Web-based Participatory System Dynamics Modelling – Concept and Prototype Development

Stefan Pickl, Armin Leopold, Bo Hu
Universität der Bundeswehr München, Germany
{stefan.pickl, armin.leopold, bo.hu}@unibw.de

Abstract

In this paper we present an innovative concept and prototype of a web platform which supports participatory modelling in the decision-making processes in the field of environmental modelling and simulation. Participatory modelling needs usually face-to-face participatory modelling sessions. In comparison to classical approaches, the platform presented in this paper shall facilitate web-based collaborative and cumulative modelling when such face-to-face sessions cannot be organised as often as desired. Successive iteration steps of the model development can thus be displayed interactively in a standard web browser together with comments and explanations made by the modeller. The platform strengthens the support of formal model construction and documentation on the one hand and reduces the effort of model re-publishing on the other hand. These approaches are discussed and characterised in the following contribution. Furthermore this platform shall be used to support participatory modelling and decision-making processes in the field of sustainable development, especially in the context of anticipatory systems.

Keywords: participatory modelling, system dynamics, web platform, sustainable development

1. Introduction

Decision support is one of the most exciting and important application fields of system dynamics which can be seen as an underlying methodology for anticipation systems in different areas (see, e.g., Dubois 2012, Ghaffarzadegan 2011, Kleer 2008). One of the main advantages of system dynamics in this context is that it provides a clear and transparent model structure which can, beside the discussion of the simulation results, promote the cooperation between the system dynamics modellers and decision-makers in the sense of participatory or group modelling (Andersen 1997).

In ideal cases System Dynamics modellers and the "people in the actual systems" (Forrester 1994) or decision-makers have interactive, face-to-face sessions all the time. Such a collaborative or participatory modelling process can be described as an efficient way to share useful knowledge between different actors in the aim to improve the collaborative decision-making process. Collaboration is often necessary to solve different issues which may be caused directly by the actors' activities and decisions. The need of collaboration does not aim at solving technical aspects only, but also at building

International Journal of Computing Anticipatory Systems, Volume 30, 2014
Edited by D. M. Dubois, CHAOS, Liège, Belgium, ISSN 1373-5411 ISBN 2-930396-19-9

or adapting the project organisation in the area of implementation of decisions. In many situations, however, due to long distance or tight schedules group meetings cannot be organised in a frequent way.

In this paper we present our concept and prototype for supporting participatory modelling using a web platform, which can be seen as a part of a modern anticipatory system. A system dynamics model viewer, as a part of this, streamlines the model publishing and thus enables a web-based collaborative and cumulative (Hagel 2005) modelling when face-to-face participatory modelling sessions cannot be organised as often as desired. Not only the result of the model development but also its successive iteration steps can be displayed interactively together with comments and explanations made by the modeller. Furthermore this web system also provides possibilities for all participants of the collaborative process to contribute to online discussions. Model development is thus closely connected to and also triggered by shared model understanding and intensive discussion. Not only the interpretation of the results of the simulations but also a well understanding of the models used for the decision support themselves is of increasing importance because of the increasing complexity and often global impacts on future developments (f. i. on sustainable development, see section 2.2) of the decisions which are based on the models.

In the following section we first discuss some aspects of participatory system dynamics modelling. The prototype of our web viewer of system dynamics models is presented in section 3. Furthermore we describe in detail the innovative method to resolve the underlying problem and discuss in addition the obtained results. The relationship to computers anticipatory systems is characterised. Section 4 concludes our contribution.

2. Participatory modelling

2.1 Classical decision support systems: Participatory modelling as an essential component of a participatory decision process

Today's decision-makers are urged more often to assess the impact of their measures and their major intentions on the basis of different aspects, for instance, in terms of sustainable management (Bonjour 2009). This necessitates using applied scientific models, for example system dynamics models, as instruments for identifying and evaluating different kinds of impacts of alternative decisions.

As described by Bonjour, most decision support systems have to integrate the following decision-making features:

- multi-criteria multi-perspective design problem,
- knowledge-intensive distributed product modelling and also
- conflict-oriented problem solving (Bonjour 2009)

Operational, tactical and strategic planning

In a more general point of view the process of decision-making can be considered as a cognitive process leading to the selection of specific actions among several alternatives. In scientific literature, three decision levels have been distinguished according to their temporal impacts (from short to long term): operational, tactical and strategic. However, every decision has to be associated with human activity, which represents the operational context of this issue.

