Generic Adaptation Process

Evgeny Knutov, Paul De Bra, and Mykola Pechenizkiy

Department of Computer Science, Eindhoven University of Technology
e.knutov@tue.nl, debra@win.tue.nl, m.pechenizkiy@tue.nl
P.O. Box 513, 5600 MB, Eindhoven, the Netherlands

Abstract. Adaptive Hypermedia Systems (AHS) have long been mainly represented by domain- or application-specific systems. Few reference models exist and they provide only a brief overview of how to describe and organize the 'adaptation process' in a generic way. In this paper we consider the process aspects of AHS from the very first classical 'user modelling-adaptation' loop to a generic detailed flowchart of the adaptation in AHS. We introduce a Generic Adaptation Process and by aligning it with a layered (data-oriented) AHS architecture we show that it can serve as the process part of a new reference model for AHS.

1 Introduction and Background

Throughout the development of the Hypermedia and later Adaptive Hypermedia (AH) research field people have been trying to create 'reference' models of these categories of systems. Major reference models have been favouring a layered architecture, starting with the Dexter Hypertext Model [7], and later the Tower Model [5] (introduced as the Extensible Data Model for Hyperdocuments) and this was continued in adaptive hypermedia with the most referenced AHAM [6] model, followed by other systems/models, such as LAOS [11] (elaborating layered approach), APeLS [4], the Munich model [10], etc. However, these developments were mostly concerned with the structure and/or the data model, but not as much with the process underlying the adaptation.

In the paper we examine the issue of aligning the adaptation process, based on an extensive list of AH methods and techniques [9], with a layered structure of AHS. We show that to some extent the process influences and defines the composition and the sequence of such a layered structure in such a way that it partially arranges the order of the layers, defines couplings and determines the major transitions in the system. We show that the process driven approach gives more insight in AH development methods and the composition of the AH system.

1.1 Adaptation Process Modelling

Hereafter by *Generic Adaptation Process* we mean the interaction in AHS which starts with the goal statement, exploits features of the user and domain models in

different contexts and adapts various aspects of the information and presentation to the user. Figure 1 shows this user modeling / adaptation loop as originally presented in [3].

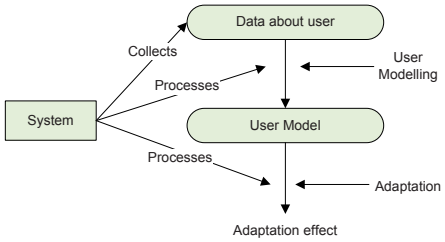
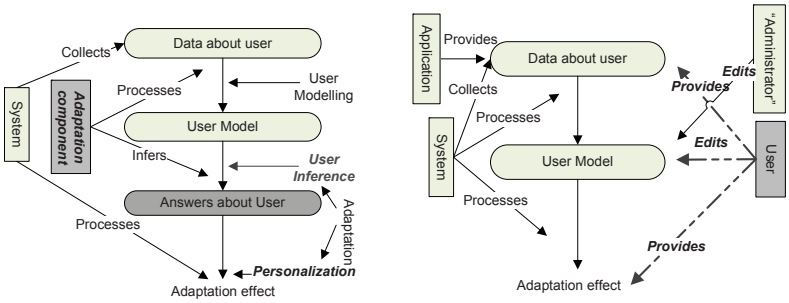


Fig. 1. Classic loop user modelling - adaptation

Considering a generic adaptive system one may think not only about defining a framework or reference (data) model but also about what the adaptation process within the system looks like, beyond what Fig. 1 shows. Fig. 2 shows some extensions of the classical loop, taking into account that selection of user information or reasoning about the user model to obtain answers about the user is an essential part of the adaptation process (Fig. 2a) and that either the user or an administrator (or both) need the ability to scrutinize the user model (Fig. 2b).



