PRAGMATICS OF STORYBOARDING
Web Information Systems Portfolios

Klaus-Dieter Schewe
Information Science Research Centre, Palmerston North, New Zealand

Bernhard Thalheim
Institute of Computer Science, University of Kiel, Germany

Keywords: Pragmatics, Web information system, Information portfolio, Utilisation portfolio.

Abstract: A Web Information System (WIS) can be described by a storyboard, which on a high level of abstraction specifies who will be using the system, in which way and for which goals. Syntax and semantics of storyboarding have been well-elaborated. Pragmatics is the necessary complement addressing what the storyboard means for its users. The part of pragmatics concerned with usage analysis by means of life cases, user models and contexts has been dealt with before. In this paper we complement usage analysis by WIS portfolios, which comprise two parts: the *information portfolio* and the *utilisation portfolio*. The former one is concerned with information consumed and produced by the WIS users, which leads to content chunks; the latter one captures functionality requirements.

1 INTRODUCTION

A Web Information System (WIS) is an information system that can be accessed through the world-wide-web. So far, many approaches to WIS conceptual modelling have been developed, e.g. (Ceri et al., 2003; De Troyer and Leune, 1998; Houben et al., 2003; Lowe et al., 2002; Rossi et al., 1999; Schewe Thalheim, 2005), most of which are centered around content and navigation modelling, occasionally coupled with specific requirements models.

In (Schewe Thalheim, 2005) we characterised a WIS by strategic characteristics such as purpose, mission, intentions and ambience (more details in (Moritz et al., 2005)), usage characteristics such as tasks, users and stories, content and functionality characteristics, context, and presentation, which leads to an abstraction layer model for WIS development. Central to this approach to WIS development is the method of storyboarding, which on a high level of abstraction specifies who will be using the system, in which way and for which goals. In a nutshell, a storyboard consists of three parts:

- a set of *tasks* that are associated with goals the users may have,
- a set of *actors*, i.e. abstractions of user groups defined by roles that determine obligations and rights, and user profiles determining preferences, and
- a *story space*, which itself consists of a hierarchy of scenarios describing scenes and actions, and is accompanied by a *plot* describing the action scheme.

Syntax and semantics of storyboarding including customisation to preferences have been well elaborated in (Schewe Thalheim, 2005; Schewe Thalheim, 2007*a*; Schewe et al., 2009). However, in order to link storyboarding to the systems requirements and to provide guidelines and means to derive the complex storyboards from informal ideas about a WIS without any technical bias, this has to be complemented by pragmatics, which according to (Webster, 1991) is the "balance between principles and practical usage".

In (Schewe Thalheim, 2007*b*) we addressed the pragmatics of storyboarding focusing on usage analysis. Based on intentions we investigaed *life cases*, *user models* and *contexts*. Life cases, capture observations of user behaviour in reality, and can be used in a pragmatic way to specify the story space. Life cases have already been envisioned in (Carroll, 2004) and integrated into the entire software engineer-

Schewe K. and Thalheim B.
PRAGMATICS OF STORYBOARDING - Web Information Systems Portfolios.
DOI: 10.5220/0002800400400047
In *Proceedings of the 6th International Conference on Web Information Systems and Technology (WEBIST 2010)*, page
ISBN: 978-989-674-025-2

ing process in (Harel Marelly, 2003). They generalise business use cases as in (Robertson Robertson, 2006). User models that are specified by user and actor profiles, and actor portfolios.They are used to get a better understanding of the tasks associated with the WIS, and the goals of users. Goals have been identified as a crucial component of requirements engineering in (Giorgini et al., 2002). Task descriptions are also used in participatory design, e.g. in (Carroll, 2004; Kensing Blomberg, 1998; O'Neill Johnson, 2004). Contexts characterise the situation, in which a user finds himself at a certain time in a particular location. For WISs we must handle different kinds of contexts and analyse the way they impact on life cases, user models and the storyboard.

