Collaboration and Modeling in Ambient Systems: Vision, Concepts and Experiments

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Abstract

We focus on organizations developing products: A product is developed through the development of a model of the product and the model is developed through collaboration among developers. We relate the model in physical and informational spaces. Actual interaction with informational model space has effect on the physical space and vice versa. The collaboration process is supported by a collaboration environment where we relate informational and physical spaces. Actual collaboration in physical space is reflected in the informational space and vice versa. Finally, also model and collaboration environment are related.

1. Introduction

Systems to support organizations in the process of developing products are presented. Products are developed through collaboration on models of the product. The systems seek to relate and combine real-world systems, informational systems and models into a cohesive whole. Typically traditional systems supporting the development process do so in a fragmented way, with an emphasis on either physical or informational systems, but not both types.

The presentation is organized as a scenario involving Hans Christian Andersen’s House illustrating the overall vision. The scenario is followed by a brief characterization of the ingredients of the system: collaboration model, collaborative modeling and relations between model and modeling. Finally, the notion of ambient systems is introduced as background for the vision.

In ambient systems users participate in several ongoing computations. Time and space aspects are central in the systems. The systems usually identify users, collaborate intelligently, and support users in their ongoing activities. The notion of software-based system is a moving target in the software engineering discipline. Technologies continuously evolve our understanding of potential systems. The domain and type of such future systems challenge the software engineering discipline. But typically the available technologies of software engineering neither support appropriate collaboration of users, customers and developers nor offer advanced language and tools for individual work of the developer. The system envisioned includes essential and general aspects of ambient systems: The concepts and relations enable less expensive, more efficient and less complex software development processes and systems.

The purpose is to support collaboration and modeling by means of ambient systems. The functional requirements [1] to the system are not specified, revised and evaluated explicitly through the development process. The vision and concepts introduce additional challenges and complexity to the functionality of the system. The non-functional requirements (qualities) [1] include understandability, flexibility and efficiency in the collaboration and modeling process. The vision and concepts support the qualities by offering additional possibilities and advantages.

The design and implementation process of the system is based on prototyping [2] with iterations consisting of functional selection, construction, evaluation and further use. In general for a prototype functional selection has been ad hoc, construction has been simple and straightforward, evaluation has been informal, and further use of most systems is mainly extensive and successful. Evolutionary prototyping has not been intentional but various designs and implementations turn out to be reusable. Both exploratory and experimental prototyping have been explicit and mainly successful.

2. Scenario: Andersen’s house

The scenario is a complicated rebuilding of Hans Christian Andersen’s House in Odense (HCA scenario). Fig. 1 (left) is the old building (Andersen’s childhood home in Odense) of which several models exist. Fig. 1 (right) is a model of a revision of the house with facilities for exhibitions etc.
A group of people is working on the redesign project where some of them are situated in Copenhagen, others in Odense etc. Project meetings are arranged either at the same physical location or in informational space. In informational space project members are projected onto wall screens at the respective locations and anyone in the group can see and hear each other.

Some models of the house are physical plastic models or drawings and others are informational abstract diagrams presenting specific perspectives on the building. One physical model is at one location only, but is projected onto wall screens at other locations. Informational models are shared on screens at all locations.

Another physical model also exists in informational form. The participants may modify the physical model and the effect is shown both at the projections of the physical model and in the physical model. Others may modify the informational model to affect the physical model accordingly.

During the meeting the group needs assistance from other persons in the company. From the organization model the relevant persons are located and moved in the organization model to participate in the project meeting. The persons accept to participate and join the meeting in either physical or informational space.

During the meeting the group realizes that actual information about Andersen’s House is needed. A person present at Andersen’s House is then included in the meeting. That person is wearing positioning and communication equipment. A three dimensional model in informational space is created and pictures from the on-location person are related to the model of the house. The other participants can direct the person in Andersen’s House by pointing at the model.

