Institution: University of Liverpool

Unit of Assessment: 11 – Computer Sciences & Informatics

Title of case study: Agent-Oriented Software Engineering: The Gaia Methodology

1. Summary of the impact (indicative maximum 100 words)

This case is based on economic impact. It shows how research by Professor Michael Wooldridge at the University of Liverpool on the Gaia Methodology for agent-oriented software engineering improved the performance of the Swiss company Whitestein Technologies AG and of international users of its key product. Specifically, the research enabled Whitestein to develop its business process management system (BPM) *Living Systems Process Suite* which delivers several million pounds per year of revenues, corresponding to 50% of their total business revenues. Users of Whitestein's Living Systems Process Suite since 2008 include Daimler AG, Transcor Astra Group, Vienna Insurance Group, and the US Department of Veterans Affairs. In 2010 Gartner, the world's leading IT advisory company, recognized the impact and innovation of the Living Systems Process Suite by naming Whitestein a Cool Vendor in BPM.

2. Underpinning research (indicative maximum 500 words)

Between 1998 and 2005, Wooldridge (Professor at the Department of Computer Science at University of Liverpool between 2000 and 2012) investigated the possibility of using the agent metaphor in the development of complex distributed systems. The key idea was to design a distributed system as a society of cooperating agents. The central design principle was that there was no centralised control, with agents acting as semi-autonomous, independent decision-makers. At the time, the idea of agent-oriented software engineering was entirely new, and Wooldridge was one of the key proponents of this emerging paradigm.

It rapidly became clear that existing software engineering methodologies and modelling frameworks were entirely unsuitable for developing agent-oriented systems, and so Wooldridge began to develop such methodologies, based on his experience working with Mitsubishi Electric Plc on cooperating information systems. The result was the Gaia methodology for agent-oriented analysis and design: it is this methodology that forms the basis of this impact case study. A key principle of the Gaia methodology is designing independent decision-making entities that will nevertheless, through their interaction, achieve the design goals of a system.

The Gaia methodology was deliberately intended to be accessible for software engineers versed in current state-of-the-art software engineering practice. The methodology proposed a set of models, together with associated semi-formal notation, that go from requirements capture and system analysis through to system design.

The requirements are captured in a roles model and an interactions model. The roles model identifies a number of abstract organisational roles, which agents in the system play. These roles are, in turn, defined with respect to the responsibilities, permissions/resources, activities, and protocols with which they are associated. Responsibilities and permissions relate to the obligations that the role entails, and the resources and rights available to an agent for fulfilling the role. A notation is provided to capture these. Responsibilities in Gaia are directly derived from system-level goals as described in a system requirements statement. They provide a transparent and explicit goal-oriented view of the software requirements. Finally, a protocol model identifies in a high-level, black-box manner, the way in which agents occupying roles might interact. These three models together map distinct roles into agent types, identify the services that agents provide to one another, and thus provide a template for the design of the resulting software system. The Gaia methodology additionally provides guidelines and techniques to develop these models.

Gaia was essentially the first coherent and complete methodology to take the idea of agent-oriented software engineering seriously, and to attempt to communicate the ideas of multi-agent systems to

non-specialist software engineers. The scientific influence of the Gaia methodology has been significant. For example, the two key publications on this work (see below) have accrued in total more than 3600 citations on Google Scholar (see http://tinyurl.com/d9y73zj). Research on the Gaia methodology continues to this day, with many refinements and extensions being proposed over the past decade.

3. References to the research (indicative maximum of six references)

Key publications:

- F. Zambonelli, N. R. Jennings, and M. Wooldridge. Developing Multiagent Systems: The Gaia Methodology. In ACM Transactions on Software Engineering Methodology, 12(3):317-370, July 2003. http://dx.doi.org/10.1145/958961.958963
- M. Wooldridge, N. R. Jennings, and D. Kinny. The Gaia Methodology for Agent-Oriented Analysis and Design. In Journal of Autonomous Agents and Multi-Agent Systems. 3(3):285-312. 2000. http://dx.doi.org/10.1023/A:1010071910869

Other publications:

- F. Zambonelli, N. R. Jennings, A. Omicini and M. Wooldridge. Agent-Oriented Software Engineering for Internet Applications. 326–346 In A. Omicini, F. Zambonelli, M. Klusch and R. Tolksdorf, editors, Coordination of Internet Agents, Springer Verlag. 2001 http://dl.acm.org/citation.cfm?id=375897.375923
- M. Wooldridge and P.Ciancarini. Agent-Oriented Software Engineering: The State of the Art. In P. Ciancarini and M. Wooldridge, editors, Agent-Oriented Software Engineering. Springer-Verlag Lecture Notes in AI Volume 1957, January 2001. http://dl.acm.org/citation.cfm?id=370870

Interaction between Professor Wooldridge and Whitestein was enabled by European Co-ordination Actions:
Agent Link 2 (2000-2003, EUR 800K, Liverpool PI Wooldridge) and Agent Link 3 (2004-2005, EUR 1.1M, Liverpool PI McBurney).

4. Details of the impact (indicative maximum 750 words)

In the early years of this century, a number of international companies were interested in commercialising the then-nascent area of software agent technologies, with the goal of obtaining competitive advantage in the fiercely complex area of distributed software systems. Whitestein Technologies AG was one such company. Based in Switzerland, with offices in Zürich, Stuttgart, Luxembourg, and Bratislava, Whitestein is a software solutions provider, operating in the domains of financial services, logistics, and telecommunications, both in the private and public sector.