In this paper we extend our work on WIS pragmatics focusing on WIS portfolios, which address the pragmatics associated with content and functionality. We distinguish between *information* as processed by humans and *data* as its carrier that is perceived or noticed, selected and organized by its receiver. Content is complex and ready-to-use data, and may be enhanced by concepts that specify the semantic meaning of content objects, and topics that specify the pragmatic understanding of users.

Thus, information is directed towards pragmatics, whereas content may be considered to highlight the syntactical dimension. If content is enhanced by concepts and topics, then users are able to capture the meaning and the utilisation of the data they receive. Analogously, functionality refers to functions offered by the system, thus highlists the dynamic aspects of the syntactic dimension, whereas *utilisation* is linked to the stories supporting users' life cases, thus is directed towards pragmatics. This distinction is illustrated in Figure 1.

Accordingly, a WIS portfolio consists of two parts: the *information portfolio* and the *utilisation portfolio*. The former one is concerned with information consumed and produced by the WIS users, which leads to content chunks. We will elaborate on this in Section 2. The latter one captures functionality requirements. We will elaborate on this in Section 3 focusing on utilisation portfolios for learning WISs.

2 INFORMATION PORTFOLIOS

A WIS portfolio consists of an *information portfolio* and a *utilisation portfolio*. They are mapped to content and functionality specifications, respectively. In doing so we distinguish between *content* provided by the WIS and *information*, which is related to an actor or user.

2.1 Consumption and Production of Information

Following (Schewe Thalheim, 2005) on a high level of abstraction we may think of a WIS as a set of abstract locations, which abstract from actual pages. A user navigates between these locations, and on this navigation path s/he executes a number of actions. We regard a location together with local actions, i.e. actions that do not change the location, as a unit called *scene*.

Then a WIS can be described by an edge-labelled directed multi-graph, in which the vertices represent the scenes, and the edges represent transitions between scenes. Each such transition may be labelled by an action executed by the user. If such a label is missing, the transition is due to a simple navigation link. The whole multi-graph is then called the *story space*.

A *story* is a path in the story space. It tells what a user of a particular type might do with the system. The combination of different stories to a subgraph of the story space can be used to describe a "typical" use of the WIS for a particular task. Therefore, we call such a subgraph a *scenario*. Usually storyboarding starts with modelling scenarios instead of stories, coupled by the integration of scenarios to the story space.

Each WIS user who enters the system with a particular goal has information needs that have to be satisfied by the system. In addition, an active WIS will also request information from its users. We use the term *information consumption* for the information provided by the system to its users, and *information production* for the information entered by a user into the system.

When a user enters the WIS, the information needs are usually not known in advance. Part of the needed information may depend on other parts, on decisions made while navigating through the WIS, and even on the information provided by the actor him/herself. That is, the information consumption and production depends on the path through the WIS, i.e. in our terminology on the story. Therefore, information consumption and production is associated with each scene of the story space. Assuming that there is a database for the data content of the WIS with database schema $\mathcal{S}$, information consumption on a scene s definitely accounts for a *view* V_s over $\mathcal{S}$. That is, we have another schema $\mathcal{S}_V$ and a computable transformation from databases over $\mathcal{S}$ to databases over $\mathcal{S}_V$. Such a transformation is usually expressed by a query q_V.

- With each scene s we associate a view $V_s =$

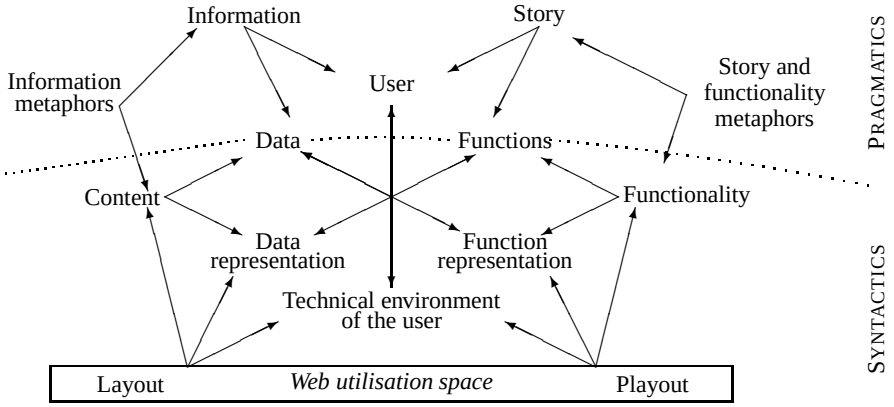

Figure 1: The Web Utilization Space Based On the Characteristics of WIS.