3. Modeling and collaboration

3.1. Concepts and spaces

We focus on a system that addresses the general challenges for the organization to develop models of products. The concepts tangible object, context, and association [3], [4], [5] support collaborative modeling and collaboration models. These concepts are abstractions and in addition they supply each other and may be combined in collaboration descriptions and executions. Tangible objects cover autonomous entities like users, devices, etc. Associations cover group activities between tangible objects like collaborations, meetings, etc. And contexts cover universes in which tangible objects and associations exist—like rooms, places, etc. Fig. 2 illustrates the concepts schematically: Contexts are illustrated by three boxes. A context includes tangible objects—either users or devices illustrated respectively by stick figures and green circles. Associations are illustrated by figures with a pink center. The users and devices are tangible objects related by the associations and existing in the contexts. The system is dynamic i.e. the actual instances of tangible object, context, and association may appear and disappear.

The system supports the activities of the organization across two dimensions: the physical dimension and the informational dimension. The physical dimension encompasses the real-world as we know it: stakeholders, meeting rooms, computers, whiteboards, and other physical tools and artifacts. These are crucial aspects of the organization that must be supported. The informational dimension encompasses the models that are being produced, the tools that are used, and information about the organization, process and product.

The challenge is to support various aspects of development—including the users, the process, and the product—by a system that combines physical and informational dimensions. Not only are these two dimensions important, but they are intimately connected. Traditionally, much of our work takes place with informational content but in physical environments, with physical tools and with other people. Additionally, the surrounding context of the product—namely, the development organization itself—has significant informational content that should be managed. Traditionally, such contextual information has been described in a more or less implicit and informal fashion; the products themselves have assumed prime focus. But products do not exist in a vacuum: They are developed in and for a context.

We also push the envelope: not only do we combine physical and informational dimensions of work, but we
invent new ways of enriching the physical dimension with informational content. We do this by incorporating concepts and technology from pervasive and ubiquitous computing. In this way we combine the physical and informational spaces, and additionally we create new ways of working and representation.

3.2. Model space

Efficient modeling is crucial to the organization. To that end, we conceive of the model space. The model space encompasses the tools and techniques that we use to create models, the models themselves and the relationships between different models. The model space is the content of the models and the ways in which we interact with these models (through tools and techniques). The model space exists in some kind of physical environment—this is necessary, because we need physical artifacts and environments to express our models. And there must be interplay between the physical environment and the model space: this is a key motivation behind the vision. Fig. 3 illustrates collaboration (to the left) that results (the blue arrow) in a model (to the right) in model space. The model relates material in both informational and physical spaces. For example in the HCA scenario model space may include models of the house, rooms and artifacts from Andersen’s life.

Fig. 3: A model is developed in model space

Models include potential possibilities in model space with developers looking at models of organization, process and products while situated in a developer’s pervasive computing milieu. To create a model space, we conceive of technologies and tools. We imagine a room with advanced user interfaces: wall-screens, 3-D shutter glasses, holobenches, and other augmented physical material (physical artifacts with “informational coating”). In informational space, we conceive of a number of closely related tools that can observe, manipulate, and communicate with systems and users (developers and managers). This may include models that reflect systems in execution, diagrams that we can modify in real-time, databases with drill-down and slice-dice capability.

3.3. Collaboration environment

We conceive of an environment supporting the model space called the collaboration environment. This typically includes a room in physical space that will support meeting and work sessions, for the purpose of exploring and creating in the model space. A collaboration environment is optimized for modeling and collaboration. This means that there is physical support for the model space: wall-screens, sound and vision capabilities, tables, wall space and floor space to walk around while working. There is also informational support: wireless networks, software for maintaining the models, connections to databases that hold models and code, access to online systems, and groupware. The collaboration environment is not just a room: it is designed for developers to work together in the model space. Fig. 4 illustrates the collaboration environment: The environment relates material in both informational and physical spaces. For example in the HCA scenario project collaboration may take place in meeting rooms, offices and laboratories with computers and various devices.

