

## SEMANTIC WEB TECHNOLOGIES FOR ENHANCING WEB-BASED DECISION SUPPORT SYSTEM FOR DESIGNING AND MANAGING DRYING AND STORAGE OF CEREAL GRAINS

### Summary

*Emerging technologies enhancing implementation of more advanced software were analyzed and applied to upgrade the standalone DSS Ziarbit, developed by the authors in past years, to a form of a Web-based decision support system embedded in Semantic Web frameworks. The system was developed to support design and management of cereal grain drying and storage processes. New technologies were used for problem domain analysis, UML diagramming, knowledge representation and Semantic Web implementation, and recent Microsoft programming environments were applied (.NET 4.5, ASP .NET 4.5, C++/CLI and C# available in Microsoft Visual Studio 2012, and Windows Phone SDK 8). In order to ensure interoperability, a concept of Internet-based Knowledge Center (IKC) was introduced and the new system was developed within the IKC framework.*

**Key words:** Web application, decision support, .NET technologies, cereal grain processing, Semantic Web, Poland.

### 1. Introduction

For farmers, agriculturally related businesses and industries involved in grain drying, handling and storage it is necessary to have prompt, relevant and reliable information to make better decisions and maintain quality standards. Fast, flexible access to information available on the Web is essential. It could be attained by keeping decision support software up to date, especially by taking the advantage of innovative and effective ICT opportunities. New advanced technologies available for developing Web-based decision support applications can increase functionality, reliability, usability, maintainability and performance of such applications [5, 15]. Integration of information derived from diverse sources and transformation of the DSS to an adoptable Semantic Web-based DSS is a strong trend for future system development [1, 4, 6]. Additional new possibilities are offered by smartphone applications for interaction between users and servers [2, 9].

The objective was to indicate, implement and analyze emerging technologies useful either for developing new systems or for upgrading old-day standalone applications to a form of Web-based decision support system embedded in Semantic Web frameworks. Implementation of new technologies was exemplified by an upgrade of a standalone DSS *Ziarbit* developed by the authors in past years [14] with an intention to support design and management of cereal grain drying and storage facilities.

### 2. Material and methods

The new version of the “Ziarbit” Web-based decision support system was developed with the use of several methods appropriate for project management [3] and software engineering [11], especially for the problem domain analysis and UML 2.4.1 diagramming, knowledge representation and Semantic Web standards [7], and recent Microsoft technologies [10, 12]. As programming environments, .NET 4.5, ASP .NET 4.5, C++/CLI and C# 5.0, available in Microsoft Visual Studio 2012, and Windows Phone SDK 8

were chosen. To satisfy the goal of interoperability and reusability of existing Web-based knowledge [5, 15] a set of Semantic Web languages was used [1, 4, 7]. In particular, to ensure the interoperability, an original concept of Internet-based Knowledge Center (IKC) was introduced [7, 8], this concept became a framework for the new system development.

A light version of the system was also developed for smartphones, on the basis of methods appropriate for smart apps development [2, 9].

### 3. Results

The model for the problem domain (Fig. 1) was based on three principles:

- 1) Identification and description of terminology, vocabularies, processes, etc. of the knowledge domain.
- 2) Design of data sets as parts of the decision support system scenario. Knowledge is brought to a solution from Resource Description Framework in attributes (RDFa) content outside the IKC space in a form of existing ontologies and semantic vocabularies (LinkedData space) and also from custom ontologies designed within the IKC. Due to the lack of the semantically enabled resources, in terms of the Semantic Web technology usage, preparation of such outside resources was also required.
- 3) Development of an Agent Service and/or Software to consume the knowledge from the IKC space.

The core elements of the IKC architecture (Fig. 2) were based on the principle: mature, stable and proven technologies and software available for free.

- Proxmox Virtual Environment, PVE (Fig. 3) - the open container based solution, which enabled rapid building of the required environments along with prototyping and trying many different configurations and settings. In addition, the environments created on top of the PVE could be built with usage of turnkey Linux distributions preconfigured for the specific roles – like Web Server – and with the TurnKey Hub Service they could be automatically backup on the Amazon S3 platform.