(s_V, q_V) called *information consumption view*. Elements of $q_V(db)$ for some database db represent the *information consumption* of an actor.

- With each action α we associate a data type t_α called *information production type*. Values of type t_α represent the *information production* by an actor.

Information consumption and information production of an actor for all scenes together define the information portfolio of the actor.

2.2 Information Need and Demand

We distinguish between the *information need* and the *information demand*. The former one refers to a perceived lack of something desirable or useful, while the latter one results from an act of demanding or asking.

The information need is generally related to objectives such as becoming informed. It is based on the intuitive insight that the current information and knowledge is insufficient for the task under consideration, or the necessary information cannot be easily derived from data that is currently available, or the uncertainty, indefiniteness, fuzziness, and contradictions do not permit drawing conclusions.

The information need can be considered to be subjective, but at the same time it can be the reason for a certain user visiting a website without an intention that is related to a life case. The information need is based on the conceptual incongruity in which a user's cognitive structure is not adequate to a task, e.g. when a user recognizes that something wrong in their state of knowledge and desires to resolve the anomaly, when the current state of knowledge is less than what is needed, when internal sense runs out, or when there is insufficient knowledge to cope with gaps, uncertainties or conflicts in a knowledge area. Therefore, as the behaviour of actors is mainly related to life cases and the portfolio, we have to distinguish between information provided for support of life cases and auxiliary consumed information that is provided to visitors as a service.

The information demand is related to the portfolio under consideration and to the intents. We may distinguish between information that is necessary, desirable, or feasible. The information demand is mapped to the views defining information consumption and production for each scene of the story space as defined above. The information demand is characterised by information that is missing, unknown, necessary for task completion, and directly requested.

We can distinguish between the information demand of an actor and the information demand of a user. As actors represent groups of users, the information demand of a user contains the information demand of an actor. While the information demand of actors is determined by the portfolio, the additional information demand of a user is determined by the user profile.

2.3 The Concept of Persona

The information demand is used to derive the information consumption of each user. This is related to the definition and meaning of information for the user based on received / requested data, which has to be organized, interpreted, understood, and integrated into his/her knowledge. In general, this would require to model the user, the specific request of the user, the ability to understand the data, and the skills, which is infeasible. However, as the information demand of actors is a subset of the one of users represented by the actor, we can use prototypes of individuals called *personae* to determine the information demand. In addition, we model a task-oriented life case of these

individuals, and derive the information demand, data requirement, and the specific utilisation requirements.

A *persona* is characterized by an expressive name, profession, intents, technical equipment, behaviour, skills and profile, disabilities, and specific properties such as hobbies and habits. A persona is a typical individual created to describe the typical user based on the life cases, the context, the portfolio, and the profile. User models characterize profiles for education, work, and personality. This characterization can be extended by

- identity with name, pictures, etc.,
- personal characteristics such as age, gender, location, and socio-economic status,
- characterization of reaction to possible users error,
- specific observed behaviour including skill sets, behavioural pattern, expertise and background, and
- specific relationships, requirements, and expectations.

EXAMPLE 1**.** Let us consider an information service of a city and focus on business people. For these we develop the following specific portfolio:

User Profile. Jack-of-all-trades is a business man. He intends to visit the city through a short-term visit. He is interested in culture and history. He likes short distances and 4-star or better hotels. He is usually in a hurry. He likes good dining and talking. Additionally, he is familiar with technology.

Intention and Information Demand. Jack-of-all-trades visits the information site for business trip preparation. His information demand includes hotel information, spare time information for the evenings, and information on the central traffic.