Fig. 4: Collaboration Environment

The collaboration environment supports how people work together physically in the same room, as we are physical creatures. But like other enterprises, the organization can be geographically distributed. Thus, the collaboration environment is also a virtual environment, one that supports remote collaboration. There are two scenarios for this. In one scenario, multiple sites employ their own collaboration environments, thus bringing groups of teams in different locations ‘together’ in a unified model space. In a second scenario, we consider developers accessing the model space from more limited devices and spaces such as a PDA, notebook computer or desktop computer. The reasons for this include the cost of building a collaboration environment, the lack of resources at a given location, and the fact that developers may be mobile. In both scenarios, developers are allowed to enter and participate in the model space, being able to perform actions that are reflected in the model space and examine the state of the model space.
4. Dimensions and relations

Several dimensions are involved:
• In the collaboration environment a model is developed and the model exists in model space. The collaboration environment may itself be described by a collaboration model. The collaboration environment and the model space are related.
• A model relates material from informational and physical spaces, i.e. a model may have both informational description and physical existence (and this existence may be an execution if generators are available for descriptions).

4.1. Physical and informational relations

In model space:
• Physical models are built from various building bricks (LEGO bricks are a famous example). Autonomous models not only adjust to external modifications but may adjust themselves. Various devises may be part of these models with various interfaces.
• An example of an informational model is an object-oriented model. Elements of object-oriented models are classified and may be specialized and aggregated. The models are equipped with interfaces. Informational models also have the possibility to explain themselves.

Fig. 5: Model space: Relations between informational and physical material

Models in these spaces are coupled—a modification to one model makes a coupled model change accordingly. Several physical and informational models may coexist in coupled form. Each model exposes its unique qualities to be accessed through its specialized interface. Fig. 5 illustrates relations in model space: The red curves illustrate how various elements from informational and physical spaces are coupled. The individual qualities of a model make the interaction unique for the user. For example in the HCA scenario you may point to a wall in the physical house and the same wall in informational models is visualized—and vice versa.

In collaboration environment:
• In physical collaboration users interact according to the usual practice, and their understanding of their interaction is typically only implicit. Devices with interfaces may be involved in the interaction.
• In informational collaboration abstractions for describing the collaboration may be available, e.g. like the association concept. Either associations may prescribe the interactions of the collaboration or actual interactions may be registered by associations. An association description supports an overall understanding and explanation of the collaboration.

Models are coupled but each model exposes its unique qualities. Traditional physical collaboration may be registered and analyzed. For example in the HCA scenario a person in the physical room may communicate and interact with a person projected on the wall—and vice versa.

Fig. 6: Relations between collaboration environment and model space

Finally, collaboration environment and model space are related too:
• Identical elements in model space and collaboration environment may be coupled.
• Interfaces for model and collaboration may be coupled.

Fig. 6 illustrates relations between environment and model space: The red curves illustrate how various elements are coupled. For example in the HCA scenario project meetings may be coupled to models of the house: A physical wall may both be used in the environment to support manipulation of artifacts and be a wall in a physical model of the house containing artifacts from Andersen’s life. Also the environment may include rooms at Andersen’s house. A repository in information space may both be used in the environment to manage the reconstruction of artifacts and be a wall in a physical model of the house containing artifacts from Andersen’s life. Also the environment may include rooms at Andersen’s house. A repository in information space may both be used in the environment to manage the reconstruction of artifacts from Andersen’s house and be used to organize the same artifacts in the model. Finally, the same interfaces may be used for browsing through rooms in an informational model and rooms of the informational collaboration environment.

4.2. Description, dynamicity and layer

Models relate physical and informational material appropriately, but additional dimensions exist:
• We distinguish between descriptions of models and existence, i.e. instances from the descriptions. Typically, descriptions mostly involve
informational material but may also include physical material. And typically, instances mostly consist of physical material but essential aspects may be available as informational material. Generators may automatically create instances from a description. In Fig. 7 generation of instances from descriptions is illustrated by red arrows: To achieve simplicity a description is illustrated by informational material only (bottommost) and an instance by physical material only (topmost).

