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How Interactive Whiteboards Can be Used to Support Collaborative Modeling

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Abstract: Modeling is a key activity in system analysis and design. Users as well as stakeholders, experts and entrepreneurs need to be able to create shared understanding about a system representation in various phases of a design process. In each of these phases it is important to align views and ensure that differences in understanding of the system are resolved. Visualization is of high importance in this process and thus a logic approach is to involve stakeholders in collaborative modeling. Technology like interactive whiteboards may provide new opportunities in the support of collaborative modeling. In this paper we offer insights from an exploratory research on experiences in using interactive whiteboards in collaborative modeling, based on semi-structured interviews.

Keywords: collaborative modeling, interactive whiteboards, system and design, groups, technology.
Categories: H.5.3

1 Introduction

Modeling is a key activity in system analysis and design. There is broad agreement that it is important to involve various experts, stakeholders and users in a development cycle [Boehm, Gruenbacher & Briggs (01); Fruhling & Vreede (05); Standish Group (95)]. While these parties are often interviewed or in other ways heard, they often lack the skills to actively participate in the modeling effort. If users are not involved in systems analysis tasks, their problems, solutions, and ideas are difficult to communicate to the analyst. Further, analysts and entrepreneurs might have mental models, visions of a solution or system design, but might lack the adequate means of articulating these in terms familiar to all stakeholders involved [Hill & Levenhagen (95)]. While there are means to verbally explain models, such as metaphors, storytelling [Lukosch, Klebl, & Buttler (08)], etc., a graphical representation is often more effective. ("A picture tells more than a thousand words" [Larkin & Simon (87)]). In order to use models as a basis for discussion, it would be useful if the all stakeholders can be actively engaged in the construction and modification of such models.

In the context of infrastructures design and within the System of Systems paradigm [Sage & Cuppan (01)], it is common practice to involve different skills in the modeling activity because systems of this kind are complex and generally require different perspectives. In such applications, collaborative modeling is *de facto* a requirement. The same applies for complex distributed simulation models developed within the HLA framework [Klir and Elias (85)].

However, building models in groups can be challenging [Renger, Kolfschoten, and Vreede (08)]. There is an on-going research to develop new ways to support model building groups using facilitation techniques and technology, see for example [Eden and Ackermann (04); Orwig and Dean (07); Rouwette, Vennix, and Thijssen (00)]. Research in technological support for collaborative modeling has mainly focused on group support systems [Dean, Lee, Orwig, and Vogel (94); Lee, Dean, and Vogel (97)]. Less is known about alternative technologies for collaborative modeling.

The goal of this paper is to provide first insights in the various settings in which interactive whiteboards can be used to support collaborative modeling. To this end we first define collaborative modeling and describe the functionality of interactive whiteboards. Next we describe the interviews that we conducted to elicit experiences with interactive whiteboards for collaborative modeling. Subsequently, we discuss the lessons learned that we derived from the interviews. We end with conclusions and directions for further research.

2 Collaborative Modeling and Interactive Whiteboards

The previous half century has witnessed a paradigm shift from a purely analytical approach to the so called systems approach. While the first consisted of an approach in which breaking systems down to simpler components and studying them in isolation was the main complexity reduction strategy, the latter leans more towards holism and adds synthesis i.e. an integrative perspective on systems, in which, not only understanding components is important, but also understanding how their overall structure (components and links) generates system level functions. Modeling emerged as an essential asset in the system thinking toolbox, with various semi-formal and formal (often graphical) techniques for the representation and specification of systems (SADT, causal diagrams, statecharts, UML, Petri nets, flowcharts etc.)

Interestingly, modeling can also be seen as a succession of an analysis step and a synthesis step. First, the relevant entities in the system are identified and constructed, and then the whole system model is synthesized from the identified parts with the proper causal or structural connections [Sarjoughian and Zeigler (99)]. Modeling is indeed a crucial instrument in the resolution of all system problems, be it system analysis, system design, or system inference, with the only difference being how the modelers navigate between levels of system knowledge [Klir and Elias (85)].