Content Requirements. The information demand may be mapped to general city information, information on restaurants, traffic, culture, business clubs, and good dining addresses. Therefore, the information consumption of Jack-of-all-trades must be supported by the corresponding databases. At the same time, Jack-of-all-trades requires a handy booking service.

Life Case. The life case we envision includes a brief survey on the city including places to see, the selection of a convenient hotel, a survey of events of interest, the booking procedure for events, a search for good dining places, and some information what else to see and whom to talk to.

Specific Utilisation. The collection of data is similar to a basket collection. Jack-of-all-trades prefers shallow navigation and fast search. He is also interested in highlights for the period he is considering.

Jack-of-all-trades can be exemplified to be a specific persona:

Personal: name: Bernhard Karlowics, age: 48, male, married, lives in northern Germany, profession: business assistant, income: around ***Euro***50.000 per year

Robustness: errors are not taken as own errors, download time is critical

Kind of User: kind but pretentious, makes quick decisions, interested in history, culture, classical musics, usually in a hurry

Specific Behaviour: resumes story also after hours

Specific Interactivity: works alone, with interruptions, no time for concentrated reading, final results expected

Profile: middle level manager, Masters degree in business and computer engineering, workoholic (around 60 hours per week)

Portfolio: collection of travel details with confirmation and payment, prefers hotels with four-stars or higher, checking through direct connection to booking services

Life Case: preparing for travel, single use of the system, email confirmation necessary, spare time information, events of interest, dining places, business clubs

Context: business environment, typically client-server computers at workplace, occasionally mobile phone for contact while on the move

The explicit specification of personae has several benefits. They provide communication means within the development team, focus on a specific target set of actors, and help to make assumptions about the target audience. Thus, personae may augment the WIS portfolio specification, but should not be overused.

2.4 Content Chunks

In order to model the information portfolio we collect the information demand of all actors we would like to support. In addition, we can include some specific information demand of users matching with the groups of users. This information demand can be combined into a single content chunk that is demanded by all actors of similar steps in the life case. This information demand can later be modelled within a database model.

This combination turns around the viewpoint we have taken so far. We try to envision which content is necessary for which actors or users. We may start with the intention why an actor may demand a given content. The content-centered view allows us to derive a specification of steps in which a certain chunk of content is requested.

The content-centered analysis is used during brainstorming sessions in which we try to derive scenarios, intentions, and the information need of users. At the same time we can derive the service kind, utilisation, actors, presentation, content, and functions supporting this content. We can also derive directly the intersection among the content chunks, which provides a basis for the development of queries to extract the content demanded from the WIS.

Content chunks are arranged within *content-extended scenarios*, in which each scene is associated with a content chunk. This content chunk combines the consumption of actors, auxiliary content that is provided for the support of users, and the content that is additionally provided due to the intentions of the WIS provider and the context of the current scene. We further enhance this scenario by data that is produced by the actor or that stems from the environment.

EXAMPLE 2. Let us continue Example 1 and consider the booking scene. If the actor has decided to choose a particular hotel, then we may associate with the choice action the selection of an identification for the hotel, which extends the booking scene with the content that provides information to the actor on hotels. With the choice of a hotel the actor leaves this scene and produces the selection data. In the next scene the actor can be asked about the payment.

The same scene can also be used in a different scenario, in which the actor first collects all choices in a basket and later confirms those choices, which are the most appropriate.

The information portfolio is also enhanced by information that depends on the WIS context. This can define content associated with control, which normally is internal to the WIS and not accessible by applications, content that is used to determine the transitions and to control the WIS context, e.g. for the pre- and post-scene conditions, transition conditions depending on the databases used, or assignment for collaborating actors, etc., content that might be useful as reference, e.g. meta-information on time, responsibility, and links to other WISs, or application-specific data that is not accessible by the WIS.

The content set required for each step in a life case may become too large. So we must prioritise the development of content chunks. There are two perspective for prioritising:

- In the usability perspective we evaluate the impact the content has for the the WIS portfolio. The impact is based on the occurrence the content has in steps and activities and on the number of actors requiring this content. The impact is high if the majority of users need it frequently or cannot continue their work if the content is missing.
- In the economic perspective we evaluate the cost/benefit relation. Since projects have limited budget, contract commitments, resource restrictions, technological constraints, marketplace pressures, and deadlines we must limit the efforts. We may classify those content chunks which have high impact into strategic, high value, targeted and luxuries.

