Institution: University of Brighton	
Unit of Assessment: B11 Computer Science and Informatics	
Title of case study: Using Diagrams at Nokia to Protect Privacy	**ICS [1]**

1. Summary of the impact

The University of Brighton's (UoB) research has reduced information misuse and decreased the threat of data and identity theft in Nokia Location and Commerce (L&C). Further impact has been to lower the risk of corporate liability and consumers' personal loss. UoB's innovative research in the creation of concept diagrams now underpins and provides rigour to Nokia L&C's privacy engineering processes. Consequently, they can now communicate complex information across diverse teams in an intuitive and accessible manner. Ultimately, the impact is on all customers and users of Nokia's L&C's services worldwide.

2. Underpinning research

UoB has a 16-year history of developing diagrammatic logics for modelling complex systems. This research has culminated in the development of concept diagrams that are semantically powerful, but also capable of modelling and reasoning about information systems. Privacy engineering in the telecommunications sector requires management of an ever-wider range of customer data, and protection from data abuse and misuse. Research at UoB in diagrammatic logics, automated diagram drawing and theorem proving has enabled the production of communicable, understandable and fit-for-purpose privacy protection models by Nokia L&C.

Research contributions started in 1997 with the groundbreaking development of constraint diagrams [reference 3.1] to specify precisely software models as an alternative to symbolic notations. Constraint diagrams were formalised in an EPSRC project [3.7], but reasoning with them proved difficult because of necessary restrictions placed on the syntax. This led KENT, HOWSE and Gil (Technion) to develop the spider diagram fragment of constraint diagrams in 1999 [3.2]. Inference rules for spider diagrams were designed allowing reasoning on purely diagrammatic models [3.7]. However, spider diagrams are too inexpressive for privacy engineering.

In 2007, concept diagrams were developed by HOWSE and STAPLETON, strongly informed by Nokia, with [3.4] receiving the 'Best Paper' award at the Australasian Ontology Workshop (AOW) in 2009. Concept diagrams use the core syntax of constraint diagrams to extend spider diagrams, whilst overcoming reasoning difficulties. Concept diagrams are specifically designed for modelling ontologies [3.4, 3.5], being sufficiently expressive for modelling complex systems, including those arising in Nokia's privacy engineering.

Software tools have been developed to support modelling. In particular, algorithms for automatically drawing the Euler diagram fragment of concept diagrams have been designed and implemented. The first such algorithm, by FLOWER and HOWSE, received 'Best Paper' at Diagrams 2002 [3.3]. Advanced algorithms were proposed in EPSRC projects [3.7, 3.8], culminating in a novel approach by STAPLETON and HOWSE, with Zhang and Rodgers (University of Kent), which draws Euler diagrams with circles, which is their most natural form [3.6]. Automated diagram drawing is important when making inferences about models using software support.

To help modellers make inferences about their models, STAPLETON and FLOWER, in part collaboratively with Urbas and Jamnik (University of Cambridge), have implemented diagrammatic theorem provers; this includes research that won 'Best Paper' at Diagrams 2004 and was supported by the Leverhulme Trust [3.10].

To create diagrammatic ontology models easily, convenient ways of drawing diagrams electronically are needed. Sketch recognition systems allow stylus-based drawing on touch-screen devices. Such a system was developed by STAPLETON and DELANEY, with Nokia and Plimmer (University of Auckland) during [3.9]. The implemented software understands automatically the drawn diagram's semantics, supporting end users in the ready creation, and sharing, of diagrammatic ontology models.

Key Researchers:

Aidan Delaney: Lecturer (April 2005–July 2006), Senior Lecturer (Aug 2006–to date).

Jean Flower: Senior Lecturer (Sept 2000–October 2004).

John Howse: Senior Lecturer (Sept 1988–Aug 1992), Principal Lecturer (Sept 1992–Dec 2000), Reader (Jan 2001–July 2004), Professor of Mathematics and Computation (July 2004–to date).

Stuart Kent: Lecturer (until 1999).

Gem Stapleton: Research Officer (Sept 2004–July 2005), Research Fellow (Aug 2005–July 2006), Senior Research Fellow (Aug 2006–Aug 2010), Principal Research Fellow (Sept 2010–May 2011), Reader (May 2011–to date).

3. References to the research

The outputs marked with a # are those that best indicate the quality of the research

[3.1] # KENT, S. (1997) Constraint diagrams: visualizing invariants in object-oriented models. *Proceedings of OOPSLA*, ACM SIGPLAN Notices, 32(10), pp.327–341. DOI: 10.1145/263700.263756. [Quality validation: OOPSLA is the leading conference in the area and this paper has been cited over 200 times (Google Scholar). Research led to [3.7]]

[3.2] # GIL, J., HOWSE J., and KENT, S. (1999) Formalizing spider diagrams. *Proceedings of the IEEE Symposium on Visual Languages 1999*, pp.130–137. DOI: 10.1109/VL.1999.795884. [Quality validation: received the 'Most Influential Paper Award' at the IEEE Symposium on Visual Languages and Human-Centric Computing 2009 for important influences on VL/HCC research or commerce over the last ten years. Cited 65 times (Google Scholar).]