Given the scope and complexity of the systems being tackled nowadays and the development of the System of Systems paradigm [Sage and Cuppan (01)], heterogeneous and multidisciplinary teams are routinely required to work collaboratively to gain insight on systems through model building. In this paper, we define collaborative modeling as the joint creation of a shared graphical representation of a system [Renger, Kolfschoten, and Vreede (08)]. Collaborative modeling encourages the creation of shared mental models of a system. It also helps stakeholders to distinguish the current state of the system from the system as it should be (standards, official descriptions) and the system as it could be (envisioned changes and future requirements) [Barjis, Kolfschoten, and Verbraeck (09)]. To support collaborative modeling Interactive whiteboards can be used (IWB) (also known as electronic whiteboard).

An IWB is an interface device which has a large display that is accessible for a group, and the possibility to manipulate content on the display by the use of styluses, fingers or other devices as a mouse pointer. Specific modeling software for IWB's often enables text or line recognition and transformation into digital text boxes and straight connection lines, which enhances the intuitiveness of the interface, see for example [Damm, Hansen, and Thomsen (00)].

An exemplar situation where collaborative modeling is necessary is simulation federation development in the High Level Architecture framework for distributed simulation [IEEE (00)]. The Federation Development and Execution Process (FEDEP) has been proposed as a guideline inspired by the iterative waterfall model from software engineering. It consists of five steps: *requirements definition, conceptual model development, federation design, federation test and integration, and federation execution* [IEEE (03)]. Although collaboration is essential in federation development, no explicit reference to the modes of collaboration was made in the original FEDEP. The second and third steps in the process *(conceptual model development, federation design)* make extensive use of collaborative modeling and can be conducted in either synchronous or asynchronous collaboration modes [Sarjoughian and Zeigler (99)]. For these phases groupware and online communication tools can be used, e.g. group support systems [Boehm et al. (01)], wiki's [Yang, Wu, Koolmanojwong, Brown, and Boehm (08)], and collaborative modeling systems [Sarjoughian and Zeigler (99)].

To support collaborative modeling, besides improving the expressive power of modeling techniques, it becomes important, from a methodological perspective, to understand the dynamics of collaborative modeling, making this subject a major challenge in the field of System Engineering. Interactive whiteboards offer the benefits of digital technology without sacrificing the 'live' visual interaction within a group. The large display enables all participants to follow the expressions of others. Moreover, IWB's are expected to be of value for collaborative modeling because they allow group members to manipulate the model directly, supporting dynamic evolvement of the model.

The balance between individualistic and collectivistic approaches for promoting creativity in organizations is still in debate [Goncalo and Staw (06)]. Modeling being essentially a creative activity, it is of interest to discover the advantages and possible shortcomings introduced by collaborative modeling. An IWB can be a laboratory for studying the effects of live collaboration on modelers' effectiveness as a consequence of responsiveness to norms or conformity. These questions are not central to the present research and deserve further investigation. The study or design of large systems tends to exceed individual human cognitive capacity due to the large body of knowledge needed and makes collaborative modeling essential. However, we did not find precise methods and guidelines on how to create models in groups in true interaction. Literature on collaborative modeling often suggests that a modeler creates the model based on input of the group [Andersen and Richardson (97)]. However, we feel that experts might value the ability to manipulate models themselves as to express their perceptions and ideas with respect to the system, and to transfer their mental models. Interactive whiteboards enable capturing of mental models and versioning. This enables participants to address different complexities at a time while capturing insights during the modeling effort.

Although specific group support systems to support collaborative modeling have been developed (e.g. [Dean, Lee, Pendergast, Hickey, and Nunamaker (97); Ram and Ramesh (98)]), Aytes suggests that traditional whiteboards are more suitable for collaborative modeling tasks that require considerable group interaction [Aytes (95)]. Therefore, they could stimulate participation, feelings of data ownership and buy-in. Research in the use of IWB's to support collaborative modeling is mainly directed at the design and development of software tools [Damm et al. (00); Qi, Grundy, and Hosking (03)]. However, as is stressed by group support system researchers [Dennis, Wixom, and Vandenberg (01); Nunamaker, Briggs, Mittleman, Vogel, and Balthazard (97); Vreede, Davison, and Briggs (03)], the effectiveness of collaboration support technology depends on the process guidance in the use of tools that help them to create models that inform system analysis and design. In this paper we explore how IWB's are used and what types of guidance might be effective to improve the quality of the resulting models and the achievement of shared understanding.

