Institution: University of Bath

Unit of Assessment: B11 Computer Science and Informatics

Title of case study: Virtual warehousing and market intelligence in online book retailing

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

Bath research on the design of multi-agent software systems governed by norms and institutions has directly influenced the development of the essential business systems of an internet-based trading company, and been instrumental in their success.

The Book Depository (BD) was founded in 2004. In 2005, their Chief Technical Officer, Emad Eldeen Elakehal, sought the expertise of Julian Padget in the Department of Computer Science at Bath, and began a part-time PhD, working on the application of normative frameworks to the design and implementation of business systems. Elakehal has applied these principles in the design and construction of two key subsystems of BD's software infrastructure: the catalogue maintenance system (live since 2006) and the price checker and setter system (since 2008). Their effectiveness has underpinned the growth and success of the company by providing robust software implementation of business processes that adapt to changing market conditions. The company's turnover grew from £24M to £120M from 2008 – 2011, and continues to grow. The software systems enabled this growth to take place with no increase in the operations team's manpower, and now handle a catalogue of over 8 million titles, from 120 suppliers, all available within 48 hours to customers on the Book Depository's own web site or via Amazon's marketplace: all Amazon book customers have seen offers of books generated by this software. The software underpins BD's award-winning business, a unique offering in the book retail sector which attracted takeover by Amazon in 2011. BD's Managing Director states that "without the agent/norm based technical systems not one of the business' USPs could have been effectively realised."

2. Underpinning research (indicative maximum 500 words)

Norms are a well-established concept in law, social sciences and economics that express constraints on individual behaviour or obligations defining situations that are to be achieved or to be avoided. The long-term objectives of this research are (i) the expression of norms in a form suitable for both human and software comprehension and (ii) design patterns for the creation of software that is capable of norm-compliant behaviour.

Our work on the formalization of norms in computer science and artificial intelligence began in the late 1990s [1]. Borrowing from work in the domains noted above, Padget & colleagues proposed that the distributed economy afforded by the Internet should exploit via mimesis the strategies evolved over thousands of years of human commerce, e.g. norms such as eligibility requirements and formal specifications of acceptable behaviour which are policed to detect early problems. The major research contributions that underpin the impact reported here are (i) the definition of a formal model for normative frameworks [2] based on the principle of real world events that "count-as" normative events, (ii) a sound and complete translation process from the formal specification into a logic program under answer set semantics, to create a model that permits the formal verification of system properties through a form of model-checking, and (iii) identifying the different requirements for the use of such models at design time, when the objective is to explore total system properties, and at run-time, when the objective is to provide normative guidance for software components [3].

The work of the first two contributions was carried out by Padget (senior lecturer), De Vos (lecturer, then SL) and Cliffe (PhD student jointly supervised by Padget and De Vos) in the period 2001-2006 and that of the third by Padget, De Vos, Cliffe (RA until 2010) and Balke (2010-2012, PhD student jointly supervised by Padget and De Vos).

Further work combined these ideas with work on agent-oriented software engineering to translate

them into the business domain, informing first the design and implementation of the catalogue maintenance system developed by the Book Depository [4] and later that of their price checker and setter systems [5]. Notable features of both these systems are (i) the attention paid to self-monitoring and self-management and (ii) the capacity to change component behaviour in response to a changing environment (especially in the case of the price checker/setter), reflecting the principles of norm-governed systems.

This latter work was carried out by Padget and Elakehal (industrially-based PhD student, supervised by Padget, since 2005). Subsequently, building on the third contribution (design vs. run-time requirements) and as a result of evaluating the development processes for the above systems, Padget and Elakehal have developed a new business-oriented software engineering meta-model for the construction of self-managing multi-agent systems [6].

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

[1] Juan A. Rodriguez, Pablo Noriega, Carles Sierra, Julian Padget. FM96.5 A Java-based Electronic Auction House. In Proceedings, Second International Conference on the Practical Application of Intelligent Agents and Multi-Agent Systems, 1997. [http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.8.1094]

[2] * Owen Cliffe, Marina De Vos, and Julian Padget. Answer set programming for representing and reasoning about virtual institutions. In Katsumi Inoue, Ken Satoh, and Francesca Toni, editors, CLIMA VII, volume 4371 of Lecture Notes in Computer Science, pages 60–79. Springer, 2006 [DOI:10.1007/978-3-540-69619-3_4]

[3] * Tina Balke, Marina De Vos, and Julian Padget. Normative run-time reasoning for institutionally-situated BDI agents. In Coordination, Organizations, Institutions, and Norms in Agent Systems V, volume 7254 of Lecture Notes in Computer Science, page tbd. Springer, 2012. [DOI:10.1109/wi-iat.2011.49]

[4] * Emad El-Deen El-Akehal and Julian A. Padget. Pan-supplier stock control in a virtual warehouse. In Michael Berger, Bernard Burg, and Satoshi Nishiyama, editors, AAMAS (Industry Track), pages 11–18. IFAAMAS, 2008. [http://dl.acm.org/citation.cfm?id=1402798]

