School of Information Systems

Domain-Driven Innovation: Principles and Practice

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This thesis is presented for the Degree of

Doctor of Philosophy
of
Curtin University

May 2013

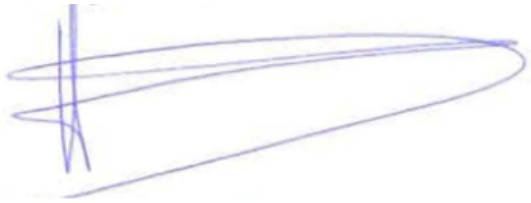
DISCLAIMER

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made. This thesis contains no material that has been accepted for the award of any other degree or diploma in any university.

This thesis is being submitted as a thesis by publication that adopts a hybrid typescript/publication character as defined under items 10.1 and 10.2 of the Curtin University Guidelines for Thesis by Publication.

This thesis is based on following publications:

1. Meersman, D., Hadzic, F., Razo-Zapata, I., De Leenheer, P., & Hughes, J. (2013). Health Service Discovery and Composition in Ambient Assisted Living: the Australian Type 2 Diabetes Case Study. *IEEE, HICCS 46 Proceedings*, 1337-1346.
2. Meersman, D. (2012). Domain Bifurcation as a Customisation and Business Intelligence Strategy in Domain-Driven Innovation. *IADIS, IST Proceedings,* 11-18.
3. Meersman, D., De Leenheer, P, & Hadzic, F. (2012). Patient and Business Rules Extraction and Formalisation Using SVN and SBVR for Automated Healthcare. *AIS, ACIS 2012 Proceedings*, 1-11.
4. Meersman, D. & De Leenheer, P. (2012). Open Innovation in Health Service Value Networks: a Methodology for the Innovation of Ambient Assisted Living Platforms and Services. *BIS (Workshops) 2012*, Springer Lecture Notes in Business Information Processing, 25-36.
5. Meersman, D. & Debruyne, C. (2011). Purchase Intent, Online Offers and Product Innovation: Misunderstandings in the Ménage à Trois. *BIS (Workshops) 2011*: Springer Lecture Notes in Business Information Processing, 132-143.
6. Debruyne, C., Meersman, D., Baert, M., & Hansenne, R. (2011). Community Driven Requests for Proposals - Applying Semantics to Match Customer Purchase Intents to Vendor Offers. *Proceedings of WEB-IST 2011*, 525-530.
7. Meersman, D., & Dillon, T. (2010). The Open Innovation Paradigm and the Semantic Web: An Ontology for Distributed Product Innovation. *On the Move to Meaningful Internet Systems 2010: OTM 2010 Workshops*, Springer Lecture Notes in Computer Science, Berlin, 49-52.
8. Meersman, D. (2009). MDPO: a Conceptual Framework for the Integration of Customer Information in Product Innovation Processes. *Curtin International Business Conference 2009, Miri, Malaysia*.
9. Meersman, D. (2007). Market Driven Product Ontologies. *On the Move to Meaningful Internet Systems 2007: OTM 2007 Workshops*, Springer LNCS, Berlin, 275-283.



11 May 2013

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"I had an inheritance from my father,

"It was the moon and the sun

"And though I roam all over the world

"The spending of it's never done."

Ernest Hemingway

For Whom the Bell Tolls

Dedicated to

Robert Meersman, my yardstick.

Acknowledgements

First and foremost I would like to thank my supervisors Helen Armstrong and Pieter De Leenheer for their insightful and generous guidance, criticism, support, and friendship over the course of the years.

I would also like to thank my other co-authors who were essential to the success of this research: Fedja Hadzic, Christophe Debruyne, Jeff Hughes, Tharam Dillon, Mathias Baert, Rami Hansenne, and Marc Kohler.

A special thanks goes out to Elizabeth Chang, for offering me an invitation and full scholarship, and with it the opportunity to leave the rainy shores of Belgium and embark on an intense and wonderful journey of intellectual discovery spanning the globe. I would like to separately acknowledge Elizabeth Chang and Tharam Dillon as my initial supervisors who were unable to continue in that capacity due to unforeseen external circumstances.