One of the main aims for establishing a model is to target operationalisation of the arguments used and thus to achieving inter-subjectivity. For this reason formal logical models are developed that structurally match the verbal argumentation chains. System dynamics is a methodology describing systems and their changes ("dynamics") using integral equation systems which can be solved by computational solvers. In this sense system dynamic models can be designed and used to support the decision-makers as a comprehensible collaborative decision support system. By designing a system dynamics model for complex system aspects the structuring of sensitive and complex argumentation chains in a simulation model can be reached in an understandable way (Forrester 1994). Furthermore the integration in a decision support system can be achieved quickly.

With every of the six major "system dynamics steps from problem symptoms to improvement" which have been defined by Forrester, from the hypotheses and stock and flow diagrams, via simulations and alternative policies, through discussions and implementations, "active recycling occurs back to prior steps" (Forrester 1994). Especially in step 2 when formulating a simulation model "writing equations reveals gaps and inconsistencies that must be remedied in the prior description" (Forrester 1994). In a collaborative or group modelling process it is an ideal case if the decision-makers and system dynamics modeller can meet and discuss frequently to have "fairly sophisticated pieces of small group process" (Andersen 1997a).

2.2 Environmental management: Sustainable development and the Copenhagen Accord as an example for the need of participatory modelling

Before we stress the importance of system dynamics to computing anticipatory systems, we introduce a concrete example in the context of environmental management.

In this section sustainable development and furthermore the Copenhagen Accord should be described shortly to explain the necessity for participatory decision support systems. It is still fact that different nations have different views about climate change. Therefore, to receive a chance to build up a common notion about sustainable development and climate change, a participatory decision support system with the help of system dynamics can be a potential help. In the authors' point of view the web-based system dynamics modelling can be seen as a potential tool to improve not only the further international discussions about a sustainable development, but also the conceptualisation of, for instance, a possible Post-Kyoto Protocol.

Sustainability is described by Gro Harlem Brundtland as the ability of humanity "to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs" (Harding 2006, p.231). Some economists, however, argue that this specific definition provides more questions than answers, especially regarding "the needs of the present" and future generations' needs. To be able to answer these questions, not only scientific knowledge is necessary. More central is the value judgement on issues such as quality of life. That is the main reason why, in the last 30 years, the concept of sustainability has led to different sorts of interpretations and still remains challenged (Harding 2006, p.234).

Sustainable management

When talking about the sustainable management of natural resources, one has to remember the issue-related Kyoto Protocol and the latest developments in this area, especially the United Nations Climate Change Conference which took place in Copenhagen, Denmark in December 2009. This specific conference marked the culmination of a slow developing two-year negotiating process to further international climate change cooperation. Many scientists and politicians hoped that at the Copenhagen Climate Conference there would be the chance to "seal the deal". The fact is, however, that most delegates left Copenhagen disappointed at what they saw as a "weak agreement" (IISD 2011, p.1f). In addition, some developing countries opposed the accord reached during what they characterised as a very "in-transparent" and "undemocratic" negotiating process. Its provisions on mitigation by developed countries are now widely seen as "clearly weak" and "a step backwards from the Kyoto Protocol". Developed countries do not commit themselves to legally-binding emission reductions. Similarly, there is no quantification of a long-term global goal for emission reductions, or specific timing for the peak of global emissions. Instead, the agreement suggests a bottom-up approach whereby developed and developing countries submit their pledges for information purposes to the Convention, a method advocated most prominently by the US (IISD 2011, p.29). Different nations have different ideas and visions about climate change and the necessary sustainable management. Different models and expectations exist. In this contribution we introduce a new approach which is closely connected to anticipatory systems.

Participatory System Dynamics modelling in anticipatory systems

Especially in this context participatory system dynamics modelling can play a central role with regard to raising the awareness in the area of sustainable management of natural resources. System dynamics can be regarded as a practical methodology to formulate sustainable management systems which have the potential to support the decision-maker's effort. Collaboration can be described as an efficient way to share useful knowledge between different actors in the aim to improve the collaborative decision-making process across country boarders. Collaboration is often necessary to solve different issues that are direct consequences of the strong interdependencies

between the actors' activities and decisions. The need of collaboration does not aim at solving technical aspects only but rather at building or adapting the project organisation in the area of sustainable management (Bonjour 2009). In this context it is important to understand both how the model can be improved for sustainable development purposes and how it can be used in support of collaborative decision-making processes with the analysis and simulation of especially anticipatory systems in the context of environmental management (Bonjour 2009).

