lamp or a X10 lamp or a lamp in any other control network.

The system architect uses the **Component Structure Specification** to assign devices and software systems to every system component. Note that the same binding provider can be used for implementing several services. For instance, the *MotionDetectionCamera* is used both for implementing a *PresenceDetection* service and a *Recorder* service.

The system architect uses the **Component Functional Specification** to specify the actions that are executed when an operation of a service is invoked. These actions are specified using the Action Semantics Language (ASL) of UML. Every operation provided for every component must have associated a functional specification. Fig. 5 shows the actions that are executed when the `presenceDetected` operation of the *GlobalPresence* is invoked. The specification determines the return value comparing the probability returned by the presence detector device (called *PD1*) with a threshold value that is fixed to 80%.

5 Implementation Details

In this section we provide some details about the finally produced pervasive system. Fig. 6 shows the overall network structure. The central server is a Pentium IV barebone with 512Mb RAM and connectivity by ethernet, 802.g and serial port. The barebone runs a Windows XP Professional Edition. We have selected the Prosyst Embedded Server 5.2 as the OSGi implementation.

In order to support the control devices (lights, switches and presence detector), an EIB network has been deployed. The pervasive system accesses to this network by

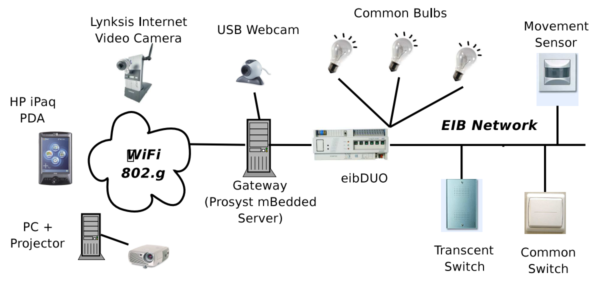


Fig. 6. Network structure of the meeting room system.

means of the EIB bundle provided by Prosyst. The barebone is physically connected to the network by the serial port.

The **camera with motion detection capabilities** is a *Linksys Wireless-G Internet Video Camera*. This camera provides the video as an ASF stream. Moreover, it can be configured to send an email when it detects some kind of motion. We have developed an OSGi driver for integrating in our system these features.

Finally, the **projector** has been implemented using *a common projector attached to a Pentium II*. This computer runs a Windows XP Home with a Windows Media Player in full screen mode. The projector computer hosts a program which provides web services for controlling the Media Player. We have developed an OSGi driver for accessing these web services from the pervasive system.

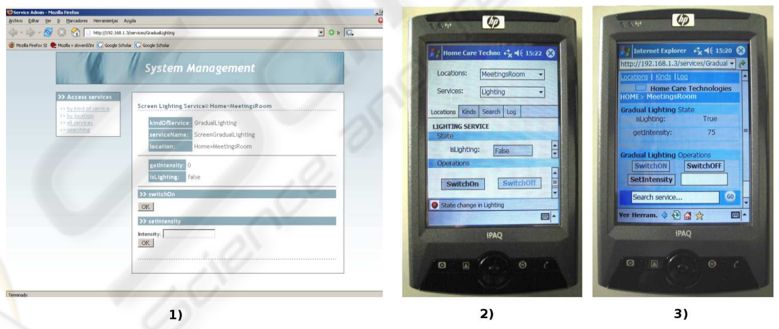


Fig. 7. The three user interfaces for managing the pervasive system.

Users interact with the system using several kind of devices, so multiple user interfaces must be provided. Currently, we provide three different user interfaces, which are shown in Fig. 7 : (1) A **Web interface for desktop browsers** (Fig. 7, 1), (2) a **native PDA application** (Fig. 7, 2), and (3) a **Web interface for PDA browsers** (Fig. 7, 3).

6 Conclusions

This work introduces an application of the Model Driven Development approach to the field of pervasive systems. Following the proposed method, the specification of the system functionality is independent of the devices selected for implementing the system. Moreover, all the specification is independent of manufacturer issues. The manufacturer dependent details are isolated in the drivers layer. These characteristics provide a high degree of manufacturer an technology independence: we can change all the implementation technologies just replacing the drivers, but from the user point of view the functionality provided by the pervasive system still remains the same.

As a future work, we plan to extend the expressiveness of PervML and the features of the implementation framework in order to give suppport to (1) the specification of richer user interfaces, maybe applying the SmartTemplates approach [5] and/or using a language for describing user interfaces like UsiXML [6], and (2) the specification as first order entities of context-awareness characteristics and their implementation using a framework like the proposed in [7].

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