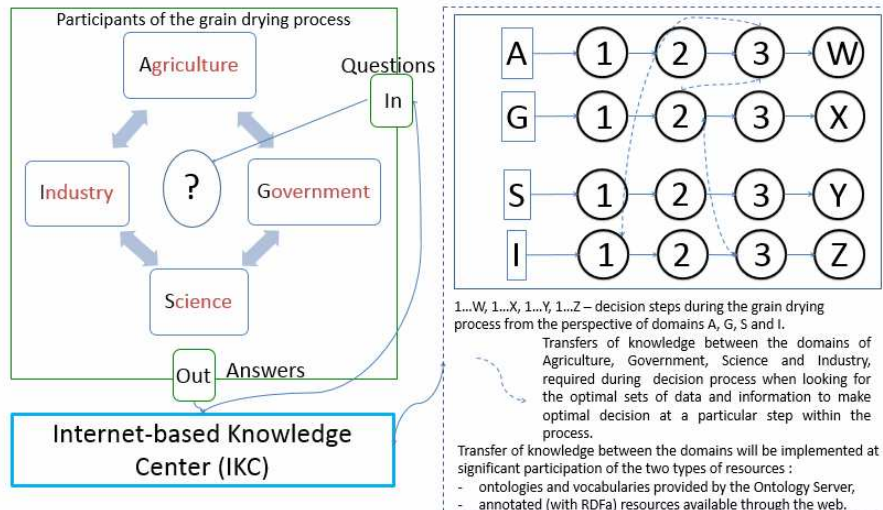


Fig. 1. Model of the Internet-based Knowledge Center (IKC)

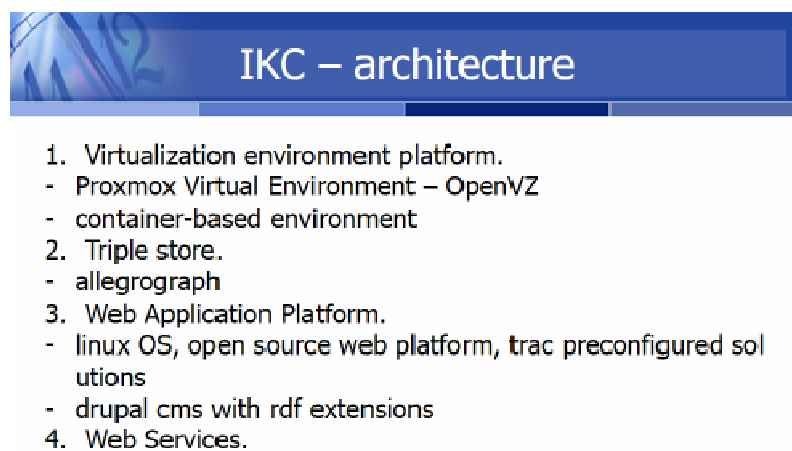


Fig. 2. Architecture of the Internet-based Knowledge Center (IKC)

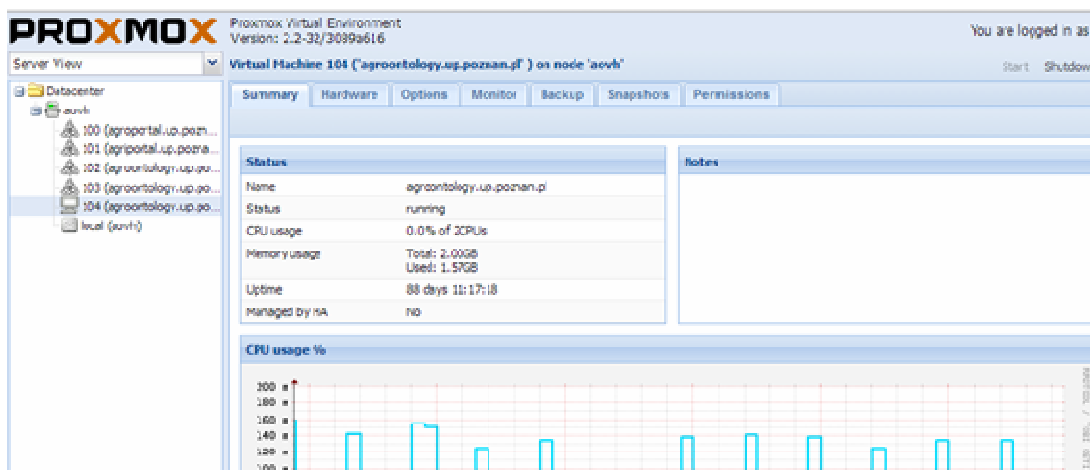


Fig. 3. Proxmox Virtual Environment

- Protégé Desktop ontology editor (Fig. 4) was used as the main ontology development tool and configured to work with visualization and reasoning plugins.
- The data model for the domain of grain drying, handling and storage (Fig. 5, Fig. 6) was approached from four main perspectives. The resources available: websites, publications, academic manuscripts, agricultural fairs, advertising material and leaflets, technical documentation, European

and national laws and regulations, they were taken under close consideration. Based on that, ontologies which captured the knowledge from those sources were designed and built.