2.3 Web-based participatory modelling

One of the key aspects of system dynamics modelling is to integrate all participants in the building of a model and not only in discussing the final result. System dynamics has specific advantages in structuring complex debates in a very understandable way (Andersen 1997, p.1). In other words, in this way decision-makers are more often integrated into the whole process of model development.

In many situations, however, due to long distance or tight schedules group meetings cannot be organised in a frequent way. Instead, new approaches based on information technology especially Web 2.0 approaches (Hagel 2005, O'Reilly 2005) are more often used to achieve group work processes. A web based system dynamics tool has the potential to quickly motivate all participants to further develop their system dynamics model.

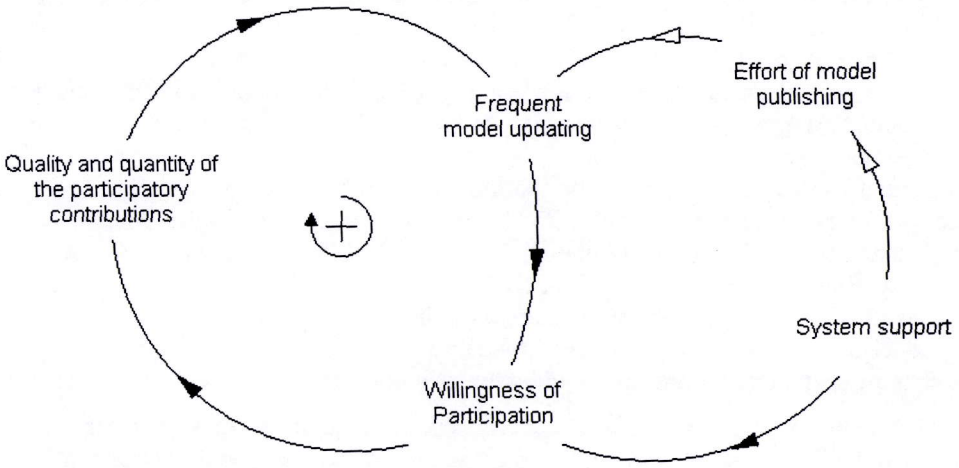

Figure 1: A causal loop diagram for participatory modelling

The prerequisite for an intensive discussion, however, is that the participants do at least understand the system dynamics model as a starting point of their discussion. To achieve this, an intensive manual preparation for publishing the model has been

necessary so far. That reduces the willingness of the modellers to update and re-publish the model, thus the willingness of the decision-makers to contribute to the discussion in turn. Since facilitating frequent cumulative updates present a critical success factor for Web 2.0 based collaboration the effort of model publishing needs to be reduced by means of software support. At the same time it is also important to facilitate contributions to the model discussion, as shown in fig. 1.

The result of the complete modelling process can be made more understandable if the model can be de-composited in successive steps which lead from scratch to the final stage. The web based viewer and certainly the confidence in using system dynamics modelling can be essential for the success of the whole modelling project (Richmond 1997, p.134). Furthermore this specific method of system dynamics modelling strengthens the support of formal model construction, and identification of action steps to maximize the overall impact of the intervention on the modelling team (Huz 1997, p.165). Related to this context, Cavaleri and Sterman present that different managers reported that the necessary systems thinking helped shifting many people's thinking from a mainly reactive mode to a more strategic mode, which gave them an edge over competitors who relied on a traditional view of managing (Cavaleri 1997, p.176).

3. Prototype of a web viewer of system dynamics models

As mentioned previously the success of a model-based collaborative decision-making process does not only depend on the sharing of a common view of the results of the model simulation. It is also essential to achieve a mutual understanding of the model itself. Since the modelling process today is generally an iterative one (Forrester 1994) a model viewer should be capable of representing the different iterative steps interactively. It is aimed to provide this system dynamics model viewer as a part of a working environment for participatory model building (Andersen 1997) in the next years. A simplified use cases diagram of the working environment is shown in fig. 2. When a decision-maker views the model with the model viewer both textual documentations made using the modelling & simulation environment (MSE) and explanations about the each iteration step made on the web-based participatory modelling platform are displayed step-by-step in synchronisation with the model which is displayed graphically. The decision-maker can also easily comment and discuss the model together with the modeller using the functions provided by the web platform.