EXAMPLE 3. The `www.cottbus.de` WIS provides information on hotels, booking services, etc. For the decision, which information should be provided we may use a classification along usability and economic perspective. We can then assign final decisions to the evaluation such as approved ($\surd$), under review ($\diamond$), and rejected ($\not\surd$). In a similar way we may evaluate all content chunks we discovered. The evaluation is used for deciding which content is to be developed and to which extent.

Content chunks are often composed only of data, i.e. they relate to media objects on the conceptual model (Schewe Thalheim, 2005). The description of the data is based media types, viewpoints, and adaptation facilities. Content is also based on semantics, i.e. associated concepts capturing basic pieces of knowledge or their annotations, and restricted by pre- and postconditions. Content must also be annotated using a commonly agreed vocabulary or a dictionary. This agreement is bound to actors or communities. We denote items of dictionaries by topics. The pragmatics also reflects the context of potential usage. As content is often used in a form that combines content chunks with other content chunks we also specify related content chunks.

3 UTILISATION PORTFOLIOS

The second constituent of the WIS portfolio is the *utilisation portfolio*, which can be considered to be a collection of requirements for functionality and WIS utilisation in general. It describes the intentions of the users, their goals, their context, and their specific requirements, and as such is based on the life cases that

were modelled before, and the profiles and the portfolio of the users and actors. Furthermore, the actor context must be taken into account. Therefore, we first discuss the utilisation portfolio and then derive its impact on the functionality required by the user.

The utilisation portfolio combines the actor or user perspective to the WIS. We already know intentions of users, their profiles, and their life cases. Users are grouped to actors for which portfolios have already been developed. Based on the portfolio and the context specification life cases were extended.

The WIS utilisation portfolio cannot be described in general for all different categories of WIS such as e-business, learning and edutainment, communities, etc., though these categories are mixed in real applications. The separation into categories eases, however, the description of the WIS utilisation portfolio. In the following we will describe the development of the WIS utilisation portfolio for learning WISs.

A large number of WISs provide learning and edutainment services. Examples of technology-supported learning include computer-based training systems, interactive learning environments, intelligent computer-aided instruction systems, distance learning systems, and collaborative learning environments. The general brand $\mathcal{P}^{\mathcal{W}}2\mathcal{U}^{\mathcal{A}}$ of a WIS (Moritz et al., 2005) has to be specialised for edutainment WISs:

Provider $\mathcal{P}$. For the time being providers are mainly educational institutions or educational communities. Then the provider plays the role of a teacher.

Product $\mathcal{W}$. Since control and assessment of learning progress is a still unsolved issue and appropriate presentation of complex information is often not feasible, edutainment WISs concentrate on easy-to-understand information or easy-to-grasp knowledge.

Users $\mathcal{U}$. Users of edutainment WISs are mainly students, people seeking for continuous education, workers in companies with a specific portfolio, people interested in auxiliary information, or groups of such users. The main behavior of such users is characterised by the role of the learner.

Activities $\mathcal{A}$. Activities are mainly centered around learning, searching for content, collecting content, and solving exercises. Activities also include to ask questions, to act in teams for problem solving, and to discuss issues associated with the learning material.

Thus, typical learning WIS brands take the form **Teacher**$^{\mathcal{W}}$**2Learner**$^{\mathcal{A}}$, where $\mathcal{W}$ stands for content_chunks or knowledge, and $\mathcal{A}$ can be one of {receive, respond, solve_in_teams,raise_questions, possibly_apply}, {learn, validate, control, advice}, {recognise, listen, work_on_it, solve_exercises, ask_urgent_questions}, {discuss, get_feedback, work_on_it}, etc.