- AllegroGraph enabled the access to the created domain ontologies and vocabularies. The data sets were explored with the use of Queries section and SPARQL language.

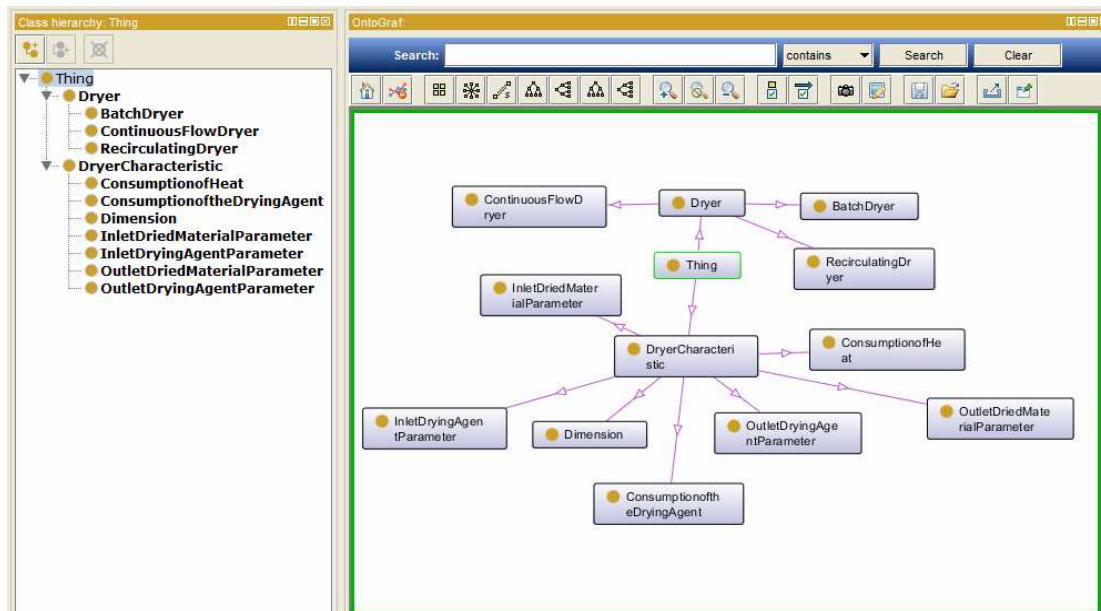


Fig. 4. Protégé Desktop ontology editor

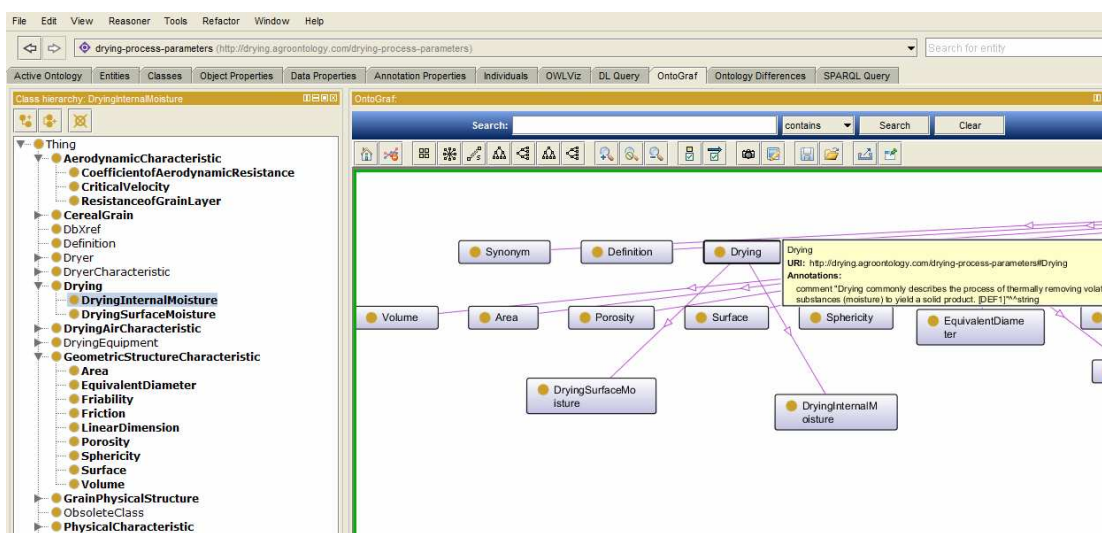


Fig. 5. The data model for the domain of grain drying, handling and storage – selected parameters for drying