- Physical and informational models are not necessarily static, but may also be dynamic: Associations are part of models and describe collaborations between the elements of a model. And these descriptions may enable and control actions. A collaboration model not only describes interaction (by associations between the users participating in the development process) but may also describe the organization of the interacting users.

- Descriptions and instances are organized in layers: The product from a collaborative modeling process may be a collaboration model. From a collaboration model an instance may be generated that is itself a collaboration process. Fig. 7 also illustrates this situation: The blue arrow indicates the development of a model, and from this model another collaboration process is generated.

5. Experiments

In ambient systems, we evolve from “users interacting with information systems” to “users participating in active systems”. Information systems support participants’ intentions and work tasks. However, participants have the initiative: they deliver and ask for information. In ambient systems participants can have the initiative. However, the goal is not to provide information per se, but explicitly to support various activities in the physical world, i.e. enable, control, document, explain, etc. collaborative activities.

Ambient systems are combinations of reality-virtuality continuum systems (e.g. [6], [7]) and ubiquitous computing systems (e.g. [8], [9]) including intelligent robotics (e.g. [10], [11]). The conceptual understanding underlying these systems is based on real world systems, their model systems and the combination of these in terms of concepts and phenomena. Users interact with several of such real world or model systems simultaneously. Users need models to understand and use ambient systems and developers need models in order to design and implement these systems [12].

Modeling is based on target, referent and model system [3]. And tangible objects, contexts and associations are concepts and phenomena in the referent system as abstractions of artifacts and interaction [4]. Associations are abstractions over interaction [5]: The directive of an association gives the sequencing rules for interactions among the autonomous entities participating in the association. The interactions are processed sequentially and only the entity itself executes its methods. An entity concurrently executes its contributions to the collaboration in the context of the entity.

The experiments include a mock up of the HCA scenario as an exploratory prototype. As expected this HCA prototype was illustrative concerning the understanding of the intension as well as the possibilities of the system. Several minor experimental prototypes have supported the possibilities and efficiency especially of software and hardware as well as experience concerning human interface.

An important exploratory prototype with modeling collaboration between individual artifacts is presented in [13]. An artifact has a basic structure and a behavior and we model interactions between these artifacts. The model is executable—and the artifacts interact in physical space e.g. by handling other artifacts and moving in relation to each other. The artifacts interact in informational space by sending messages between each other. An artifact is a physical LEGO figure that
also exists in the informational space. The scenario is children playing with dolls with behavior: Dolls can walk, shake hands, talk, etc. They play by making the dolls interact by creating and manipulating sequences of behavior: The family wakes up, the mother goes to work, the father tidies the home, etc.

The virtual environment of the experiment is illustrated in Fig. 8: The top part is a visualization of informational (to the left) and physical (to the right) spaces. The logical part at the bottom is an application framework in JAVA with Tangible Object, Context and Association as abstract classes. The simulator in the middle part maintains the repository of tangible objects, contexts and associations, and supports user interaction with the virtual environment.

Even though the focus is on children’s play with collaborations between artifacts, the system is mainly domain independent. However, the model is in focus while the environment mostly is non-existing. The evaluation of this ambient system includes

- Even though being domain specific the functional support is promising and no essential problems have been detected (including technology).
- Abstraction and concepts (tangible object, user, habitat and association) support understandability for the user and thereby usability of the system.
- The relation of informational and physical spaces supports efficient and flexible development of collaboration models.

6. Conclusion

A vision of collaboration is presented together with supportive concepts. Collaborative development of models is supported by an environment and a model space. In both environment and model space physical and informational material are related in order to support efficient and flexible modeling process and product. Design and implementation are conducted by prototyping. This ambient system is not only general but also powerful and understandable.

Further work must include and relate to existing systems and results for collaboration and modeling. Additional experimental prototyping should only be conducted when more experience concerning potential functionality is necessary. The existing exploratory prototype [13] should be extended and revised to further investigate understanding, flexibility and efficiency. A challenge is to include the environment (and not merely the model) explicitly. This continuation must be conducted mainly as an evolutionary prototype in order to ensure that this experiment includes a certain size and a necessary amount of functionality.

7. References