Edutainment WIS are currently mainly or exclusively supporting student actors. Students obtain knowledge through teachers, their schedules, and their abilities; they need guidance, motivation, and control. The behaviour of actors may, however, be more complex, in particular in case of learning groups, in which the collaboration of students depends on a cooperation profile with rights and obligations. Communication partners exchange content, discuss and resolve questions, seek for hints or for better understanding, supporting and motivating partners are users with control, motivation and supporting functions. Furthermore, teachers have various obligations and rights, and are involved in a variety of roles.

In order to derive the utilisation portfolio we analyse the word fields associated with common verbs in the learning context such as learn, know, master, study and nouns such as skill. This gives rise to stories and consequently determines the functionality requirements.

Learn. Learning is a very complex activity that includes gaining knowledge, understanding, obtaining skills, etc. by studying, instruction or experience. In addition, learning is associated with memorizing, being able to perform some task, and to know this ability. Learning is based on obtaining content, discovering the concepts behind them, annotation, ordering, and integration. Learning is associated with the role of a learner or student, who are usually supported by other actors who teach and instruct. Learners determine content with certainty, usually by making an inquiry or other effort. They check the content to find out whether it is useful or whether additional content is needed.

Know. As learning aims at improving skills, abilities, and knowledge, the improvement should be measurable and learning success examined. Knowing means to be cognizant of a fact or a specific piece of information and to possess knowledge or information about. It may also include to know how to do something. Learners obtain first-hand knowledge of states, situations, emotions, or sensations, and the change in knowledge is acknowledged and recognized by other actors.

Master. Learning usually intends to enable mastering problems and to become proficient and skilled in some area. This mastership is closely related to practising and experimenting with the new knowledge.

Study. Studying refers to the activities associated with learning, i.e. reading learning content, excercising, checking, examining, inspecting, surveying, etc. Therefore, the presentation of the learning material and the storyboard are essential. Furthermore, learners need to mind, perpend, think (out or over), and weigh, which requires time and workplaces. Studying can be performed by oneself without any teacher, supporter, or observer.

Skill. Skills are abilities that have been acquired by training, e.g. abilities to produce solutions to some problems. A learner is trained until s/he obtains these skills.

These word fields have a complex structure, which leads to functions requiring other support functions associated with related word fields such as discover, ascertain, catch on, and determine. One difference to the word fields for e-business is their iterative application. The word fields are extended by the learning style to be supported. The three different learning styles – sequenced or blended learning, interactive learning, and group learning – result in rather different scenarios. So far, only sequenced learning approaches have received the necessary theoretical basis in pedagogical research and didactics. Interactive learning is still an open research issue.

EXAMPLE 4. The KOPRA project within the German University Notebook Initiative was aiming at the support of adaptive and collaborative learning, focusing on practical training in database programming. The system is supporting communication and interaction of learners, organization and coordination of collaborating communities, free access to material depending on the progress, roles and portfolios of partners, and the stepwise development of training material. Learners act in a collaborative setting depending on their needs and the goals of the learning program.

The analysis of the word fields above highlighted the utilisation of importance of exercising of crucial part of the WIS. While often only multiple-choice exercises are supported, complex exercises have a more complex pattern. Figure 2 shows the derived scenario for exercise training for this case. Learners are allowed to choose either their own data or data provided by the system. Learners may also choose an algorithm that can be used for solving the exercise.

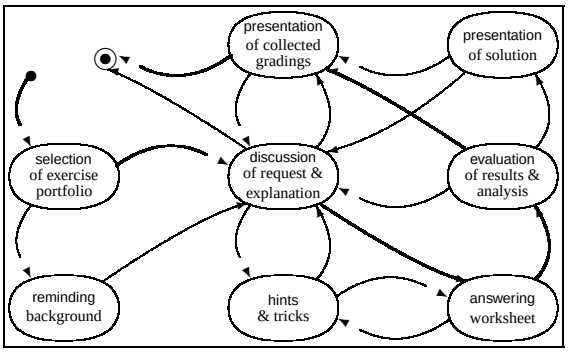

Figure 2: KoPra scenario for training with optional exercises.