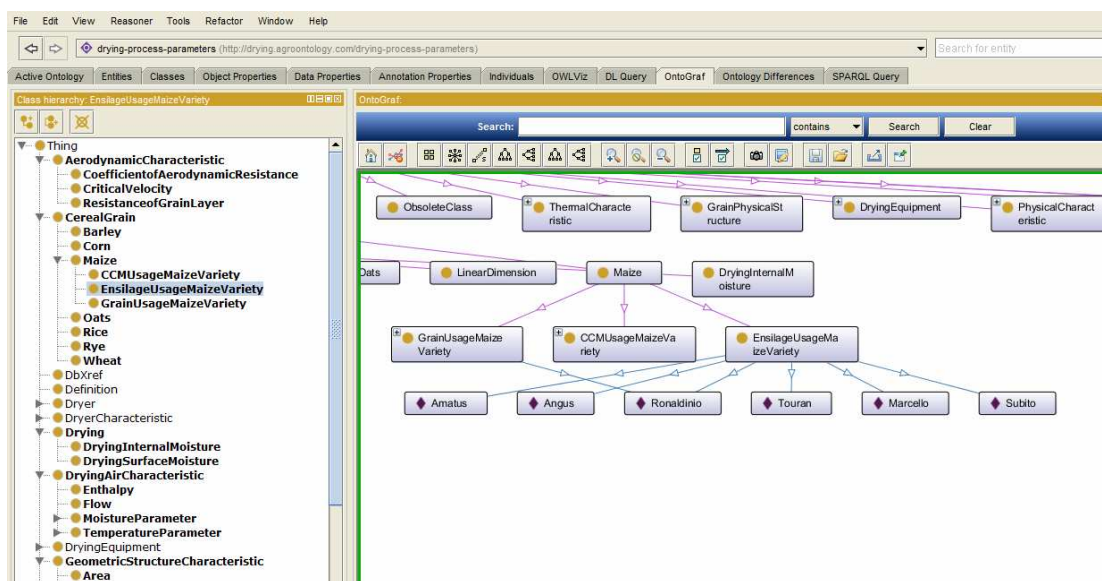


Fig. 6. The data model for the domain of grain drying, handling and storage – selected parameters for cereal grain

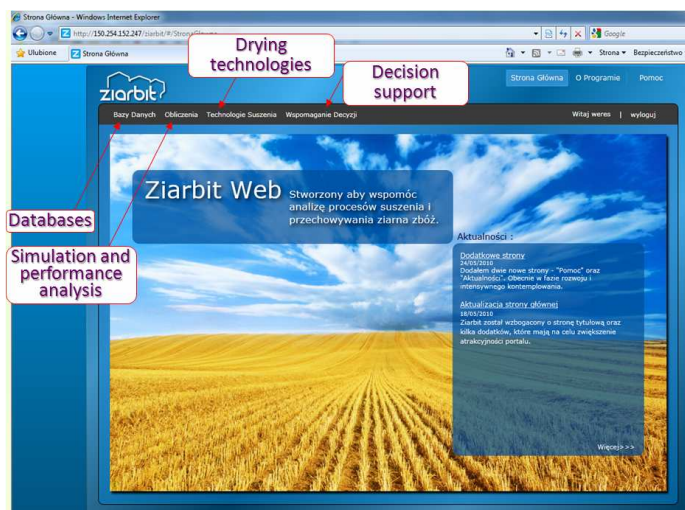


Fig. 7. Ziarbit - a Web-based DSS for designing and managing cereal grain drying, handling and storage. PC client (left), smartphone client (right)

A new approach to a decision support system for agriculture was elaborated due to implementation of recent advances in ICT, and a new version of DSS *Ziarbit*, a software application for analyzing, designing and managing cereal grain drying and storage was designed (Fig. 7). Ontologies required for semantic processing approach were constructed, and the Internet-based Knowledge Center was the framework for the analysis. A pioneer smartphone application to communicate with the server was also developed. DSS *Ziarbit* was composed of:

- 1) databases for grain drying, handling and storage,
- 2) simulation and performance analysis (calculation of drying air properties, simulation of the moisture content changes in grain, computation of drying systems performance),
- 3) decision support for selecting appropriate equipment and conditions for drying cereal grains, with the access to data available online.