We have chosen a web-based and XML-centric architecture to maximise the reach of the model viewer. As shown in fig. 3 a system dynamics model in Vensim's MDL format (Ventana Systems 2009) is first transformed into XML then into an image. The two logical modules, "Mdl2Xml" and "Xml2Img", are embedded in an existing web content management system respectively collaborative authoring system which was first introduced in 2004 and has been being developed since then continuously (Hu 2004, Hu 2006, Hu 2010) to take the advantage of existing content management functions like role and group based access control, layout and design control, forum management functions and more.

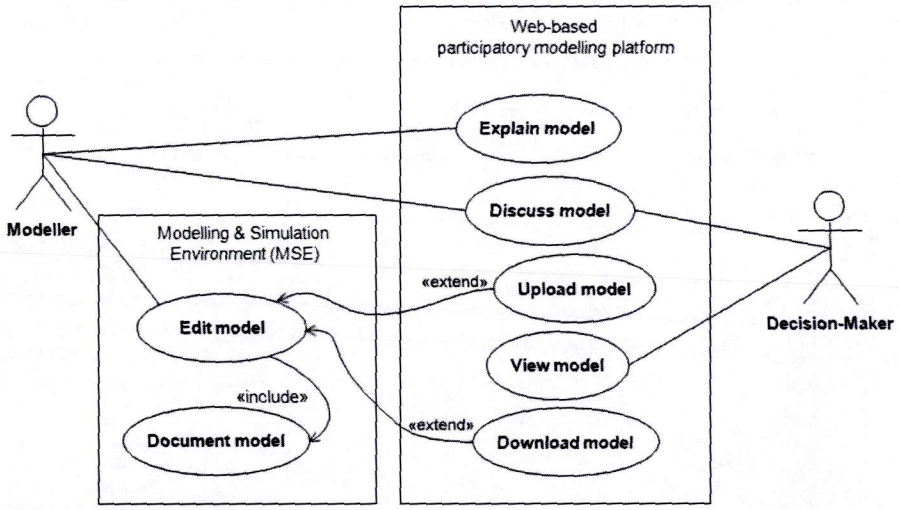

Figure 2: Use cases diagram for a web-based participatory modelling platform

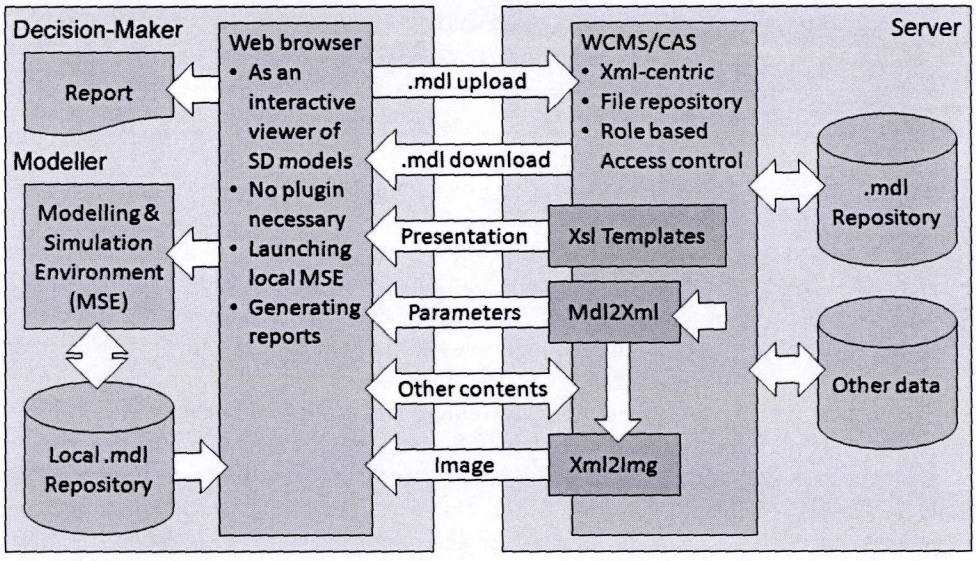

Figure 3: A web-based and XML-centric architecture for the system dynamics model viewer

Using the functions provided by the model viewer system dynamics models in Vensim's native MDL format can be managed by the server directly. To publish a model for discussion the modeller uploads the model simply to the server. The model can be viewed by each person having access to the web site using a standard web browser. The

most essential feature is certainly that each variable of the model can be assigned to a certain step of the iterative model development. The assignment is carried out within the Vensim's simulation environment using the comment field of each model element.

