Frameworks and Interactive Tools for Scientific Knowledge Systematization

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EXTENDED ABSTRACT

A concept for Scientific Knowledge Systematization is presented, existing of three components: knowledge development, value adding and knowledge management.

To put this concept in practice, a software framework architecture and supporting tools is developed to facilitate efficient knowledge integration and an improvement and acceleration of the development of specific model applications. Within Wageningen University and Research Centre (WUR) this is supported by Wageningen Systems.

Wageningen Systems is a research program of Wageningen UR and based on the assumption that knowledge is not only based in the heads of employees and text books, but also in models and databases. The use of this digital knowledge is strongly influenced by the way this knowledge base is built up, distributed and equipped with tools for interactive exchange of this knowledge. It is the strategy and philosophy of Wageningen UR that innovative knowledge is best developed by both deepening (fundamental) research and broadening (applied) research, referred to as an integrated approach. A knowledge system is necessary to stimulate and facilitate such an integrated approach in environmental sciences.

The international context that Wageningen UR works in, requires a prominent role in the development of ontology in the field of what we call the “green/blue environment”. See: http://www.wur.nl/UK/research/research+themes/

The Wageningen Systems expertise in the field of software frameworks, interactive tools and semantic interoperability has made a clear contribution to the strong position of Wageningen UR in international integrated assessment studies. Also within Wageningen, Wageningen Systems has pushed the exchange of information and the co-production of knowledge.

1. INTRODUCTION

"One of the greatest pains to human nature is the pain of a new idea. It is, as common people say, so 'upsetting;' it makes you think that after all, your favorite notions may be wrong, your firmest beliefs ill-founded...."

-Walter Bagehot, Physics and Politics (1872)

1.1. Why knowledge, what is knowledge and how to handle knowledge

The generation of knowledge is something that for most research institutes is part of their mission. The mission and strategy of Wageningen University and Research Centre (Wageningen UR) is to provide education and generate knowledge in the field of life sciences and natural resources.

But what exactly is knowledge? The Oxford English Dictionary defines knowledge as: (i) facts, information, and skills acquired by a person through experience or education; the theoretical or practical understanding of a subject, (ii) what is known in a particular field or in total; facts and information or (iii) awareness or familiarity gained by experience of a fact or situation.

The classical definition by Plato states that in order for there to be knowledge at least three criteria must be fulfilled; that in order to count as knowledge, a statement must be justified, true, and believed. This is also known as the JTB account (Gettier, 1963).

Wageningen Systems, a research programme of Wageningen UR is based on the following trends and assumptions:

- The complexity of many problems in our society requires integration of knowledge from various disciplines and from both fundamental and applied research;
- For the development of a knowledge based economy it is crucial to increase our capacities to develop new knowledge by absorbing and applying existing knowledge;
- Innovation, the development and successful implementation of new products and services, is changing from a vertical process within an individual organization, to a horizontal system of 'open innovation' in which partners from various organizations collaborate (Chesbrough, 2003).
- Knowledge is not only in the heads of employees and text books, but also in models and databases. The use of this digital knowledge is strongly influenced by the way this knowledge base is built up, distributed and equipped with tools for interactive exchange of this knowledge.

This paper will describe the concept of scientific knowledge systematization within Wageningen Systems (chapter 2). These concepts are supported by tools for interactive access and interactive knowledge discovery. Chapter 3 will give an overview of different types of tools and illustrate the usefulness by giving examples of these tools.

2. SCIENTIFIC KNOWLEDGE SYSTEMATIZATION (SKS)

Scientific based organizations (like knowledge institutes and universities), should develop a modern concept of systemizing their knowledge. If done in a proper way, the use of knowledge can be improved and the application of software support tools can become of real added value to the organization.

For Wageningen UR the basic concept of SKS is defined, existing of three components: knowledge development, value adding and knowledge management. The next paragraphs will explain these three components.

2.1. Knowledge Development

To come to a working definition of knowledge, we have to start with data. One of the most cited model on knowledge is the knowledge pyramid of Ackoff (1989).

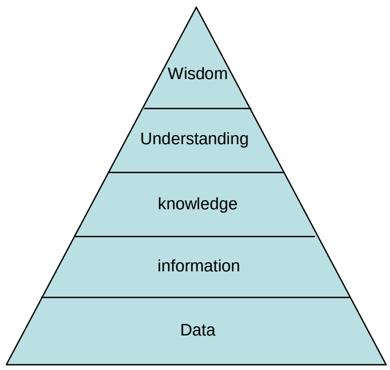

Figure 1. The data-to-wisdom pyramid

The data-to-wisdom pyramid has a foundation of data, followed by a layer of information, a layer of knowledge, a layer of understanding and finally a top layer of wisdom (Figure 1).