#### 4. Conclusion

Advanced technologies available on the .NET Framework and useful for developing Web-based DSS for agriculture were indicated and implemented. The new version of Semantic Web-based decision support software for analyzing, designing and managing cereal grain drying and storage was designed and implemented. The Semantic Web concept was turned into reality with the help of the Internet-based Knowledge Center, developed originally within this work. A test version of the smartphone application to enhance a mobile access to the system was also constructed. Conformance to software engineering standards during the whole software development process was a critical factor for accepting the developed application in operational, practical environments.

#### 5. References

- [1] Blomqvist E.: 2012. The Use of Semantic Web Technologies for Decision Support - A Survey. *Semantic Web Journal* DOI:10.3233/SW-2012-0084.
- [2] Esposito D.: 2012. *Architecting Mobile Solutions for the Enterprise*. Redmond, WA, USA: Microsoft Press.
- [3] Hundhausen R.: 2012. *Professional Scrum Development with Microsoft Visual Studio 2012*. Redmond, WA, USA: Micro-

soft Press.

- [4] Janjua N.K., Hussain F.K., Hussain O.K.: 2013. Semantic information and knowledge integration through argumentative reasoning to support intelligent decision making. *Information Systems Frontiers* 15(2): 167-192.
- [5] Kozłowski, R.J., Weres J., Rudowicz-Nawrocka J.: 2011. Computer decision support systems in managing a farm (in Polish). *AgEngPol Scientific Network*, <http://www.ageng-pol.pl/ekspertyzy.aspx>.
- [6] Kluzka T., Nowak P., Weres J.: 2011. The ontology based decision support model and scenarios for grain drying processes. In *Proc. of the 4th International SWAT4LS Workshop*. London, UK, 7-9 December.
- [7] Kluzka T., Weres J.: 2012. *Agroontology.com* – Internet-based Knowledge Center (IKC) as an implementation of the Semantic Web Knowledge Representation (KR) standards within the sample domain of grain drying process. In *Proc. of the International Conf. "Smart AgriMatics"*. Paris, France, 13-14 June.
- [8] Kluzka T., Nowak P., Weres J.: 2012. Advances in developing Web-based DSS architecture for designing and managing cereal grain drying and storage. In *Proc. of the International Conf. of Agric. Eng. CIGR-AgEng2012 "Agriculture & Engineering for Healthier Life"*. Valencia, Spain, 8-12 July.
- [9] McWherter J., Gowell S.: 2012. *Professional Mobile Application Development*. Hoboken, NJ, USA: Wrox (Wiley).
- [10] Nagel C., Evjen B., Glynn J., Watson K., Skinner M.: 2012. *Professional C# 2012 and .NET 4.5*. Hoboken, NJ, USA: Wrox (Wiley).
- [11] Sommerville I.: 2010. *Software Engineering*. 9th ed. Upper Saddle River, NJ, USA: Addison Wesley.
- [12] Troelsen A.: 2012. *Pro C# 5.0 and the .NET 4.5 Framework*. Berkeley, CA, USA: Apress.
- [13] Yang X., Bo Z., Bei Z.: 2009. Research on Semantic Decision Support System. In *Proc. of the 2009 WRI World Congress on Computer Science and Information Engineering*, 687-691. Los Angeles, CA, USA: 31 March – 2 April.
- [14] Weres J., Kujawa S., Kluzka T.: 2007. Information system for analyzing, designing and managing drying and storage of cereal grains. In *Proc. of the 6th Biennial Conference of the European Federation of IT in Agriculture and the World Congress on Computers in Agriculture EFITA / WCCA 2007*, 6 pp. Glasgow, United Kingdom, 2-5 July.
- [15] Weres J., Mueller W., Kozłowski R., Kluzka T.: 2010. Advanced technologies in developing Web-based decision support systems for agriculture. In *Proc. of the CIGR XVIIth World Congress and the 8th World Congress on Computers in Agriculture*, 6 pp. Québec City, Canada, 13-17 June.