[3.3] FLOWER, J. and HOWSE, J. (2002) Generating Euler diagrams. *Proceedings of Diagrams 2002*, Springer LNAI 2317, pp.61–75. DOI: 10.1007/3-540-46037-3_6 [Quality validation: Won the 'Best Paper Award'. Cited 92 times (Google Scholar)].

[3.4] OLIVER, I., HOWSE, J., STAPLETON, G., NUUTILA, E. and TÖRMÄ S. (2009) Visualizing and specifying ontologies using diagrammatic logics. *Proceedings of 5th Australasian Ontology Workshop*, CRPIT 112, pp.37–47. [Quality validation: Won the 'Best Paper Award'.]

[3.5] HOWSE, J., STAPLETON, G., TAYLOR, K. and CHAPMAN, P. (2011) Visualizing ontologies: A case study. *International Semantic Web Conference 2011*, Springer LNCS 7031, pp.257–272. DOI: 10.1007/978-3-642-25073-6_17. See [Chapman1]. [Quality validation: ISWC is a leading outlet for semantic web research with an acceptance rate of 19% in 2011. An ISWC 2013 tutorial was delivered on this research.]

[3.6] # STAPLETON, G., ZHANG, L., HOWSE, J. and RODGERS, P. (2011) Drawing Euler diagrams with circles: The theory of piercing. *IEEE Trans. on Visualization and Computer Graphics*, 17(7), pp.1020–1032, 2011. DOI: 10.1109/TVCG.2010.119. See [Stapleton 2]. [Quality validation: ISI Web of Knowledge ranked TVCG 13th out of 105 computer science/software engineering journals in 2012.]

Key research grants:

[3.7] HOWSE, with FLOWER, KENT and STAPLETON, Reasoning with Diagrams, EPSRC, [GR/R63516, 2002–2005, total funding £171,506]. Overall *post-project assessment: Outstanding.*

[3.8] HOWSE, with STAPLETON, Visualization with Euler Diagrams. EPSRC [EP/E011160/1, 1 2007–2009, total funding £311,422].

[3.9] STAPLETON, with DELANEY, Sketching Euler Diagrams. EPSRC [EP/H048480/1, 2010–2011, total funding £14,767]. Project partner: Nokia Research Centre; in-kind contribution costed at €25,000.

[3.10] STAPLETON, The Mathematics of Diagrammatic Logical Systems. The Leverhulme Trust [Early Career Fellowship, 2005–2007, total funding: £45,000].

4. Details of the impact

There has been demonstrable impact of the underpinning research at Nokia in its L&C Division in two main areas: the semantic web (source 5.2) and privacy engineering (5.5). The privacy area, particularly, is of high importance to Nokia because of the significant risks associated with data misuse. Nokia's adoption of UoB's research stems from the accessible nature of the formal diagrammatic logics developed, allowing effective and accurate communication between stakeholders. The partnership between UoB and Nokia was instigated by Nokia, which recognised the potential to apply our diagrammatic reasoning research to solve the significant problems with which it was faced.

Nokia's L&C Division is responsible for ensuring that data collected through L&C services is handled appropriately. All end users of Nokia's mobile devices access L&C's services. When end users interact with these software products, their data are collected and stored by Nokia, which must be done in accordance with legal requirements, stemming from many legal jurisdictions and individual policies. Nokia analyses the data for product improvement and targeted advertising purposes and must ensure that the legal and analysis requirements are met. To this end, a wide variety of stakeholders (eg lawyers, managers, software engineers, data analysts, and marketing personnel) are involved in the process of specifying what data can be used and how data must be transformed in order to ensure, for example, that end users' privacy is protected.

Producing accurate models of information, with respect to privacy concerns, is of paramount importance. A significant problem that Nokia faced was the inability of its stakeholders to communicate effectively and accurately when producing such models. They found that textual communication proved difficult, especially as people with different business backgrounds (legal, technical, consumer advocacy) and native languages are involved, leading to ambiguity and inadequate models (5.2). This is problematic because any misuse of data may have potentially catastrophic consequences for Nokia, as will be further explained below.

The first instance where Nokia used UoB's concept diagrams was on its Smart-M3 project, which focused on ontology design, developing ways to share infrastructure across software entities and devices (5.3). Concept diagrams helped Nokia design ontologies and reason about them in this project. The Smart-M3 project was migrated from Nokia Research to be used in L&C's services, and now forms a core part of their technology. The Smart-M3 project involved a small group of Nokia's researchers who trialled the use of concept diagrams, to determine whether they could be successfully used by Nokia; this trial work was undertaken in 2009–2010 and involved software engineers, supported by the delivery of tutorials at Nokia by HOWSE and STAPLETON.