[5] Emad Eldeen Elakehal and Julian Padget. Market intelligence and price adaptation. In Proceedings of the 14th Annual International Conference on Electronic Commerce, ICEC '12, pages 9–16, New York, NY, USA, 2012. ACM.[DOI:10.1145/2346536.2346538]

[6] Emad Eldeen Elakehal and Julian Padget. MSMAS: Modelling self-managing multi agent systems. Scalable Computing: Practice and Experience, 13(2), June 2012. ISSN: 1895-1767. Available via: http://www.scpe.org/index.php/scpe/article/view/774

* marks the outputs best indicative of the quality of underpinning research

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

The Book Depository is an online book retailer, founded in 2004. Book retailing traditionally falls into two classes: high-street style retailers selling the relatively small number of top-rated titles, all available instantly, and specialist stores serving niche markets, with many titles available but longer delivery times (2 – 4 weeks) and relatively few sales per title (under 1 unit/month worldwide) – the "long tail". BD's unique aim was to bring high-street style availability and turnaround time to the long tail sector.

The research of BD's Chief Technical Officer Emad El-Akehal with Padget has driven the design of two software systems crucial to BD's operations: the catalogue maintenance system and the price setter/checker. The operation of these systems enables BD's business to run: the catalogue system maintains a "virtual warehouse" of books, currently over 8 million titles, which are

physically located at over 120 distinct suppliers; and the price system monitors supplier cost and competitor prices to enable BD to offer their books at optimal pricing. [7]

The adoption of the design principles developed in Padget's research has enabled BD to deploy software systems that are highly distributed and decoupled – the software comprises many separate software agents that run on computers all around the world with minimal reliance on one another – and that can monitor and repair themselves thanks to the norm-based governance of the system. This means that the system is highly *scalable*, for example no change to the running code was required when scaling from 5 to 20 suppliers early in BD's growth, as well as being *modifiable*, so that for instance changing data format to suit a new supplier is easy, and *reliable*, because many faults and problems can be addressed by the system itself stopping the faulty agent and replacing it with a fresh one. The distributed nature of the system allows agents to be placed where they are most effective: for instance, agents that need to make a great many requests for data to Amazon's servers in the US can be located in the US, while agents holding data governed by UK law can be located in the UK.

BD's Managing Director explains the significance of Padget's work to BD's operation as follows [7]:

> "The system design was grounded on the research efforts of the company's Chief Technical Officer; Emad Eldeen Elakehal during his PhD program under the supervision of Dr Julian Padget at the University of Bath – UK. Both the catalogue maintenance (Virtual Warehouse System) and Pricing System are designed as multi agent systems and are responsible for the core and crucial elements of our daily operations. These systems in particular are responsible for the implementation of our pricing strategies and they contribute to the management of the company's offers in both third party marketplaces and our own website.
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> Both systems have shown high degree of resilience and scalability over a period of more than six years and they are still in operation today. We are able to change and modify the system attributes easily with minimal amount of development effort, as a result of their norm/agent based design. The company's operations and the number of transactions have grown more than 10 fold since implementation and the systems were able to scale up to support this growth. This acceleration is clearly reflected in the company's annual revenue, turnover increased from £24M in 2007/8 – first year of operating these systems – to over £120M in 2010. The company continues to grow with expectation of reaching circa £150m turnover this current year, 2013.
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> The size of the operations and technical support team who looks after these specific systems has remained static over the last six years, due to the reliability of the software and to its dynamic features."

Thanks to these systems, and Padget's work with Elakehal, BD has been able to fulfil its goal of offering its 8 million titles with 48 hour turnaround, **creating a service in the long-tail sector that was previously unavailable**. It has rapidly become the market leader in long-tail book provision. As the Managing Director notes, **turnover has grown from £24 million to over £120 million** in the period since 2008.[7,8] Most remarkably, this has been possible with *no increase in the operations team*: the software systems are still managed by just two staff. The success of the business is directly attributable to the effectiveness of their software systems: BD's managing director states that "without the agent/norm based technical systems not one of the business' USPs could have been effectively realised." [7]

Every user of Amazon who has searched for a book has been a user of this software. The Book Depository sells its books via Amazon's third-party "marketplace", and every book search returns "new and used" price results, one of which is invariably from the Book Depository. This marketplace offer is generated by BD's software; the fulfilment of orders placed via Amazon is also handled by this software. The Book Depository became such a significant player in the long-tail sector, winning the Queen's Award for International Trade in 2010 [9], that Amazon chose to

acquire the company in 2011 [10]. Though now an Amazon subsidiary, BD continues to trade in the same way under its own brand, using the same software.[7]

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

[7] Factual statement from Managing Director, the Book Depository.

[8] Book Depository data from Companies House. Report generated from FAME database 25th July 2013.

[9] The Book Depository wins Queen's Award 2010, http://www.thebookseller.com/news/book-depository-wins-queens-award.html (archived version of 29 August 2013 held on file)

[10] Amazon Purchases the Book Depository. http://www.retailgazette.co.uk/articles/23044-amazon-purchases-the-book-depository (archived version of 29 August 2013 held on file)