Data can be defined as ‘a set of discrete, objective facts existing in symbolic form that have not been interpreted’ (Davenport and Prusak, 1998).

Data becomes information when it has been shaped by humans into meaningful and useful form (Laudon and Laudon, 1998)

Information is meant to shape the outlooks and insights of the receiver (Davenport and Prusak, 1998). So information is data that is enriched by context. Information gives answers to the *what-question.*

Information only becomes knowledge after it has been examined and compared to other information or data, and then is applied to describe or predict or adapt a situation (Kock et al, 1997). Knowledge gives answers to the *how-question*.

Increased understanding comes when answers to the why-question can be given. Finally resulting in Wisdom which gives the ability to perceive and evaluate.

2.2. Value adding

The different layers of the knowledge pyramid can be seen as layers with increasing value (figure 2). This is basis for the knowledge valorization concept in Wageningen Systems. Data, information, knowledge and understanding contribute to doing the things right. Wisdom is the component to allow us to do the right things.

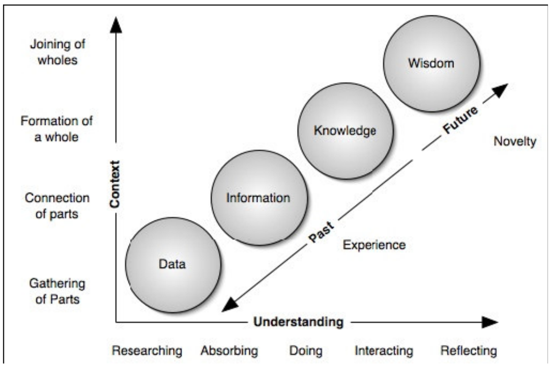

Figure 2. View on the data-wisdom hierarchy (Clark, 2004)

2.3. Knowledge management

In the field of knowledge management there is a distinction between tacit and explicit knowledge (Polanyi, 1966). By definition, tacit knowledge is knowledge that people carry in their minds and is, therefore, difficult to access.

Tacit knowledge is not easily shared because often, people are not aware of the knowledge they possess or how it can be valuable to others. Like Polanyi says: "We know more than we can tell." By enabling the exchange of tacit knowledge of individuals, the organizational knowledge base can be extended. This process is often referred to as socialization. However, an organization needs to transform tacit knowledge into explicit knowledge to be able to use it in the organizational context (Nonaka and Takeuchi, 1995). Both sharing and conversion of knowledge lie in the core of knowledge creation and can take one of four forms: socialization, externalization, internalization, or combination (Figure 3).

from / *to*	Tacit	Explicit
Tacit	Socialisation	Externalisation
Explicit	Internalisation	combination

Figure 3. Types of knowledge conversion, (Nonaka an Takeuchi, 1995)

- *Socialization* is characterized by observation of others, training on the job and in software engineering by pair programming.
- *Externalization* is characterized by articulation of personal know how and modeling
- *Internalization* is characterized by reading manuals, documentation and learning by doing
- Examples of *combination* are combining data, models and model integration.

3. WAGENINGEN SYSTEMS APPROACH

Wageningen Systems focuses on the ability of Wageningen UR to 1) find and access, 2) value, 3) integrate and 4) use knowledge to provide integrated solutions for the problems of its stakeholders. To do this, Wageningen Systems focuses on four generic subjects; 1) ontology and knowledge bases, 2) frameworks for knowledge integration, 3) Quality Assurance and 4) interactive tools.

In the following paragraphs is indicated how these subjects are deployed to allow for software support for scientific knowledge systematization.

3.1. Knowledge bases and ontology

The challenge in transferring, sharing and integrating knowledge is the conceptual understanding. To achieve this, we need explicit semantics and a shared conceptualization.

To enable semantic interoperability between the knowledge of Wageningen Systems, the problem of semantic conflicts or semantic heterogeneity needs to be solved. For this ontology is used.

One of the most cited definition for ontology is from Gruber (1993): “an explicit and formal specification of a conceptualization”. A “conceptualization” is explained as an abstract model of a phenomenon, identifying the relevant attributes. A conceptualization is an abstract, simplified view of the world that we wish to represent. Every knowledge base or knowledge-based system is committed to some conceptualization. (Gruber 1995)

“Formal specification” refers to the fact that the language semantics are machine readable. Often this is done by use of W3C OWL (Ontology Web Language, Patel-Schneider et al., 2004). A formal specification helps to communicate the definition of terms in a context independent ways and formal language semantics allows some automated consistency checks.