I am very grateful to my industry partners and domain experts who generously provided their time, resources, and/or commitment to create the opportunity for my collaborators and me to engage in real-world innovation contexts. These are Bart Stevens, Michiel Drabbe, Mathias Baert, Maarten Smolders, Callum Girvan, Vish Ramakonar, Simon Watt, Anthoney Malone, Steve Harley, Moyez Jiwa, Kreshnik Hoti, and Karel Van Isacker.

Furthermore I would like to thank Martin Hepp for inviting me to Innsbruck as a visiting scientist in the early days of my research; John Venable for his inspiring presentations and ensuing conversations on Design Science Research; Rainer Unland for our philosophical musings drinking XXXX on my terrace overlooking the beautiful Swan River; Peter Dell for providing support, stability, friendship, and opportunities in challenging times; Ann Nowé for inviting me to Brussels as a speaker; Aldo De Moor and Jo Pierson for their guidance in the very early days of my research; Pieter Ballon for his generosity and patience in the finalisation stages; and Paul Alexander for acting as my chairperson.

Of course I want to thank my beautiful wife Helia Dezhpoor, love of my life, who through her love, caring, support, and truckloads of patience, helped create the circumstances for success; my father, Robert Meersman, to whom this thesis is dedicated, and who has been my great academic inspiration throughout my life: from toying with a Silicon Graphics computer at his lab at the VUB during childhood, to our vivid academic discussions today; Rada Gavrilovic, my mother, who through her unwithering love and support also nourished aspects outside of science, and helped shape me into the man I am today; Daniel Meersman, my brother, who is far away in Mexico, but will always stay close to my heart like he always has; and Ana, my one and only cuñada - si se puede!

I will always have the fondest memories of studying and working in Australia due to the incredible group of friends, colleagues, and fellow sufferers Pedram, Meifania, Chris, Michael, Marc, Anna, Lukas, Markus, David, Pedi, Dang, Thomas, Sergej, Andrej, and Zoe.

Furthermore, I would like to thank my family in law Amir, Aki, and Kamelia for their love and support.

"Here I am, brain the size of a planet and
they ask me to take you down to the bridge.
Call that job satisfaction? 'Cos I don't."

Marvin the Paranoid Android (Douglas Adams)

A Hitchhiker's Guide to the Galaxy

1. Chapter 1: Introduction

1.1. A Changing Landscape

When I started working on this thesis, it was 2009. Twitter was in the process of becoming mainstream (Chang and Evans 2009); the value of Facebook was in the single digit billions (Kramer 2009); the iOS App Store was open for business for less than a year with about 20.000 apps (Schramm 2009); Groupon had been founded in only a couple of cities (Economist 2011); cloud computing was still picking up steam (Google Trends 2013); 3D printing was starting to make its way up Gartner's Emerging Technologies Hype Cycle (Gartner 2009); and Roger Magoulas of O'Reilly was just about the only person in the world talking about Big Data (Magoulas and Morica 2009).

Everything always generates data, but it is the newfound capacity to capture, process, store, and link this data that is changing the very fabric of human interactions and cognition. Technology companies such as Cisco, HP and IBM are in the process of deploying global webs of trillions of internet-enabled sensors that provide massive amounts of real-time data about any object in the world (Evans 2011, MacManus 2010). The deployment of a global broadband network infrastructure for an Internet-of-Things that connects humans, agents, sensors, objects, processes, and services represents the next stage for complex systems, ambient intelligence, and augmented reality in the information society.

The world is generating and recording data about the world at a rate of 2.5 quintillion bytes per day (IBM 2012). This rate is continuously increasing, whilst data storage costs continue to decrease significantly, resulting in a current accumulated 2.2 zettabytes of business data that costs 1.1 trillion to store and secure (Messmer 2012). Infrastructure providers are selling shovels and pans in the gold rush of the 'Big Data' boom, and businesses are capturing, storing, and processing data with increasing volume, variety and velocity.