Nokia's Smart-M3 project was a success, demonstrated by its transfer from research to use in L&C's services. As a result, during 2011 Nokia rolled out the use of concept diagrams across its privacy engineering work, in the L&C Division. Concept diagrams are now used in the specification of data processing requirements, for example (5.5), that arise in the provision of L&C's services (5.1). In particular, Nokia's internal taxonomies and ontologies and their relationships, for data analytics purposes, are now defined formally using concept diagrams and can be communicated to diverse stakeholders quickly and consistently (5.1, 5.5). Nokia has found that concept diagrams are understood much more intuitively and accurately by diverse (non-engineering) audiences in this domain of privacy engineering.

The communication and other benefits that Nokia has realised through using concept diagrams is further reflected in their use in *all* discussions related to the collection of data, including purpose, use, the information type, security and provenance (5.1). The classification infrastructure derived using concept diagrams forms the basis of Nokia's data asset cataloguing, used to hold and reason over data sets.

UoB's research has led to the improved protection of Nokia's consumer data, thus reducing Nokia's risk and liability, and increasing the speed of its product development cycles, which has obvious impact in terms of cost reduction (5.1). These improvements are brought about because concept diagrams allow Nokia to reduce ambiguity problems and they have been easily understood by Nokia's stakeholders, including both technical and non-technical staff. Moreover, the succinctness of representation that concept diagrams afford aids accurate communication. The consequences of this improved communication include reduced development times for

Nokia's company standard information classification systems and more effective alleviation of security and privacy threats to Nokia and its consumers (5.1).

Reducing miscommunication between disparate groups removes key risks relating to the processing of data, such as potentially analysing data in a manner that is illegal and could lead to financial penalties: the risk of potential future losses has been reduced. The scale of these potential losses can be extremely large, exceeding tens of millions of euros and immeasurable financial implications arising from damage to the Nokia brand and, thus, Nokia's market value (5.1).

The maturing nature of the privacy engineering process at Nokia has been subjected to a capability maturity model review with improved outcomes in rating, thus demonstrating improved performance (typically CMM1 or CMM2, increasing to CMM3). Moreover, concept diagrams have been instrumental in Nokia's compliance and audits relating to ISO2700 (a certification standard for information technology and management information systems) and ISO9000 (a family of standards providing guidance to ensure that products and services meet customer requirements and that quality is consistently improved) (5.1).

As a direct consequence of the underpinning research, Nokia gained access to concept diagrams that allowed them to move quickly in solving data security and provenance challenges, privacy protection mechanisms and to avoid costly delays in production.

5. Sources to corroborate the impact

5.1 Nokia Corporation testimonial available from: the Chief Privacy Officer, HERE; the Chief Architect of Data Analytics, HERE; the Director, Legal, IP, Privacy and Government Relations, Nokia Corporation, and; the Senior Manager, Core Platforms Technology Evaluation, HERE. This statement confirms that commissioned research has been used directly between the technical team members and the consumer and non-technical team members to aid communication and reduce development times with clear economic benefit to Nokia that is visible to the end consumer. Please note that Nokia L&C was later called Navteq and is now called HERE.

5.2 Translating Research Film: The Chief Privacy Engineer at HERE has appeared in a University of Brighton production (2012), describing the impact achieved by the underpinning research. Available at:
http://www.brighton.ac.uk/research/films/visual_communication.php?PageId=40.
[Accessed: 12 November 2013].

5.3 The Smart-M3 Project is described. Available at: http://en.wikipedia.org/wiki/Smart-M3.
[Accessed: 12 November 2013].

5.4 Patent applications by Nokia: these applications are in the area of the Semantic Web. The patents are centred on the data structure that is the core of Nokia's analytics system, which is part of Nokia Services. The ideas in these patents were derived using diagrammatic reasoning; some diagrams can be seen in these applications, modified from concept diagrams by lawyers, for the purpose of the patent application. Examples of patent applications, derived using visual modelling techniques, are available at:
http://www.faqs.org/patents/app/20110093463 filed in 2010, published 2011, under review [Accessed: 12 November 2013].
http://www.faqs.org/patents/app/20110072003 [Accessed: 12 November 2013].
http://www.faqs.org/patents/app/20110145303 [Accessed: 12 November 2013].

5.5 Further evidence to support the impact of UoB's research at Nokia is evidenced by collaborative publications. The following joint publication demonstrates a simplified framework developed for privacy modelling, co-authored by the Chief Privacy Engineer at HERE: I. Oliver, J. Howse, G. Stapleton. *Protecting Privacy: Towards a visual framework for handling end-user data.* IEEE Symposium on Visual Languages and Human-Centric Computing, 2013. Although simplified, the framework demonstrates the spirit in which Nokia has applied concept diagrams and includes evidence of uptake by lawyers at Nokia (see the paper's conclusion).