Founded in 1999, Whitestein aimed to develop a robust, industrial-strength suite of software development tools and techniques, which would leverage the advantage that they perceived the agent paradigm would gain in the complex software systems marketplace. To this end, Whitestein developed an Agent Modelling Language (AML), which was essentially a UML-adapted instantiation of the Gaia methodology. In the words of Whitestein's current Chief Operating Officer:

> "Gaia directly influenced, and indeed inspired, the development of our Agent Modelling Language (AML)." (16 March 2012)

This is borne out by the standard reference on AML:

> R. Cervenka and I. Trencansky, *The Agent Modeling Language – AML: A Comprehensive Approach to Modeling Multi-Agent Systems*, Birkhäuser Verlag, 2007.

which both cites Gaia preeminently among agent-oriented methodologies (page 4), and offers Wooldridge's work as the rationale for the development of AML (page 6).

The AML was in turn used as the basis for Whitestein's GO-BPMN language. GO-BPMN (Goal-Oriented Business Process Modelling Notation) is a proprietary extension of the Object Management Group's Business Process Model and Notation (OMG BPMN 1.2/2.0 – see http://www.bpmn.org/). This extension makes it possible to specify objectives (goals) directly in a process model. The GO-BPMN language is the centrepiece of Whitestein's Living Systems Process Suite for business process management (BPM) which is the major commercial offering by

Whitestein.

The chief advantage brought by the Gaia/agent approach over alternative BPM approaches is its goal-orientation, both at the model level (notation) and at the execution level. The execution level has a goal-oriented engine wherein every process instance is managed by an agent. Process goals are explicitly represented within the agents, which then reason about the optimal path of execution for the process in real time. The goal-oriented view is significant in that it allows businesses to abstract away from the specific processes used to achieve business goals, and to reason instead about business goals, the relationships between them, and the overall processes and plans that can be used to achieve these goals. Competing BPM frameworks tend to focus instead on procedures, rather than on goals.

In addition to his direct influence on the development of Whitestein's Living Systems Process and AML via the Gaia Methodology, between 2000 and 2005 Wooldridge also interacted with Whitestein employees through the AgentLink EC-funded Network of Excellence for Agent-Based Computing, which Wooldridge founded in 1997. A key mission of AgentLink was to foster links between academic providers of new technologies and systems and industrial consumers of such technology.

Evidence for the impact and innovation of Whitestein's Living Systems Process Suite since 2008 is provided by reports from three internationally leading IT advisory companies. First, Gartner Inc. named Whitestein a Cool Vendor in BPM in 2010 (see [3] in Section 5). Gartner defines a cool vendor as a company that offers technologies or solutions that are *innovative* (enable users to do things they couldn't do before) and *impactful* (have, or will have, business impact - not just technology for the sake of technology) and states in its report:

> "The concept and architecture behind Whitestein's Living Systems Process Suite is unique because it leverages a multiagent approach to create self-adaptive behavior in a proactive and reactive manner."

Second, international analyst and consultancy firm Ovum Ltd. states in its report from 2011 (see [4] in Section 5):

> "The Living Systems Process Suite stands out because of its goal-oriented structure, which delivers adaptive case management capabilities as a seamless extension of dynamic BPM."

Third, European IT advisory firm MWD confirms in 2010 (see [5] in Section 5):

> "Many BPM technology vendors talk about being able to support continuous process improvement and dynamic process optimization, but with an approach that uses goals as a first-class design citizen rather than being an add-on specified in a monitoring tool, the Living Systems Process Suite truly delivers on that promise."

Whitestein's Living Systems Process Suite delivers several million pounds per year of revenues, which corresponds to 50% of their total business revenues. Whitestein now has more than 50 employees (figures accurate as of March 2013). Customers of Whitestein's BPM technology since 2008 include the following:

- Daimler Benz AG has used Whitestein's BPMS since 2009. It has been deployed to over 12, 000 users in Daimler engineering centres worldwide (see [6] in Section 5).
- Global energy commodity trader Transcor Astra Group uses Whitestein's BPMS since 2011 for commodity and financial instrument trading processes (see [7] in Section 5).
- Vienna Insurance Group uses Whitestein's BPMS since 2011 to gain operational agility in damage assessment (see [8] in Section 5).
- The US Department of Veterans Affairs are using Whitestein's BPMS for automated claim processing. Here, Whitestein's Living Systems Process Suite is at the core of an automation project that was nominated by PEX Week Orlando 2013 as one of four finalists for the 2013 Best BPM Project award (see [9] in Section 5).

In summary, the Gaia methodology provided the foundation upon which Whitestein developed tools and services that provide the core of their successful continuing business. The approach provides clear advantages for Whitestein and their customers in an important marketplace.

5. Sources to corroborate the impact (indicative maximum of 10 references)

1. Chief Operating Officer of Whitestein Group can be contacted to corroborate the influence of Gaia on AML and the use of Whitestein's BPMS by Daimler, Transcor Astra Group, Vienna Insurance Group, and US Department of Veterans Affairs.

2. Whitestein's main web site: http://www.whitestein.com/.

3. The article on Leading Industry Analyst Firm: Whitestein Technologies a 'Cool Vendor' in Business Process Management (BPM) provides information about Gartner's report about Whitestein's Living Systems Process Suite.

4. Ovum Ltd's report about Whitestein's Living Systems Process Suite.

5. MWD's report about Whitestein's Living Systems Process Suite.

6. The article on "Whitestein Technologies to Provide Daimler with Novel Suite for Agile Business Process Management (BPM)" provides evidence of the use of Whitestein's BPMS at Daimler AG.

7. The article on AOT Trading Selects BPM Solution provides evidence of the use of Whitestein's BPMS at Transcor Astra Group.

8. The article on Slovexperta Selects BPM Solution from Whitestein to Reduce Total Claims Cost and Gain Operational Agility provides evidence of the use of Whitestein's BPMS at Vienna Insurance.

9. Evidence of the use of Whitestein's BPMS at US Department of Veterans Affairs.