The convergence of advances in nanotechnology, materials sciences, robotics and artificial intelligence is creating the capacity to create, manipulate and miniaturise physical objects with an unprecedented accuracy, granularity, versatility, and speed. These emerging 'mind over matter' technologies are expected to have an almost unimaginable impact on every aspect of human life and functioning (Roco 2006). The merging of the digital and physical realms represents the next stage in the servitisation of traditional manufacturing industries, and is expected to disrupt and transform global supply chains and the nature of business even further in what is already (perhaps somewhat overenthusiastically) being called the 'Third Industrial Revolution' (The Economist 2012).

Today, the business landscape is being disrupted by the advent of these and other technologies, business models, and paradigms – and will continue to be transformed by sweeping scientific and technological advancements and their convergence in societal applications. 'Innovation' permeates throughout these evolutions as a concept, subject, goal, driver, and constant. As a result, the moniker of innovation in business research covers a very wide variety of topics, perspectives, models, processes, and definitions.

With global and rapid changes affecting most industries and indeed the very nature of business, the question becomes: what approaches to innovation will withstand the test of time? Will it be only the most general models, or can we build more specific models whilst taking into account the intertwined evolutionary trends towards increased openness, interconnectedness, granularisation, servitisation, and cyber-physicality? In fact, can we build innovation models and frameworks that are more suited for the future than the current State of the Art? These questions underlie the motivation and utility theories of the artefacts that were developed in the context of this thesis, further explained in the following sections.

1.2. Scope

The research reflected in this thesis served as a basis for the development of a number of design *artefacts* that can be useful for collaborative knowledge-based innovation in a variety of domains. The resulting artefacts include:

- A modular framework that is suitable for open innovation (openness), relies on semantic technologies to integrate disparate domain data (interconnectedness), can be used by any actor including individuals over the Web (granularisation), caters for product, service and platform innovation scenarios (servitisation), and proposes a unification of the physical realm of products with the digital realm of services (cyber-physicality);
- A set of process stages embedded in the framework that can offer an extension to current innovation process models and practice via the integration of additional stages that cater for knowledge intricacy;
- A collection of principles that can be used within or outside the context of the framework; and
- A number of validated methods and methodologies for domain modelling/classification, and ideation.

In the pursuit of the applicability of the resulting Domain-Driven Innovation (DDI) framework to as many domains as possible, the foundational research has traversed four industry domains: Real Estate CRM, Scuba Diving Equipment, Online Travel, and Ambient Assisted Living. The methodological and practical implications of such an inter-domain approach are discussed further in the following section and in Chapter 3: Methodology.

1.3. On Hypotheses

This thesis adopts a hybrid methodological approach that blends Action Research with Design Science Research (see Chapter 3). The work represents an exploration of constructing artefacts in collaboration with stakeholders from four industry domains. The artefacts constitute a number of information

system assets and principles that can improve the process of knowledge-based innovation industry domains with disparate attributes. The reasoning behind working with a variety of domains is that it allows for an elicitation of common elements from the *practice* in the innovation processes in disparate domains, arriving at *principles* that can be used in a prescriptive fashion by innovation researchers and practitioners.

Being a Design Science project, I did not work with predetermined experimental hypotheses. Rather, I worked with ideas on the utility of artefacts and how things could work and/or be improved, articulated in the form of *innovation objectives*. This follows the Design Science principle of developing a *utility theory* rather than hypotheses. Of course, any utility theory could in fact be *worded* as a hypothesis, but the choice was made to stay within the confines of the utility theory approach. However, since the objective of the thesis is not only to create useful artefacts *on the level of the domain*, a number over overarching focus problem spaces are identified that drive the overall direction of the research. These are:

- Exploring the utility of domain models and ontologies in integrating heterogeneous data, knowledge, systems and actors in distributed innovation processes;
- Exploring the disparity between product, service, and platform innovation and if a generic, knowledge-based innovation framework can be designed that can handle this disparity;
- Exploring in what ways business information systems can be designed as innovation systems from the ground up; and
- Providing empirical support for the general principles that emerge from patterns between industry domains.