(a) User model inference - adaptation loop

(b) Collaborative user model editing (User and Administrator involved)

Fig. 2. User modelling - adaptation loops

These updated 'user-modelling - adaptation' loops give a more extensive overview of some aspects of the adaptation, however in [9] we integrated the entire classification of AH methods and techniques (see Sect. 2) with the adaptation process cycle to give a first insight into the generic adaptation process flow, see Fig. 3.

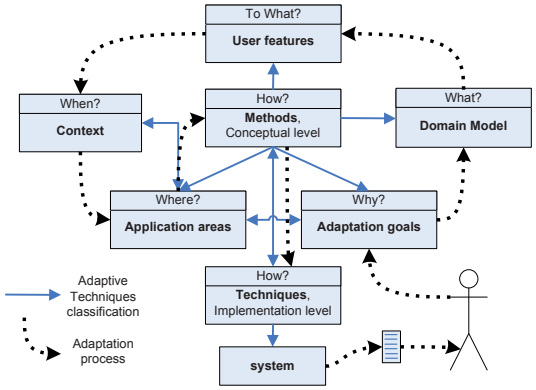


Fig. 3. Classification of AH methods and techniques; adaptation process highlights [9]

Although coupling the AH methods classification with the 'adaptation process' had a different purpose from what is shown in the classical (and later) loops of 'user modelling - adaptation' - our goal is to show the diversity of the adaptation process representation and the possibility of aligning not only the 'user-adaptation' loop into the adaptation process but the adaptation methods and techniques as well.

1.2 Goals

In this paper we describe the reference adaptation process, aligning it with the traditional 'adaptation questions' (Sect. 2) and formalizing it in a single generic manner. In particular, we:

- *provide a flowchart diagram of a generic AHS (based on the summarization from [9])*;
- *put the notion of the adaptation process in a context of a generic layered adaptation system*;
- *align the layers of AHS in a sequence chart and present the reference adaptation process.*

2 Questions of Adaptation and Adaptation Sequence

Adaptation can be defined by posing and answering six major questions:

- Why do we need adaptation? (*Why?*)
- What can we adapt? (*What?*)
- What can we adapt to? (*To What?*)
- When can we apply adaptation? (*When?*)
- Where can we apply adaptation? (*Where?*)
- How do we adapt? (*How?*)

This type of classification has been initially introduced in [3]. Here we not just revisit these questions, but address the issue of aligning them (also aligning the corresponding methods, techniques and respective modules (layers) of AHS) in a *generic adaptation process* which can serve as a process guideline and framework for defining the way AHS functions.

Fig. 3 considers the order in which the adaptation questions should be asked (and answered), thus leading to a first informal definition of the adaptation process. The *classification* of AH methods and techniques is outlined by the solid lines representing the typical dimensions for the analysis of adaptive systems [12]; at the same time we join the same classification blocks considering the adaptation *process perspective* which is depicted by dotted line. This process is usually initiated by the user stating the adaptation goal and thus answering the 'Why adaptation is needed?' question. Then in the process we consider the 'What?' and 'To What?' questions, which emphasize Domain Model (DM) and UM descriptions. 'When?' and 'Where?' go next providing context and application area definitions. Lastly, the 'How?' question describes methods and techniques on a conceptual and implementation level and finally all together result in AHS description.

Taking into account user needs and system components (anticipating both core and optionally available components) we would like to present the process which explains the transitions, states, sequences and flows in a generic AHS. First we revisit a few such systems. Then, based on the research and summarization done in [9], we present the flowcharts of an adaptive system and finally come up with the conceptual sequence chart of a layer-structured *Generic Adaptation Framework (GAF)*.

Considering the adaptation process in other systems we mention a few examples of how the authors tried to catch an idea of defining the adaptation processes (both implicitly or explicitly) in their systems and matching processes with the layered structure of their systems.