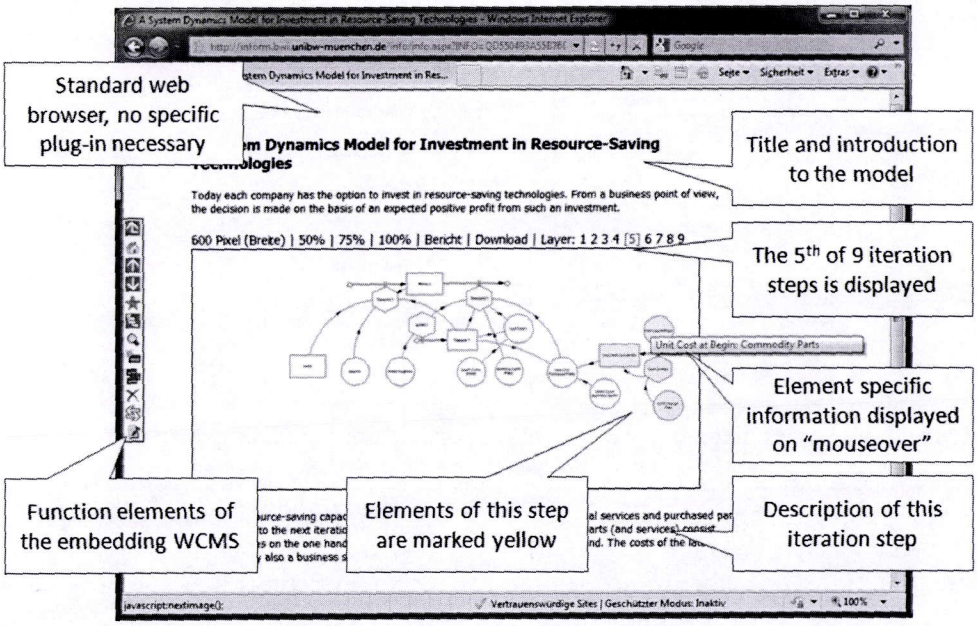

Figure 4: User interface for the system dynamics model viewer in a browser

Once uploaded to the server the iterative development of a system dynamics model can be interpreted by the system automatically and displayed step-by-step by mouse clicks (fig. 4). Another major advantage is the fact that no local software or plug-in is necessary. Moreover, since the model viewer is embedded in a web content management system even complex descriptions about the iteration steps can be integrated and synchronised with the viewer on the same web page. Furthermore a report tool lists all iteration steps together with their graphical and textual descriptions for export into a document. Additionally there exists the possibility to download the whole model as a Vensim file for further model refinement. Discussion forums and other web based tools can be linked to the web interface to streamline model development and discussion.

The web viewer is a key component within our concept of web-based system dynamics modelling environment. It facilitates a more intensive discussion and more frequent updates through reducing the effort for updating and re-publishing a system dynamics model remarkably.

Generally speaking, this web viewer of system dynamics models was developed thoroughly as a part of the web-based system dynamics modelling environment within

the last years and is now used for different types of system dynamics based projects with international partners. Especially because of the large variety of different decision makers this type of decision support tool in the context of anticipatory can be regarded as a successful and innovative tool.

4. Conclusion

From the current point of view the platform that we presented in this paper can intensify web-based participatory modelling processes. It strengthens the support of formal model construction and documentation on the one hand and reduces the effort of model re-publishing on the other hand. The modelling processes are made more transparent to all participants by the web viewer of system dynamics models since each of the iteration steps of the model development can be displayed on the web interactively.