Chapter 3 describes in further detail the methodological approach, including how the design science artefacts link up to the action research stages, and some of the limitations (and their mitigation) of the followed approach.

1.4. Thesis Structure

1.4.1. Overview

This thesis is being submitted in a hybrid typescript/thesis by publication format, meaning that parts of the thesis have been previously published as academic papers. This section provides details on how the thesis is structured in this respect. The reasoning for the hybrid format is as follows:

a) The nature of the research, which spans 4 disparate industry domains with varying collaborators for every domain, lends itself to an approach where compartmentalisation between domains neatly aligns with publications.

b) Key insights stem from the bridges between domains, calling for a more elaborate narrative than usual with a traditional thesis by publication format.

c) Examiners are assisted by the knowledge that large parts of the thesis have already been peer reviewed by the research community.

Each domain follows one or more publications reflecting the research in that domain. These are indicated at the start of the domain chapters 4A-4D in the chapter preface section. The roles of the co-authors are explicated as well in the preface. Sections indicated with "P" in Table 1.1 are collaborative work insofar the original publications had more than one author. When writing 'we' in those sections, I mean "my collaborators and I". Other sections are first person singular or passive voice to reflect my individual work. For the 'thesis by publication' sections of the domain chapters, the co-authors are as follows:

- Ch. 4A - Real Estate CRM: sole author
- Ch. 4B - Scuba Diving Equipment: *Davor Meersman and Tharam Dillon*
- Ch. 4C - Online Travel: *Davor Meersman, Christophe Debruyne, Mathias Baert, and Rami Hansenne*

- Ch. 4D - Ambient Assisted Living: *Davor Meersman, Pieter De Leenheer, Fedja Hadzic, Ivan Razo-Zapata, and Jeff Hughes*

Table 1.1: Hybrid typescript/publication content clarification

Section/Chapter	4A	4B	4C	4D
Preface	T	T	T	T
Introduction	P	P	P	P
Background	P	P	P	P
Approach	P	P	P	P
Case Study	P	P + T	P	P
Intermediate Discussion	P	P + T	P	P
Domain Innovation Process	T	T	T	T

Each domain chapter has the following sections:

- Preface
- Introduction
- Background
- Approach
- Case Study
- Intermediate Discussion
- Domain Innovation Process.

Table 1.1 clarifies the content origination for each section of the domain chapters. "T" stands for typescript (hitherto unpublished work), whilst "P" stands for publication (based mainly on publications).

There are three levels of reflection, evaluation, and analysis:

- Domain-level: evaluation and analysis of artefacts on the level of the domain (sections "Case Study" and "Intermediate Discussion" in each domain chapter);
- Domain-related meta-level: evaluation of the innovation process artefacts of a domain in relation to an initial process template ("Domain Innovation Process" section in each domain chapter); and
- Trans-domain meta-level: synthesis of the meta-level artefacts into a generally applicable framework and principles (Synthesis Chapter).

Fig. 1.1 provides an overview of the structure of the thesis. There are 6 chapters in total, with Chapter 4 being the largest since it includes the 4 industry domain chapters.