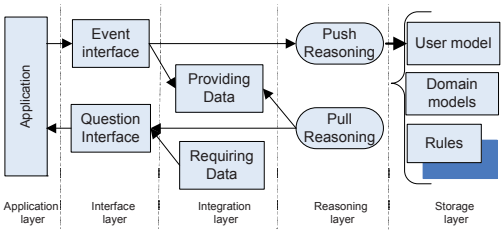


Fig. 4. Overview of the General Ontological Model for Adaptive Web Environments (GOMAWE)

In the GOMAWE system [1] (Fig. 4)the authors tried to fit the adaptation process in the general ontological model of the system they designed. Though there is still much to be considered in terms of the real inter-layer transitions,

we can already observe a few basic transitions such as the Event Interface which either triggers the *Push Reasoning* or provides the data for the *Pull Reasoning* interfaces of the Reasoning layer. Here 'Push' is responsible for transforming user events into UM updates which happens when users interact with the system, and 'Pull' retrieves the UM state. Moreover these connections tie different layers of the designed system together.

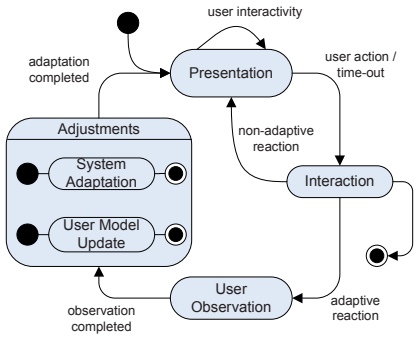


Fig. 5. Lifecycle Model of Adaptation (Munich Model)

The Munich model defined by Koch in [10] (Fig. 5) presented the lifecycle model of adaptation in the UML formalized notion. It defines the following 'layers' or components or states to be tied by these process loops: presentation, interaction, user observation, and adjustments of the systems (which include Adaptation itself and UM updates). These cycles start with an initial presentation and a default UM. Stereotypes are usually used to provide the information for the initial UM. Then the following steps of adaptation cycle follow [10]:

- *System Interaction* - which describes how to react to certain user action(s), resulting in the termination of this cycle and adaptive continuation.
- *User observation* - in which the evaluation of the information got from UM is being done.
- *Adjustments* - comprising the two sub-states: *User model update* - in which UM attributes are updated; *System adaptation* - in which the adaptation is performed (adaptation of presentation, content or navigation) utilizing the state of UM.
- *Presentation* - when the system presents the adaptable elements taking into account the information system knows about the user and remains in this state until the user starts interacting with system over again.

To some extent most of the adaptation 'loops' fall under this classification. Most of these interactions are continuous and recursive when the user continues using the system and explores the knowledge base in depth. We should also mention that here we don't consider any concurrent loops that may happen and influence each other in every aspect.

3 Adaptation Process Flowcharts

In the following section we summarise the procedural knowledge of the data/control and other flows in AHS and come up with the generic representation of AHS processes.

Hereafter we present the adaptation process flowcharts, which generalize the functionality of the AHS. In fact these flowcharts follow the system properties summarization presented in [9], (Tables 1, 2). Based on the summarised (and generalized) functionality we devise these generic adaptation process flowcharts. The abstract representation of the process is shown in Fig. 6 which is elaborated further.

We distinguish the following flowcharts:

- abstract adaptive process flowchart (Fig. 6);
- goal acquisition and adaptation (Fig. 7);
- adaptation functionality (Fig. 8);
- test-feedback functionality.

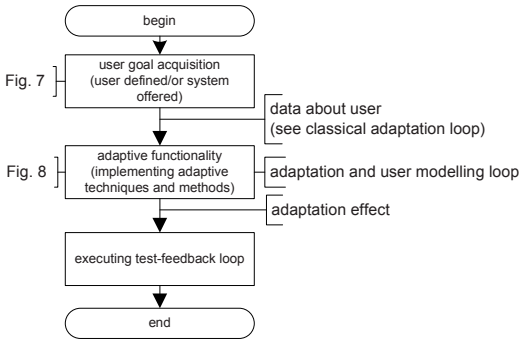


Fig. 6. Generic Adaptation Flowchart (to be considered as the aggregation of Figs. 7-8)

Each flowchart represents a certain aspect of the adaptation process, annotated to give more insight in the description of some blocks. On the right side of each chart we link parts of the process to the layers of the GAF model. The communication between the layers is illustrated in Fig. 9. We also mark with numbers the exact correspondence of Fig. 9 calls and transitions with the outlined blocks on the flowcharts (Figs. 7-8) in order to show the conformity of the sequence and flowchart approaches.