4 CONCLUSIONS

In this paper we extended our previous work on pragmatics of Web Information Systems. We introduced WIS portfolios, which are composed of an information portfolio and a utilisation portfolio. The information portfolio captures information consumption and production by users in the scenes of the story space. This is linked to the information needed by a user to understand the task and the information demand to perform the appropriate action. Modelling information demand of all potential users is infeasible, but the concept of *persona* permits to deal with prototypical users instead. The integration of information demands leads to content chunks.

Likewise, the utilisation portfolio consists of tasks users might wish to accomplish within the system, and goals they want to achieve by this. It can be considered as the necessary means for collecting functionality requirements. Different from the information portfolio the utilisation portfolio depends on the application category. Here we focused on the category of learning WISs.

WIS portfolios complete the research on WIS pragmatics, which is an independing connector element between systems requirements and conceptual models. In this paper, due to space limitations we had to omit many details, which are reported in an extended journal version (Schewe Thalheim, 2010).

REFERENCES

Carroll, J. M. 2004. Participatory design of community information systems - the designer as bard, *in* 'COOP', pp. 1–6.

Ceri, S., Fraternali, P., Bongio, A., Brambilla, M., Comai, S. Matera, M. 2003. *Designing Data-Intensive Web Applications*, Morgan Kaufmann, San Francisco.

De Troyer, O. Leune, C. 1998. WSDM: A user-centered design method for web sites, *in* 'Computer Networks and ISDN Systems – Proc. 7th Intern. WWW Conference', Elsevier, pp. 85–94.

Giorgini, P., Mylopoulos, J., Nicchiarelli, E. Sebastiani, R. 2002. Reasoning with goal models, *in* 'ER', pp. 167–181.

Harel, D. Marelly, R. 2003. *Come, Let's play: Scenario-based programming using LSCs and the play-engine*, Springer, Berlin.

Houben, G.-J., Barna, P., Frasincar, F. Vdovjak, R. 2003. HERA: Development of semantic web information systems, *in* 'Third International Conference on Web Engineering – ICWE 2003', Vol. 2722 of *LNCS*, Springer-Verlag, pp. 529–538.

Kensing, F. Blomberg, J. 1998. 'Participatory design: Issues and concerns', *Computer Supported Cooperative Work* 7(3/4), 167–185.

Lowe, D., Henderson-Sellers, B. Gu, A. 2002. Web extensions to UML: Using the MVC triad, *in* 'Conceptual Modeling – ER 2002', Vol. 2503 of *LNCS*, Springer-Verlag, pp. 105–119.

Moritz, T., Schewe, K.-D. Thalheim, B. 2005. 'Strategic modelling of web information systems', *International Journal on Web Information Systems* 1(4), 77–94.

O'Neill, E. Johnson, P. 2004. Participatory task modelling: users and developers modelling users' tasks and domains, *in* 'TAMODIA', pp. 67–74.

Robertson, J. Robertson, S. 2006. *Requirements-Led Project Process*, Addison-Wesley.

Rossi, G., Schwabe, D. Lyardet, F. 1999. Web application models are more than conceptual models, *in* P. Chen et al., eds, 'Advances in Conceptual Modeling', Vol. 1727 of *LNCS*, Springer-Verlag, Berlin, pp. 239–252.

Schewe, K.-D. Thalheim, B. 2005. 'Conceptual modelling of web information systems', *Data and Knowledge Engineering* 54(2), 147–188.

Schewe, K.-D. Thalheim, B. 2007. *a* , 'Personalisation of web information systems - a term rewriting approach', *Data and Knowledge Engineering* 62(1), 101–117.

Schewe, K.-D. Thalheim, B. 2007. *b* , 'Pragmatics of storyboarding for web information systems: Usage analysis', *International Journal of Web and Grid Services* 3(2), 128–169.

Schewe, K.-D. Thalheim, B. 2010. 'Pragmatics of web information systems - information and utilisation portfolios'. submitted for publication.

Schewe, K.-D., Thalheim, B. Wang, Q. 2009. 'Customising web information systems according to user preferences', *World Wide Web* 12(1), 27–50.

Webster 1991. 'Webster's ninth new collegiate dictionary'.