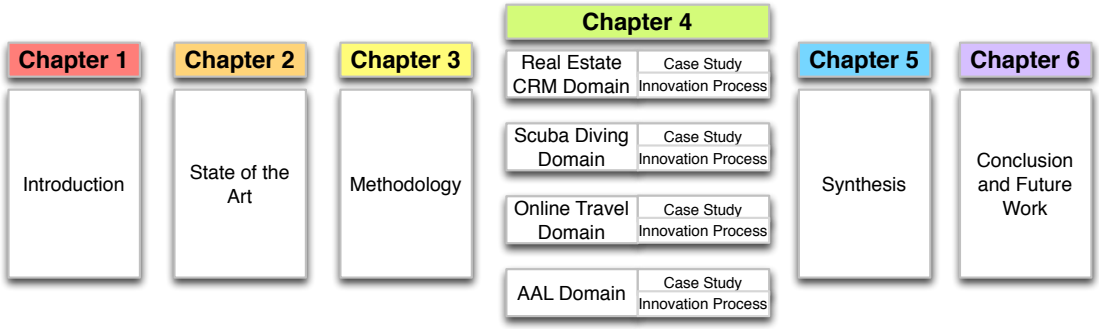

Fig. 1.1 Thesis Structure

1.4.2. Chapter 2: State of the Art

Chapter 2 discusses the State of the Art (SOTA) in innovation process models and the main stages of innovation, inter-organisational knowledge creation and sharing including enterprise and product ontologies, co-creation models in the context of open and collaborative innovation, and the distinction between products, services, and platforms in innovation with reference to the advent of Service-Dominant Logic and Service Science paradigms. The SOTA is related to current gaps in the field that will be addressed over the course of the thesis. Chapter 2 includes only the SOTA that is also applicable outside of one given industry domain. Industry-specific background elements can be found in the 'Background' sections of the domain chapters.

1.4.3. Chapter 3: Methodology

This chapter present a novel hybrid action research / design science research methodology that was used to explore in depth the 4 industry domains whilst eliciting common principles and theories at the meta-level. An overview of design science research and action research approaches is given including a discussion of their shortcomings in terms of individual applicability to the research design. The hybrid methodological framework is presented in terms of all its components and their interrelationships. An overview is given of how the industry domains were traversed over the course of the PhD project timeline. This chapter also provides a quasi-generic (meaning 'almost generic' since some stages are appended and/or are named differently, but the order and most stages remain stable between domains) innovation process model that serves as a backbone for analysis of the innovation process in the industry domains, and for the resulting DDI framework. Finally, a theoretical positioning of the artefact evaluation and analysis is provided.

1.4.4. Chapter 4A: Real Estate CRM Domain

The Real Estate Customer Relationship Management (CRM) domain covers a research project that was carried out for a Malaysian CRM service provider that had faced problems with expanding into new domains. Because of the high cost associated with CRM customisation, a large investment had to be made whenever a client from a hitherto unserviced domain would be added to their portfolio. Bifurcation (branching into two whole parts) of domain models is introduced as a strategy for customisation and business intelligence in the Malaysian real estate CRM system. The process of bifurcation forms part of a broader innovation strategy. The overarching approach is described, the bifurcation process and resulting domain models are discussed, and the results of the approach are analysed. Finally, the Real Estate CRM domain innovation process is discussed and analysed.

1.4.5. Chapter 4B: Scuba Diving Equipment Domain

This chapter describes the development and application of a formal domain model of the scuba diving equipment domain in the context of an innovation process. The specifics and advantages of domain ontology construction for product innovation are discussed and examples of the domain model are given to illustrate design choices. The domain model was then used in conversations with domain experts on the largest scuba diving forum on the Web. The discussions concerned the detailed discussion of parts of the second stage regulator, and the questions and discussions are focussed on unearthing possible improvements to the design. The main idea of the application of the domain model was to ascertain whether a non-domain expert (me) could reason and interact with experts on the web based on the concepts and relations contained in the domain model, and whether the level of granularity of the domain model was sufficient for use in a collaborative, web-based innovation process. Finally, the Scuba Diving Equipment domain innovation process itself is discussed and analysed.

1.4.6. Chapter 4C: Online Travel Domain

This chapter describes a large project concerned with the design and development of a semantic platform that matches a customer's purchase intent against vendor offers. The customers' perception on particular products, including evolving needs and preferences, were captured in a request and product ontology, in turn used to annotate vendor offers. The use case development for the domain was done in collaboration with the largest winter sports platform of the Netherlands. During the project an important gap ('peripheral data') was observed between the intent descriptions of users and the available data in product descriptions. It is argued that through the inclusion of peripheral data, vendors are able to innovate according to customer preference, and users receive increasingly relevant results. The outcome of the project is, amongst other artefacts, a customer-driven innovation system. Finally, the innovation process enabled by the system is evaluated and analysed.