In the *'Goal acquisition and adaptation flowchart' (Fig. 7)* we start with the group analysis, thus assigning the user to a group or acquiring group properties in order to take them into account while choosing the adaptation goals. Here we also make assumptions that the user can belong to only one group and may not switch to another group within a session. The user may have his/her own

goal or be advised by the system to (also) use the group goal. In any case goal suitability is checked to determine whether the user can follow it. All suitable goals are elaborated in a sequence of concepts or the most appropriate 'project' (defined set of concepts to study) is chosen.

The *'Adaptation functionality flowchart' (Fig. 8)* presents the main Adaptation Engine (AE) functionality in a sequence of concept-content adaptation steps for a particular user. In general we analyse conditions for a particular step and execute adaptation rules which apply adaptation techniques and perform presentation, content and navigation adaptation. After that UM attributes are updated accordingly and the user proceeds with the next concept either on a 'one-per-click' or project-organized basis. This figure looks very similar to what was done the in IMMPS model [2], presenting a reference architecture for intelligent multimedia presentation systems where the knowledge server was separated from the main flowchart in order to separate and retain the knowledge base from other system functionality. For the same reasons to separate AE functionality we have the distinguished 'concept-content adaptation interaction' block.

'Test-feedback functionality' goes in the end. Here if such a feedback is required the user continues either with the external evaluation or internal assessment which could be the part of a project or a separate questionary or test instance. If this test is failed, user goals might be refined and he/she could be requested start all over again.

4 'Rotating' the Layers of AHS: Adaptation Process and the Layered Model

The conceptual structure of GAF [8] aligns the order of the layers in the system according to the classification of AH methods and techniques (Fig. 3). Though this order represents the basic understanding of the adaptation questions, every particular system may vary or even omit some of these, thus leading to a different composition of the system layers determined by the different adaptation process.

Now, considering the generalized adaptation process flow- charts presented in (Figs. 7-8) and the layered nature of AHS [9] we would like to present the generic adaptation process. We believe that in order to couple, align, sort and arrange the layers of such a system (both generic model or some particular domain focused implementation) one should keep in mind an adaptation process sequence that will partially determine the layers arrangement and to some extent will define the mandatory and optional elements and drive the system design.

Thus we decided to rotate the anticipated layered structure representation by 90 degrees counter-clockwise and match it with the adaptation process flowchart. Fig. 9 shows such an abstraction of a generic adaptation process in terms of the system layers. (It has been rotated once more to fit on the page and be readable.)

We have marked the communication arrows with numbers to set up a correspondence with the flowcharts, where respective blocks are outlined and marked with the same numbers. This is done to show the coherence of the sequence and flowcharts. We should also note that not every connection in the adaptation pro-