Wageningen Systems developed a Knowledge Browser to support transferring, sharing and integrating knowledge in an interactive way. The Knowledge Browser application (figure 4) facilitates the exploration of ontology, by showing relations between classes and objects by means of a “spring graph” (Wien et al, 2006). Each object in the browser is clickable and places the object in the centre of the network. Relations between this centred object and the others are visible. The number of levels shown, can be adjusted. If an object is a geo-component, it will be displayed on a map.

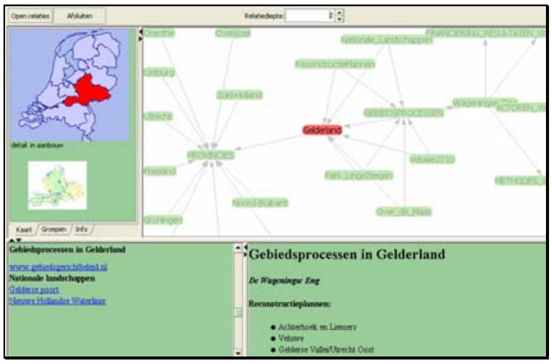

Figure 4. Graphical User Interface of the Knowledge Browser

3.2. Frameworks for knowledge integration

For complex, multi-disciplinary research projects, simulation models are used jointly by exchanging values between the simulation models (results from model A are used as input for model B). If required, conversion routines are applied to solve spatial or temporal differences. In this way, complex model-chains are generated. Constructing these configurations of connected models is usually very difficult. Each model expects input values in a specific file format or database and each model uses specific spatial schematizations.

The use of a framework for data- and model integration can simplify the integration of simulation models. A commonly used definition for framework is given by Fayed et al. (1999): “A framework is a reusable design of a system that describes how the system is decomposed into a set of interacting objects”. A system is described by a set of interacting objects. The framework does not only describe these objects, but also the interactions between these objects. In this way, a framework can be used as a reusable design for different applications (van der Wal and Wien, 2003).

For the development of frameworks for knowledge integration, Wageningen Systems adopted the Open Modeling Interface (OpenMI) (Gijsbers et al., 2005; Gijsbers et al. 2006). The OpenMI Interface is a standard interface that enables OpenMI components to exchange data as they run.

The data definition concerns what the data is about (*quantity*) and where (*element set*) and when (*time*) it applies. Each component (*LinkableComponent*) has a meta data description of its exchangeable data in terms of a *quantity* and an *element set.* Each unique exchangeable *quantity* is registered and published in a so-called *ExchangeItem*. Connections between *ExchangeItems* of

LinkableComponents are defined by a *Link* and exist as a separate entity (Figure 5). For more information see http://www.openmi.org.

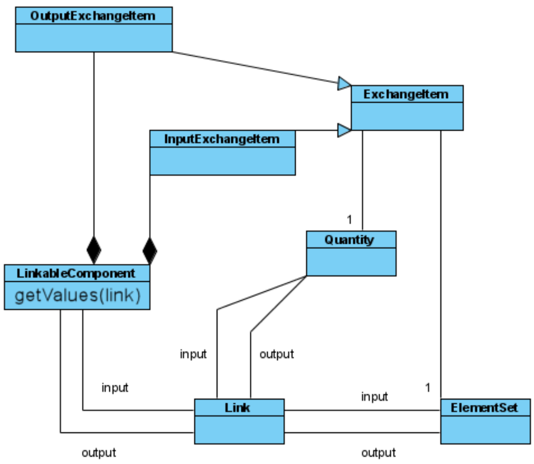

Figure 5 Simplified class diagram of LinkableComponents and Links

The OpenMI Environment comprises a set of software tools. They facilitate making new and existing model codes OpenMI compliant and they offer facilities to combine OpenMI compliant components into integrated modeling systems and then run them.

Making models OpenMI compliant is not only a technical exercise nor has it only a technical result. Implementing the OpenMI interface for a variety of models from different domains, makes it possible to combine and integrate knowledge from different domains, thus resulting in conclusions which were not easily formulated when this model integration had not been possible.

The use of OpenMI in model based Integrated Assessments is explained by Verweij et. al (2007).

3.3. Quality assurance

Quality assurance is an element of general importance in modeling, but the reason to choose is as one of the generic subjects of Wageningen Systems is a more specific one. In the past, models were mainly used by individual researchers or research teams who also had developed the model. The concepts of the data-wisdom chain and network innovation described in 2.1 imply that in the future knowledge workers in research, policy development and practical implementation more frequently will have to work with models developed by colleagues from other research groups or even other scientific disciplines. In the past, knowledge workers could 'trust' their model because they had a good insight in the scientific quality of their own contribution to the development of the model. In the future they will have to rely more often on models developed by others.