1.4.7. Chapter 4D: Ambient Assisted Living Domain

This chapter is situated in the ambient assisted living (AAL) domain in the context of the innovation process of a smart home platform of one of Australia's largest telecommunications providers. The smart home platform hardware consists of a back-end and network infrastructure, and a home gateway that controls a wireless sensor network, network communications and the delivery of a range of services including but not limited to: health, security and smart energy. The AAL Domain required a lot of groundwork to build the blueprint for a platform capable of service selection, composition, and delivery, as well as service/platform innovation. Part of the effort were the formalisation of medical practice guidelines, the development of a general domain model, the development of a patient rule base, the extraction and formalisation of medical service listings, the development of a business rules base, and the application of the e3value framework[1] for service composition and delivery. The final result was a set of integrated artefacts that allowed for an information flow across the stages of the innovation process. Finally, this service and platform innovation process is analysed and evaluated.

1.4.8. Chapter 5: Synthesis

The Synthesis chapter brings together the main insights and lessons learnt from the domain-related meta-level analysis from the domain chapters. This results in a theoretical reflection, a set of innovation principles, and a final Domain-Driven Innovation Framework that is presented here. Finally, the validation of the components of the framework is placed within the context of the respective chapters.

[1] http://e3value.few.vu.nl/

1.4.9. Chapter 6: Conclusion and Future Work

The conclusion and future work chapter sums up the main contributions of the thesis and points to future work including a European project proposal based on the DDI framework that is currently under evaluation by the European Commission.

"And yet viewing several depictions of even an imaginary city, is enlightening in a way," Leibniz said. "Each painter can view the city from only one standpoint at a time, so he will move about the place, and paint it from a hilltop on one side, then a tower on the other, then from a grand intersection in the middle – all in the same canvas."

Neal Stephenson

Quicksilver

2. Chapter 2: State of the Art

2.1. Introduction

This chapter presents an overview of the State-of-the-Art in scientific domains related to this thesis. Domain descriptions are not part of this chapter and can be found in the respective domain chapters. The first section introduces and discusses innovation as a process vs result, in light of the literature on the topic. The second section elaborates on the process of innovation with an overview of innovation process models and a discussion of the main stages of innovation. The third section discusses innovation as a paradigm, and the different viewpoints in literature on the nature of innovation, including open and closed innovation models, and bottom-up innovation. The fourth section discusses the role of knowledge in the innovation process and various standards and ontologies for exchanging information in collaborative innovation, design, engineering and production environments. The fifth and final section discusses the distinction between product, service, and platform innovation based on established theories in new product development, service science, and platform innovation.

2.2. Innovation

> ***innovation*** | ɪnəˈveɪʃ(ə)n | *noun*
>
> *[mass noun[1]] the action or process of innovating.*
>
> *[count noun[2]] a new method, idea, product, etc.*
>
> -- The Oxford Dictionary of English[3]

[1] a noun denoting something which cannot be counted (e.g. a substance or quality), in English usually a noun which lacks a plural in ordinary usage and is not used with the indefinite article, e.g. *china, happiness (Oxford Dictionary of English 2013)*
[2] a noun that can form a plural and, in the singular, can be used with the indefinite article, e.g. *books, a book. (Oxford Dictionary of English 2013)*
[3] http://oxforddictionaries.com/definition/english/innovation

Innovation can refer to both a process and the result of a process. Whilst this may seem trivial, there is some merit to making the consideration. For example when one talks about 'technological innovation', does the author mean a technology is produced, or that a technology is used in the process of innovation (leading to a much broader, indeed arguably all-encompassing, definition)?

A similar case for sorting out the nomenclature of the innovation research domain was made by Garcia and Calantone (2002), who posited that the lack of clear definitions, lack of conformance, and overlapping constructs were harming progress in the domain. Innovations are labelled as radical, incremental, really new, discontinuous, imitative, architectural, modular, improving, and evolutionary in scientific literature, but what do these adjectives and their interrelationships *signify*?