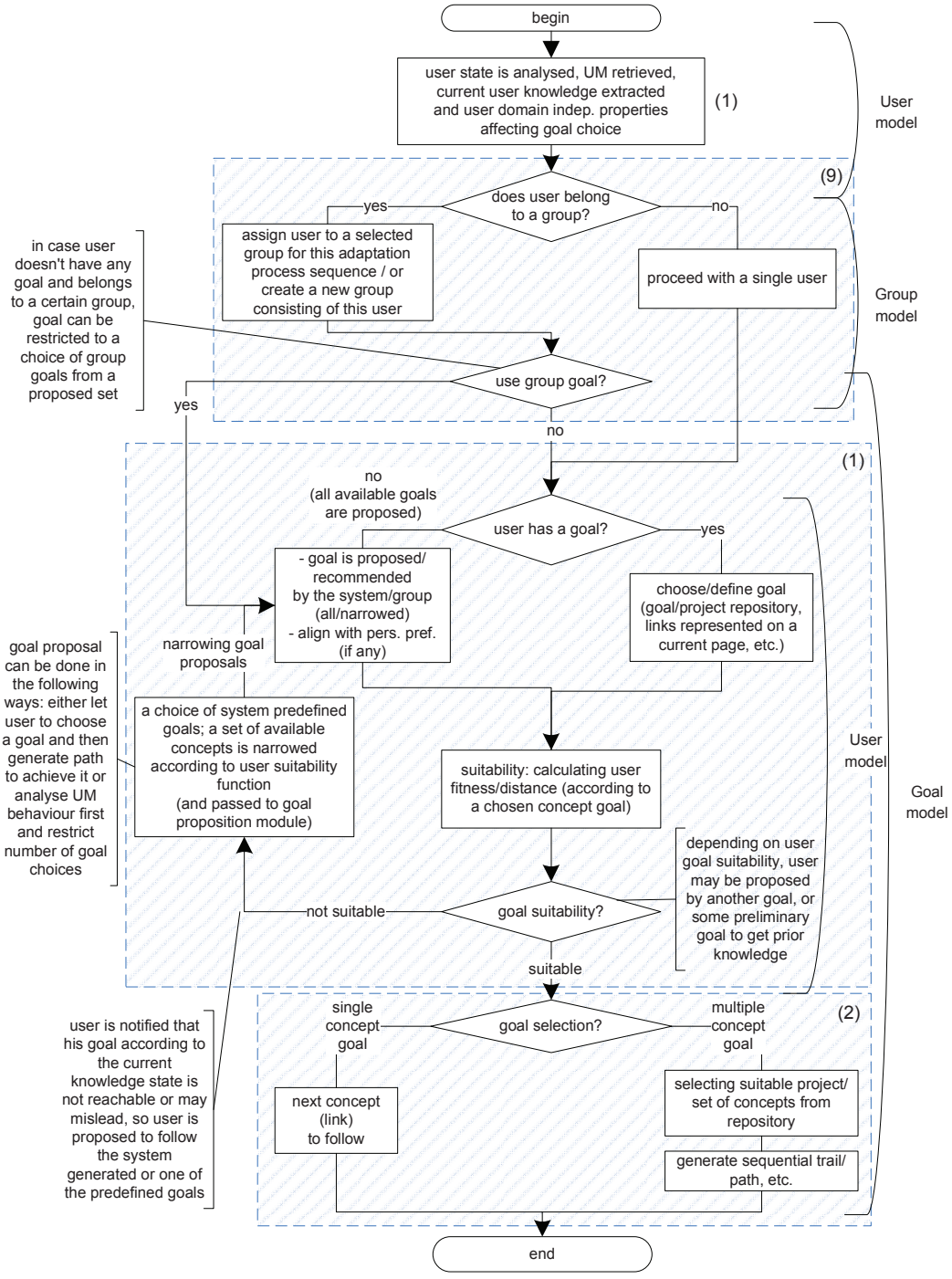


Fig. 7. Goal acquisition and adaptation flowchart

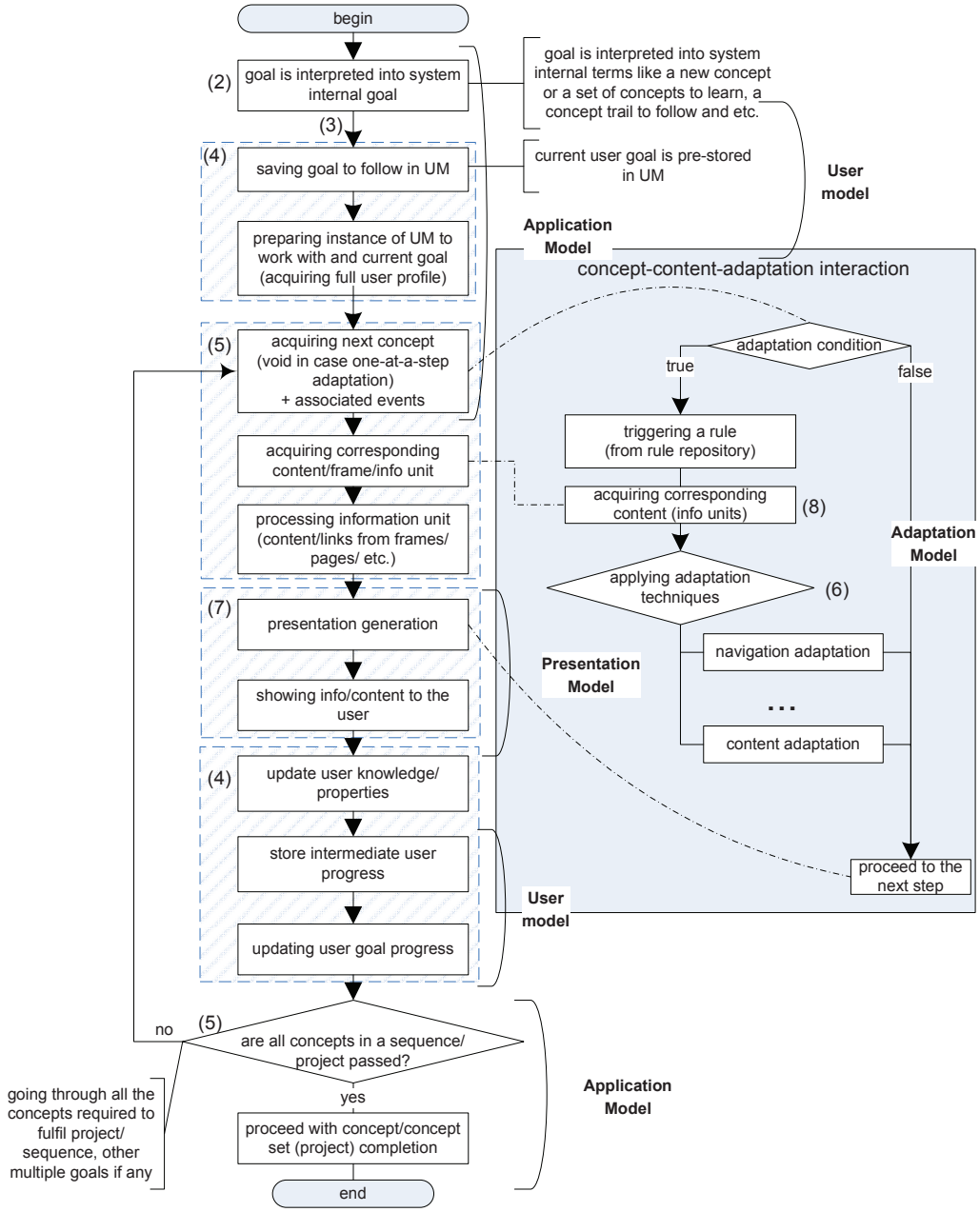


Fig. 8. Adaptation functionality flowchart

cess sequence exists in the above-mentioned flowcharts due to the more extensive description of the GAF process sequence chart. The marked connections are:

1. User goals are defined. In case the user doesn't define any goal it can be proposed by the system or a group goal is used;
2. User goals are aligned with DM, considering the conceptual structure of the domain. According to the selected goal a suitable set of concepts to follow is chosen;
3. Adaptation is initiated and control is passed to the Application Model (AM);
4. Operations of UM properties such as acquisition and update are performed here (corresponds to a few places on the flowchart);
5. Operations mainly concerned working with the concepts from DM;
6. Appropriate adaptation methods and techniques are invoked;
7. Retrieved content is passed to the Presentation model to be rendered/generated and presented to the user;
8. Corresponding content (for concerned concepts) is retrieved from the Resource model and handed over back to AM;
9. Group related operations (assigning users, retrieving group properties, defining new groups, etc.).