3 Method

Due to the exploratory nature of this research, we based our findings on the experiences collaborative modelers had with IWB's, and the observations of teachers and teaching assistants when helping groups to use IWB's in a collaborative modeling class. We used in-depth semi-structured interviews, and e-mail interviews to gather our data, which allowed us to explore and elicit the findings and opinions of the interviewees with a flexible approach [Berry (99)]. In total we interviewed nine persons, and collected another four e-mail interviews to gain insights about experiences with collaborative modeling efforts using IWB's in an educational or research setting, usually in the role of supervisor during workshops. In order to obtain a broad picture of the experiences, the interview protocol, which can be found in the appendix, covered human factors, technological factors and factors with regard to the modeling approach.

In most modeling sessions that were discussed during the interviews, several groups worked in the same room on separate IWB's. The groups created one or two models on the IWB in two to four hours. Most of the sessions were part of modeling courses in the bachelor or master curriculum of the Faculty of Technology, Policy and Management at Delft University of Technology in the Netherlands. The purpose of these sessions was to learn the modeling approach and language. For these assignments the students obtained an instruction of the modeling approach, the syntactical rules of the model and a case description of the process or system they had to model. During the session supervisors walked around to give students feedback on their modeling syntax and validity. In one session, the participants were colleagues, and the purpose of the session was to exchange knowledge and explore possible synergy between participants. Some interviewees had been involved in several sessions. Most interviewees served as supervisor in a collaborative modeling session, several also participated in a collaborative modeling session. The amount of sessions interviewees participated in or supervised varied largely from only 1 or 2 up to around 10 sessions. When answers of e-mail interviews were unclear we asked respondents for clarification. One of the authors participated in several collaborative modeling sessions, both a supervisor and as participants, and observations are taken into account in the results.

All IWB's discussed in the remainder of this article are Smart Boards for Flat Panel Display px346 with a 46 inch touch screen display, combined with MS Visio or Smart Ideas, which enables users to drag and drop blocks and arrows on a page, and to edit these by typing or writing on the IWB.

4 Results

The results and lessons learned from the interviews are discussed below on three different topics: group composition, technology and modeling approach.

4.1 Group Composition

From the interviews we identified several lessons learned about the group composition, concerning the group size, level of participation and role assignment.

Group size. In the different sessions mentioned during the interviews, the group sizes varied from 2 to 8 persons. Most interviewees perceived 4-5 persons as the ideal group size to model on the IWB's. As the size of the display allows for a limited number of people to interact directly with the screen, non-participating group members or free-riding behavior was observed at groups of 5 or more in several settings both at bachelor and master student level.

"Group size remains an important issue; I think that 4 or a maximum of 5 people is works to keep the exercise effective"

1. **Participation.** Larger groups make communication and engagement more difficult, while very small groups share less ideas and criticism, which is required to produce rich and complete models. Even in small groups up to 5 it seems that usually part of the group is more active and part is more passive/reflective in its role. Other cases were mentioned where one or two persons operated the IWB while leading the discussion in a larger group. IWB's are expected to stimulate participation as digitally storable input is perceived to be more permanent than writings on ordinary whiteboards. The visibility of the model and changes does trigger group members to contribute, except for a few cases where students had very low motivation.

"I often observed that half of the group participated, the others just stared at the smartboard"

2. **Role assignment.** One interviewee stressed that someone operating the IWB for the group, requires that such person is not only a skilled IWB user, but also at least to some extent a skilled modeler, so (s)he can reflect on syntax and representation

issues before making changes to the model. Many interviewees indicated that some participants at least took a more active role in creating the model while others were more passive/ reflective suggesting changes or additions. In terms of the roles in collaborative modeling as described by Richardson and Andersen [Richardson and Andersen (95)], the interviewee thus recommends that the role of recorder should be combined with the role of modeler/ reflector.

Figure 1: students explaining their model to the supervisor

4.2 Technology

We studied the use of the IWB interface rather than specific software tools. Therefore, we only focus on very general features of modeling tools. Some interviewees felt that the available software does not yet exploit the full potential of the IWB's. One reason is that the available tools are still based on a 'traditional' mouse-based interface. The intuitiveness of the IWB would benefit from an interface that corresponds more to the use of non-digital whiteboards, see for example the gestured-based interface described in [Damm et al. (00)]. Moreover, most available tools do not provide explicit process structure for groups that use IWB's to collaboratively build a model. The text and graphical object recognition tools of the software used were useful, but a) it took some time to get skilled in using these tools, resulting in initial frustrations, b) some block-arrow connections were not supported by the software, while required for the modeling language, resulting in messy models. These factors lead to some groups preferring to work on normal whiteboards.