In their study, Garcia and Calantone identified 15 constructs and 51 scale items which were extracted from 21 empirical studies leading up to 2002[1]: Cooper 1979; Lawton and Parasuraman (1980); More (1982), Maidique and Zinger (1984); Yoon and Lilien (1985); Cooper and de Brentani (1991); Kleinschmidt and Cooper (1991); Lee and Na (1994); Ali et al. (1995); Atuahene-Gima (1995); Green et al. (1995); Olson et al. (1995); Mishra et al. (1996); Souder and Song (1997); Schmidt and Calantone (1998); Colarelli O' Connor (1998); Song & Montoya-Weiss (1998); Veryzer (1998); Goldenberg et al. (1999); Kessler and Chakrabarti (1999); and Chandy and Tellis (2000). The resulting constructs from the comparative study are: product innovativeness; radicalness (discontinuous); newness to firm; technical content; newness to market; newness of technology; newness to customer; product uniqueness; product (superiority); synergy (fit); product/market fit; marketing task similarity; product complexity; development complexity; and product type.

[1] notably not including Chesbrough's (2003) work on open innovation and the corollary plethora of publications, concepts, theories, and insights resulting from the paradigm.

Construct	Study*
· Product innovativeness	2, 6, 7, 9, 12, 13, 15, 17
· Radicalness (discontinuous)	11, 14, 16, 18, 20, 21
· Newness to firm	1, 6, 10, 13, 19
· Technical content	4, 8
· Newness to market	19
· Newness of technology	19
· Newness to customer	10
· Product uniqueness	1
· Product (superiority)	1
· Synergy (fit)	1
· Product/market fit	6
· Marketing task similarity	3
· Product complexity	3
· Development complexity	3
· Product type	5

* Some studies used more than one construct.

1. Cooper (1979)
2. Lawton & Parasuraman (1980)
3. More (1982)
4. Maidique & Zirger (1984)
5. Yoon & Lilien (1985)
6. Cooper & de Brentani (1991)
7. Kleinschmidt & Cooper (1991)
8. Lee & Na (1994)
9. Ali, Krapfel, & LaBahn (1995)
10. Atuahene-Gima (1995)
11. Green, Gavin, & Aiman-Smith (1995)
12. Olson, Walker & Ruekert (1995)
13. Mishra, Kim, & Lee (1996)
14. Souder & Song (1997)
15. Schmidt & Calantone (1998)
16. Colarelli O'Connor (1998)
17. Song & Montoya-Weiss (1998)
18. Veryzer (1998)
19. Goldenberg, Lehman, & Mazursky (1999)
20. Kessler & Chakrabarti (1999)
21. Chandy & Tellis (2000)

Fig. 2.1 Constructs used to model product innovation/innovativeness (reprinted from Garcia and Calantone 2002)

Although this seminal study provided a much-needed contribution to the clarification of the nomenclature in the innovation management field, it has two major shortcomings:

1) Technological innovation is ill-defined as "those innovations that embody inventions from the industrial arts, engineering, applied sciences and/or pure sciences", notably leaving much to individual interpretation with an unexplicated notion of 'embodying', and a limited, yet fuzzy and un-qualifying listing of originating fields;
2) Although the process of innovation is mentioned throughout the study, it fails to make a clear semantic distinction between the process and the result, resulting in a formalisation of the latter without almost any consideration of the intricacies of the former other than as a given that precedes the result.

With that said, it should be clarified here that the main scope of this thesis will be on the process level of innovation, more specifically on the knowledge level of that process, although contributions are made to the 'count noun' aspects of innovation in the form of contributions to the nature of products and services, or 'innovations'.

2.3. Innovation as a Process

The innovation process is a subset of the economic production process as defined in production theory. Innovation converts inputs (knowledge and factors of production) into outputs (products, services, and/or platforms). Over the years, many business scholars from an array of academic fields have conceptualised this process using generic models. The following section provides an (inevitably incomplete) overview and brief discussion of some of the main innovation process models in literature.