The consequence of this general process is, that the development, use and maintenance of models and databases, requires specific attention for the following aspects of quality assurance: 1) generally accepted methods for quality assurance; 2) organizational and administrative infrastructures which support the processes of quality assurance.

3.4 Interactive tools

Access and use of the knowledge of Wageningen Systems should be tailored to the requirements of the stakeholders. To achieve this you need dedicated tools. Within Wageningen Systems we use a classification of user interaction models that is based on expectations of different users and the way they interact with the system.

The **first view** on user-interfaces responds to the requirements and expectations of domain experts. Typical characteristics of such an application are: flexible, very detailed systems with extensive functionality (many degrees of freedom and a high level of interaction) that requires much knowledge from the user.

An example of this view is SEAMLESS Integrated Framework (SEAMLESS-IF) of the EU 6th framework program project SEAMLESS (Ittersum et al, 2007). SEAMLESS-IF supports the "integrative modeler" in linking models in a model chain; and applying these model chains for different policy options.

The concepts relevant to the SEAMLESS domain (mainly the agricultural domain) and the models used in the SEAMLESS project have been put into an ontology. This ontology, together with related ones (e.g. for measurement units), are loaded into a Knowledge Manager component. The Knowledge Manager can make the links between the models. The actual exchange of information is based on the OpenMI standard.

By putting the ontology in as central position in the project and the systems architecture, this shared conceptualization is the basis for generating (Java) source code for the object classes representing all the concepts and representing the objects in relational database tables (figure 6).

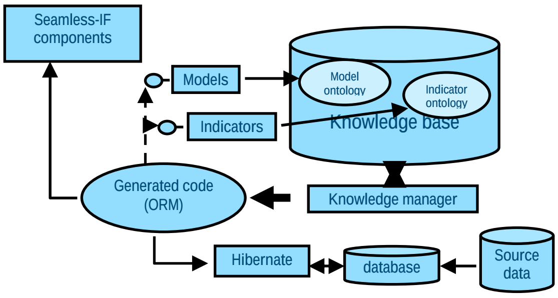

Figure 6. SEAMLESS integrated framework architecture.

The **second view** is one of an application for decision makers. Typical characteristics of such an application are that the user is guided through the application and that the application has limited functionality. This functionality is often provided in the form of a "wizard like" approach. Using the application requires 'little' knowledge.

A successful application of this type of tool is BERISP, The main objective of BERISP is to allow planners to review different types of landscape uses and habitat distribution against scientific knowledge on risks of pollutants for organisms (Cormont et al., 2006).

Another example is the Sustainability Impact Assessment Tool (SIAT) of the EU 6th framework program project Sensor (Verweij et al, 2006). SIAT let's the policy maker assess the social, environmental and economic impacts of land use related policies.

The **third view** is one of an application for a wider audience (e.g. general public or policy makers). The term we use for these applications are "Reference book". Typical characteristics of such an application are: easy to use, guided, with little functionality and little knowledge required. An example of a reference book application is Eururalis (http://www.eururalis.eu/intro.html).

Eururalis highlights policy issues in European rural areas. Eururalis links data of People, Planet, Profit and land use. Eururalis starts from contrasting scenario's and gives outcomes for the next three decades in ten year time-steps.

The **fourth view** is one of a simulation gaming application. Typical characteristics of such an application are that it offers a virtual world that stimulates experimenting. It requires little knowledge to use the application. This view is particularly useful for internalization of knowledge (from explicit to tacit) because of the experience you get from playing games.

A successful example is NitroGenius, a role play game to solve the Dutch Nitrogen problem (Erisman et al., 2002). The game is played by four players who represent stakeholders (Government, Industry, Agriculture and Society). These stakeholders have to work together to solve the nitrogen problems against the lowest costs and social consequences. However each player also has its own targets, just as in real life. These individual targets are not necessarily in line with the aim of the group to solve the nitrogen problems.

4. CONCLUSION

The international context that Wageningen UR works in, requires a prominent role in the development of ontology in the field of what we call the "green/blue environment". See: http://www.wur.nl/UK/research/research+themes/

The Wageningen Systems expertise in the field of software frameworks, interactive tools and semantic interoperability has made a clear contribution to the strong position of Wageningen UR in international integrated assessment studies. Also within Wageningen, Wageningen Systems has pushed and stimulated the exchange of information and the co-production of knowledge.

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