This experience was also reflected in the disagreement among the interviewees about skills required to operate the IWB. Experiences ranged from intuitive use to 15-60 minute training to support using manuals. Some felt that learning to operate the IWB's can be easy for hands-on learners and young students, but can be problematic for older people and non-academic professionals. The learning curve can reduce the efficiency of the technology in the short term. Also, the software used should fit the requirements of the model syntax, and compatible with software to further develop the model and to use in a report. This caused many groups to switch from using the smartboard software that enables writing recognition to MS Visio that is more compatible with the modeling language. However, this also resorted into using a keyboard and mouse for input as MS Visio is less suitable for the touch-interface. A key factor in this was the context of the modeling effort; when future use of the models was important, students choose to work with MS Visio.

"After about 30 minutes the students switched to using MS Visio and only used the IW as a screen. Inputs came from the laptop. Main reason for this was that the initial software did not support the IDEF0 modeling technique, this frustrated the students."

Summarized the following functionalities affect collaborative modeling with IWB's:

Manipulation and access rights. The interactive element of easy manipulating content directly on the display makes it a suitable medium for discussion. Most interviewees felt that the ease of model manipulation could increase efficiency. Access right to manipulate the model is achieved using styluses. Given the learning curve to use the IWB, some suggested that one skilled user should manipulate the model based on the group discussions. We also identified positive experiences with a person who specifically provided the group with technological support. Although the technology allows for more persons to work on one board at the same time, the software that we used does not support parallel work, unless multiple boards are used for one model. Access rights affect the possibilities of process support discussed below. Some groups had used the IWB's in several sessions, and a learning curve started to emerge. This helped students to use the boards more effectively. Others observed that groups found the interface not intuitive enough and abandoned it.

"The smartboards accelerated the group modeling process because models were easier manipulated compared to working with normal whiteboards"

"I didn't see the added value. It took a lot of time to get skilled in using the smartboard, for leaning, it would be more efficient to draw on a whiteboard and put it in a computer later."

1. **Overview** The use of the central screen was often mentioned as a key advantage in collaborative modeling as it engages the group and ensures that all group members are able to follow along and to respond to changes in the model.

"The use of smartboards gives a clear overview of the model for the entire group, the screen is large enough to ensrue tha they can all look at the the same aspect of the model."

2. **Text and structure recognition**. The clarity of the model improves because no handwriting and drawing is involved, and the model can be easily changed to become more readable, e.g. rearranging and aligning blocks. However, the stylus or touch input is often not specific enough, especially when group members work from different angles. This poses a barrier. Some groups resorted to using classical input devices (mouse and keyboard) or a combination of both.
3. **Storage and versioning.** Revisions of the model or different versions can be saved separately for later comparison. This possibility allows users to explore and evaluate different versions of a model recursively. In the educational setting this was not used much. However, groups tended to choose to work in MS Visio to make sure that they could work further on their models in later phases of the project.

4.3 Modeling Approach

A couple of sessions were meant to teach semi-formal modeling techniques: IDEF0 and UML. Therefore, the semantic and syntactic quality of the models is very important. In some sessions the goal was to learn policy analysis from a multi-actor perspective, which involved multiple techniques like mind mapping and causal diagramming. In another session system dynamics simulation models were manipulated on the IWB. During the exploratory sessions with colleagues mind maps were created, where no syntactic rules applied. Regarding the support for collaborative modeling with IWB's, we identified three alternative approaches:

1. **No process support**. In this setting, every participant can manipulate the model. In this setting, participants tend to hold on to the IWB stylus, and therewith to the access rights. Therefore, it is important to facilitate active and equal participation, for instance using a turn-taking rule. Such protocols can be based on the passing of the styluses. Multiple interviewees observed the emergence of process structure and roles. In all cases, the observed approach taken by participants can be identified as top-down, starting with a very coarse model and working toward more details and revisions to meet modeling rules and to resolve conflicting aspects of the model. Some groups already had an initial model and worked with the IWB's to refine and revise the model. Interviewees believed that this complies with the standard modeling techniques that participants are taught, and that the use of an IWB did not affect the modeling approach of the groups. Further research is required to see if this effect also manifests in organizational settings.
2. **Chauffeured.** In this setting one or two persons operate the IWB based on the group discussion. One interviewee felt that this could be advantageous because the IWB functions as a center of attention, so no subgroups can emerge in the group discussion. However, like interrupting speaking, interrupting drawing can be experienced as disruptive social behavior, and thus a turn-taking solution might work better. Because there needs to be agreement before changes can be made to the model, more discussion is encouraged. Because changes made to the model are more 'final' in this set-up, the recorder operating the IWB should also have a modeler/ reflector role. This setting allows for 'free-riding', i.e. observing without participating.
3. **Facilitated.** A process facilitator leads the group to create the model in several steps; e.g. first creating a list of elements, and subsequently identifying relations between elements. A few groups seemed to emphasize in the beginning of the modeling process on elements and later on relations and contextual factors, we expect that it can result in richer and more complete models, but that it might conflict with the individual cognitive modeling process. One interviewee suggested that such a separation could avoid a tunnel vision, meaning that no alternative modeling perspectives are considered by the group. Furthermore, separating generation and organizing tasks have in-built model completeness checks, which is less apparent if the tasks are combined. In the mind mapping session, several groups had two or more versions of the model. After an association phase, they needed to re-order the elements in the model to be able to draw all relevant relations.

5 Conclusion and Further Research

In this paper, we conducted an exploratory (e-mail) interview-based research about the experiences in supporting collaborative modeling with interactive whiteboards. We identified different ways of using IWB's. We stress that the way the IWB's are used depends on the primary goal of the modeling effort, e.g. learning, creating shared understanding, and creating consensus about a system representation. We found that using the IWB's is mainly useful because of the large visualization that enables all participants to see the model and engages them to suggest changes or improvements. Further a key advantage is that the model can be captured for future use. However, for this purpose, compatible software should be used. The ability to manipulate the model live, with multiple users and without creating messy changes as happens on paper or a whiteboard is considered useful. However, the use of touch or styluses as input devise seems still challenging and posed a barrier for some, while others experienced it as fun.

Optimal collaboration modes will differ according to the phases of the modeling process. While the requirement definition phase is better supported by other groupware technology, Interactive whiteboard technology can be of use in both phases of simulation conceptual modeling, i.e. model construction and model synthesis. However, we consider it to be more helpful in the latter phase, when synchronous and collocated collaboration is more often required. A promising perspective will be the development of specialized IWB software supporting common simulation formalisms such as DEVS, Petri-nets or state charts. So far we mostly gained experience with modeling for education and for the description of a current state static system. However, the conclusions drawn here should naturally generalize to conceptual modeling in the simulation field because the essence of it is still to define causal or structural relations between pre-defined concepts.

Given these advantages we identify a research challenge in exploring which group size and role allocation, approach, and tool set is more efficient and effective to support collaborative modeling in different phases of the system analysis and design process. When active participation of all group members is required, 5 seems the maximum number of participants. Probably, this number can be slightly increased when a larger (or second) screen is used and when motivation levels of participants are higher.

Furthermore, research is required to understand cognitive implications of the integration of individual system representations and its relation to the efficiency of different approaches to support collaborative modeling. In terms of technology, the intuitiveness of the interface could benefit from a design that resembles traditional whiteboards. Moreover, the IWB environment could be extended to enable flexible allocation of (parallel) access and manipulation rights in order to enable process facilitation while keeping the ability for each participant to interact with the model.

The combined use of IWB with other group support tools is an interesting perspective. It appears that groupware tools are more potent in supporting analysis with the help of software solutions for brainstorming and voting. IWB could be used as a complement in the synthesis step, when the relations between the pre-identified concepts have to be made explicit.

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Appendix

Semi-structured Interview Protocol

1. Can you tell something about your background and your specialization?
2. How often have you been involved in a collaborative modeling effort, and in what context?
3. How and how often have you been using interactive whiteboards for collaborative modeling?
4. What was the primary goal of these sessions, and what were the deliverables?
5. What are your experiences with the available time for a session, and the efficiency of using interactive whiteboards?
6. What are your experiences with the group size and background of group members?
7. How much and how are group members stimulated to participate in the process?
8. Can you identify steps in the approach taken by groups when they model with interactive whiteboards?
9. To what extent would groups have behaved differently without an interactive whiteboard?
10. Do participants need special skills to operate interactive whiteboards?

11. To what extent and how did you or someone else have a steering or guiding role in the process?
12. How do participants themselves experience working with interactive whiteboards?
13. How do interactive whiteboards provide advantages in collaborative modeling?
14. Do you see limitations in using interactive whiteboards in collaborative modeling?