Recently we are using the web platform intensively to enable web-based participatory modelling both in an educational context and for our research projects. Further research should help to understand the real impact of the web platform to participatory modelling and decision-making processes in the field of sustainable development and in related other fields, especially in the context of anticipatory systems. As a first approach we consider the classical example of decision support in the area of environmental management and demonstrate that via our approach of web-based participatory modelling. Therefore we conclude that with web-based participatory modelling a new part of decision making is developed which supports the understanding of anticipatory systems in the area of sustainable development.

References

D.F. Andersen, G.P. Richardson and J. A.M. Vennix (1997): Group model building: adding more science to the craft. *System Dynamics Review, 13, Issue 2: 187–201*

D.F. Andersen and G.P. Richardson (1997): Scripts for group model building. *System Dynamics Review, Vol. 13, Issue 2: 107–129*

Eric Bonjour, Farouk Belkadi, Nadege Troussier, Maryvonne Dulmet (2009): Modelling interactions to support and manage collaborative decision-making processes in design situations. *International Journal of Computer Applications in Technology, Volume 36, Number 3-4*

Steven Cavaleri and John D. Sterman (1997): Towards evaluation of systems-thinking interventions: a case study. *System Dynamics Review, Vol. 13, Issue 2: 171–186*

Daniel M Dubois, Stig C Holmberg: SDA (2012): System Dynamics Simulation of Inter Regional Risk Management Using a Multi-Layered Model with Delays and Anticipation. *The 2012 International Conference of the System Dynamics Society, Proceedings*, St. Gallen, Switzerland, July 22 – 26, 2012

JW Forrester (1994): System dynamics, systems thinking, and soft OR. *System Dynamics Review, Vol. 10, No. 2,* Summer 1994

Ghaffarzadegan, N., Lyneis, J. and Richardson, G. P. (2011): How small system dynamics models can help the public policy process. *System Dynamics Review, 27: 22–44*

John Hagel (2005): What is Web 2.0? *Edge Perspectives with John Hagel (Blog)*, September 25, 2005,
http://edgeperspectives.typepad.com/edge_perspectives/2005/09/what_is_web_20.html (09.12.2005)

R. Harding (2006): Ecologically sustainable development: origins, implementation and challenges. *Desalination, 187: 229-239*

B. Hu, F. Lauck (2004): Prototype of a Web and XML Based Collaborative Authoring System. *International Conference on Computing, Communications and Control Technologies (CCCT'04), Proceedings Vol. IV: 79-84*, ISBN 980-6560-17-5, Austin, USA, 14-17 August 2004

Bo Hu (2006): Correction Marks and Comments on Web Pages. *Proceedings Intelligent Tutoring Systems: 8th International Conference, ITS 2006, Springer Lecture Notes in Computer Science, 784 - 786*, ISSN 0302-9743, Jhongli, Taiwan, June 26-30, 2006

Bo Hu, Klaus Gollin (2010): Supporting Case-based Learning Through a Collaborative Authoring System. *Bernhard Ertl (ed.): Technologies and Practices for Constructing Knowledge in Online Environments - Advancements in Learning, Information Science Reference, 99-112*, ISBN 978-1-61520-937-8, Hershey, New York

Steven Huz, David F. Andersen, George P. Richardson and Roger Boothroyd (1997): A framework for evaluating systems thinking interventions: an experimental approach to mental health system change. *System Dynamics Review, Vol. 13, Issue 2: 149–169*

IISD (2011): Earth Negotiations Bulletin. *Vol. 12 No. 459*, International Institute for Sustainable Development (IISD), December 2009, http://www.iisd.ca/climate/cop15/ (10th February 2011)

Bernhard Kleer, Eva-Maria Cronrath and Alexander Zock (2008): Market development of airline companies: A system dynamics view on strategic movements. *The 2008 International Conference of the System Dynamics Society, Proceedings*, Athens, Greece, July 20 – 24, 2008

Tim O'Reilly (2005): What Is Web 2.0. *http://www.oreilly.com/*, 09/30/2005,
http://www.oreillynet.com/pub/a/oreilly/tim/news/2005/09/30/what-is-web-20.html (09.12.2005)

Barry Richmond (1997): The Strategic Forum: aligning objectives, strategy and process. *System Dynamics Review, Vol. 13, Issue 2: 131–148*

Ventana Systems (2009): Free Download | Vensim PLE.
http://www.vensim.com/freedownload.html (19.07.2009)