5 Conclusions and Future Work

In this paper we defined and elaborated various aspects of the *Generic Adaptation Process*, introduced its model, flowchart and sequence chart. To comply with the layered model we anticipate that the aforementioned process structure will influence the layered composition of the AHS in such a way that the process defined by the system engineer will partially drive the order of the layers of such AHS and define important inter-layer transitions. At the same time we anticipate that the defined processes together with the reference model (e.g. emerging GAF or well known AHAM) may serve as a foundation for the system design, defining not only the system components but the system 'functionality flow' as well, or even deviate into a separate branch of so-called 'process-driven' architectures in the AH field. Moreover the formalized process driven approach gives more insight on AH development methods and unifies this development approach and system organization as it was first mentioned in [10].

We have started elaboration of the generic layered structure of AHS in [9] and then gave the first look at this kind of layered generic structure in [8]. This led to a process-oriented view of a generic layered AHS which was presented in this paper. Based on the research done in [9] we managed to devise a generic flowchart that fits most popular AHS. And finally considering the layered (de)composition of an adaptive system we present a conceptual view of a *generic adaptation process* (Fig. 9).

In the future we plan to extend the adaptation process sequence with more details, elaborate the process description, particularly inter-layer interaction, sustaining the generic approach, at the same time emphasizing the interoperability

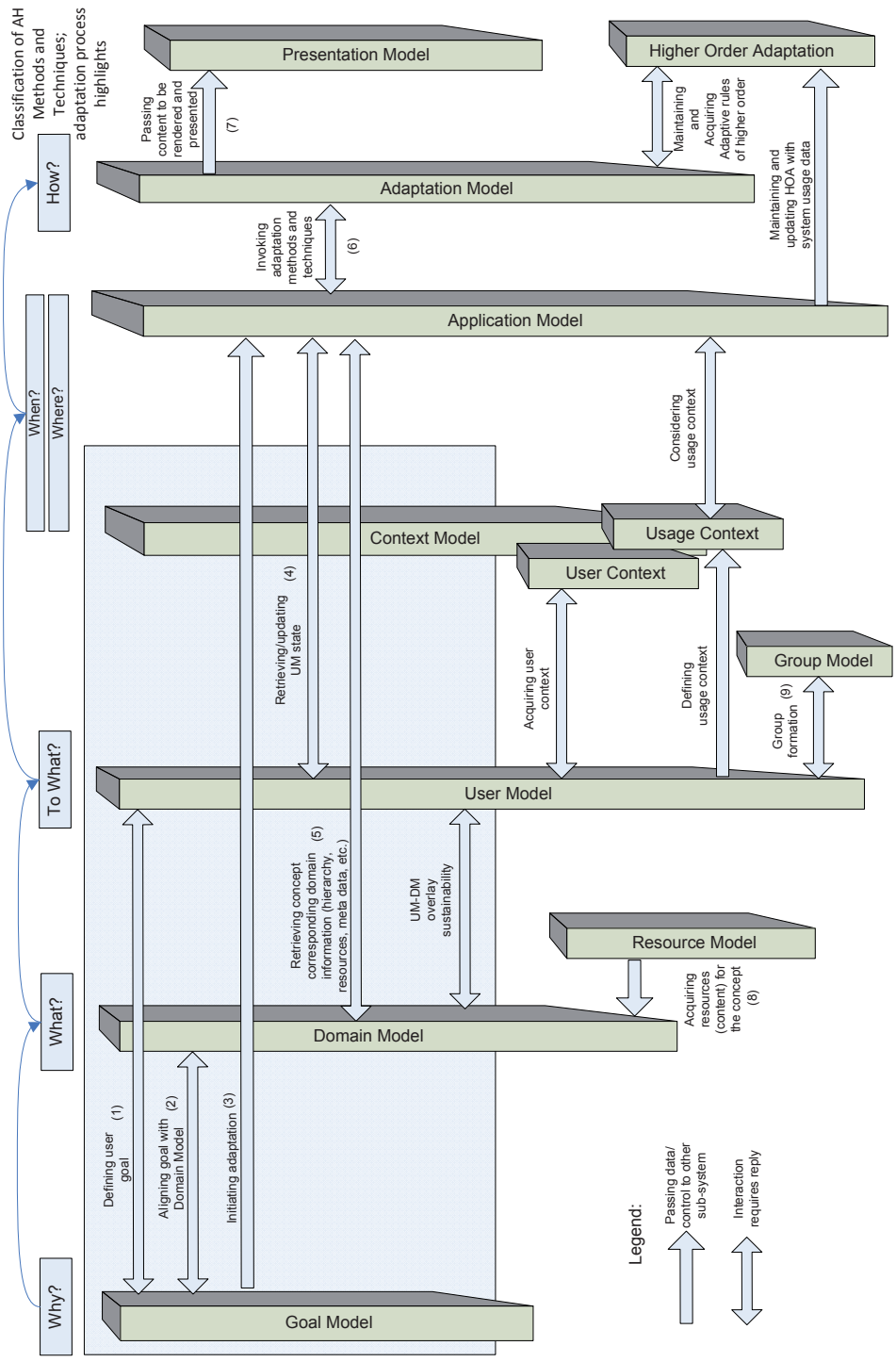


Fig. 9. Conceptual Generic Adaptation Process sequence chart

of a new AH developments (Ontologies, Open Corpus, Higher-Order Adaptation etc.) and the conventional AH approaches. This may lead to describing interoperable and alternative interaction in the system thus representing a generic view of an AH framework which includes all possible variations of adaptation functionality and techniques.

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References

1. M. Balík and I. Jelínek. Towards semantic web-based adaptive hypermedia model. 2007.
2. M. Bordegoni, G. Faconti, S. Feiner, M. T. Maybury, T. Rist, S. Ruggieri, P. Trahanias, and M. Wilson. A standard reference model for intelligent multimedia presentation systems. *Comput. Stand. Interfaces*, 18(6-7):477–496, 1997.
3. P. Brusilovsky. Methods and Techniques of Adaptive Hypermedia. *User Modeling and User Adapted Interaction*, 6(1-2):87–129, 1996.
4. O. Conlan and V. P. Wade. Evaluation of APeLS - an adaptive elearning service based on the multi-model, metadata-driven approach. In *AH*, volume 3137 of *Lecture Notes in Computer Science*, pages 291–295. Springer, 2004.
5. P. De Bra, G.-J. Houben, and Y. Kornatzky. An Extensible Data Model for Hyperdocuments. In *ECHT 92, Proc. of the 4th ACM Conference on Hypertext*, pages 222–231. ACM, 1992.
6. P. De Bra, G.-J. Houben, and H. Wu. AHAM: a Dexter-based reference model for adaptive hypermedia. In *Hypertext '99: Proceedings of the tenth ACM Conference on Hypertext and Hypermedia : returning to our diverse roots*, pages 147–156, New York, NY, USA, 1999. ACM.
7. F. Halasz and M. Schwartz. The Dexter Hypertext Reference Model. *Commun. ACM*, 37(2):30–39, 1994.
8. E. Knutov. GAF: Generic Adaptation Framework. Hypertext 2009 SRC poster, 2009.
9. E. Knutov, P. De Bra, and M. Pechenizkiy. AH 12 years later: a comprehensive survey of adaptive hypermedia methods and techniques. *New Rev. Hypermedia Multimedia*, 15(1):5–38, 2009.
10. N. Koch. *Software engineering for adaptive hypermedia systems.* PhD thesis, Ludwig-Maximilians University of Munich, Munich, Germany, 2001.
11. M. Saksena and A. Cristea. Towards more efficient generic semantic authoring for adaptive hypermedia. In *APS '06: Proceedings of the joint international workshop on Adaptivity, personalization & the semantic web*, pages 11–20, New York, NY, USA, 2006. ACM.
12. M. Schneider-Hufschmidt, T. Ktihme, and M. U., editors. *State of the Art in Adaptive User Interfaces*, pages 13–48. North Holland, Amsterdam, the Netherlands, 1993.