2.3.1. Invention Innovation Diffusion (Schumpeter 1939)

Fig. 2.2 Invention Innovation Diffusion Trilogy

Schumpeter's Invention-Innovation-Diffusion trilogy can be considered the foundational model for many innovation theories (Schumpter 1939). Schumpeter discerns three stages in the innovation process: invention, innovation, and diffusion. In Schumpeter's view, invention is considered separate from innovation, and would correspond to an ideation stage in contemporary models. After the innovation process, which concerns the development of ideas into products and processes, the diffusion stage is concerned with spreading and putting the innovations into the market. Perhaps interesting to note here also is that Schumpeter's thinking on innovation can be broadly categorised into two stages, Mark I and Mark II, with the difference being the actor of the innovation. In Schumpeter's early thinking, the innovator was an almost solitary entrepreneur who anticipated on the changing environment, whereas in his later thinking the actors became large corporations that had the capacity and scale to develop and market innovations in a more integrated fashion. The main appeal of Schumpeter's model, and part of the reason why it is still used after more than 70 years, is its broad applicability. However, the model is for this reason also very generic and perhaps more suited as a descriptive rather than a prescriptive, guiding model.

2.3.2. Cumulative Synthesis (Usher 1954)

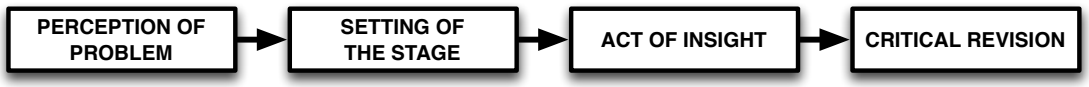

Fig. 2.3 Cumulative Synthesis

To introduce the notion of cumulative synthesis, one would need to juxtapose it to the two other approaches Usher (1954) identified and rejected to explain

the emergence of innovation. The first approach is the transcendentalist approach, which is the 'occasional genius' model where an individual attains some form of inspiration via intuition. This is rejected by Usher as unhistorical, where it is posited that acts of insights throughout history have not been a unique occasion that happen by some sort of chance, but are a result of work and conditioning., i.e. a precedence. The second approach is the mechanistic process, which views innovation in a deterministic light as an accumulation of factors over time. This is rejected by Usher over the fact that such a process cannot explain discontinuous innovation.

This leaves us with the third notion, proposed by Usher under the moniker of "cumulative synthesis" (Korhonen 2012). This approach consists of four stages:

1. *Perception of the problem*: the identification of a possible pattern for the satisfaction of a customer need
2. *Setting the stage*: a laddering process where the elements of a solution (in line with the core competency) are brought to bear in the context of satisfying that given need.
3. *The act of insight*: where a configuration of the elements are crystallised and a solution is found to the problem. Usher stressed that the constellation 'uncertainties' surround this stage, and due to this constant, variables regarding the precise configuration of the solution are difficult to predict – pointing to a shortcoming of the model: the 'stabilisation' of the variation via a label does not equal accommodation.
4. *Critical revision*: the constellation of relations are 'fully understood and worked into context'.

Usher's theory offered a contribution in bridging the invention and innovation stages (in light of the theories of that time) but falls short as a prescriptive and even explanatory model due to its lack of intricacy in stage 3.

2.3.3. Stage-Gate Innovation Process (Cooper 1986)

Fig. 2.4 Stage-Gate model

Cooper's (1986) well-known model introduces a method for structuring new product development using milestones and phases. The model is based on 60 innovation case studies from the 5 years preceding the publication. Stage-Gate consists of stage and gates. Gates are milestones consisting of a specific set of deliverables and criteria that serve as a 'quality control checkpoint' (Proven Models 2013), which is today embodied in many project and innovation management processes. Cooper defines five stages:

1. Scoping: an appraisal of a project's technical merits and prospects on the market.
2. Build Business Case: business, technical, and marketing requirements definition.
3. Development: transformation of the scope into deliverables.
4. Testing and Validation: validation of product in terms of customer acceptance, production process, and financial merit.
5. Launch: deployment and start of commercialisation of the product.

The stage-gate model was seminal in the sense that a lot of project 25 years later are run according to his constructs, meaning that the model is well-suited in operational environments. However, it is an organisational model that does not account clearly for distributed environments, hardly addresses data and knowledge integration, and does not integrate feedback loops (e.g. between development and testing).

2.3.4. PWC Innovation Life Cycle (PWC 2011)

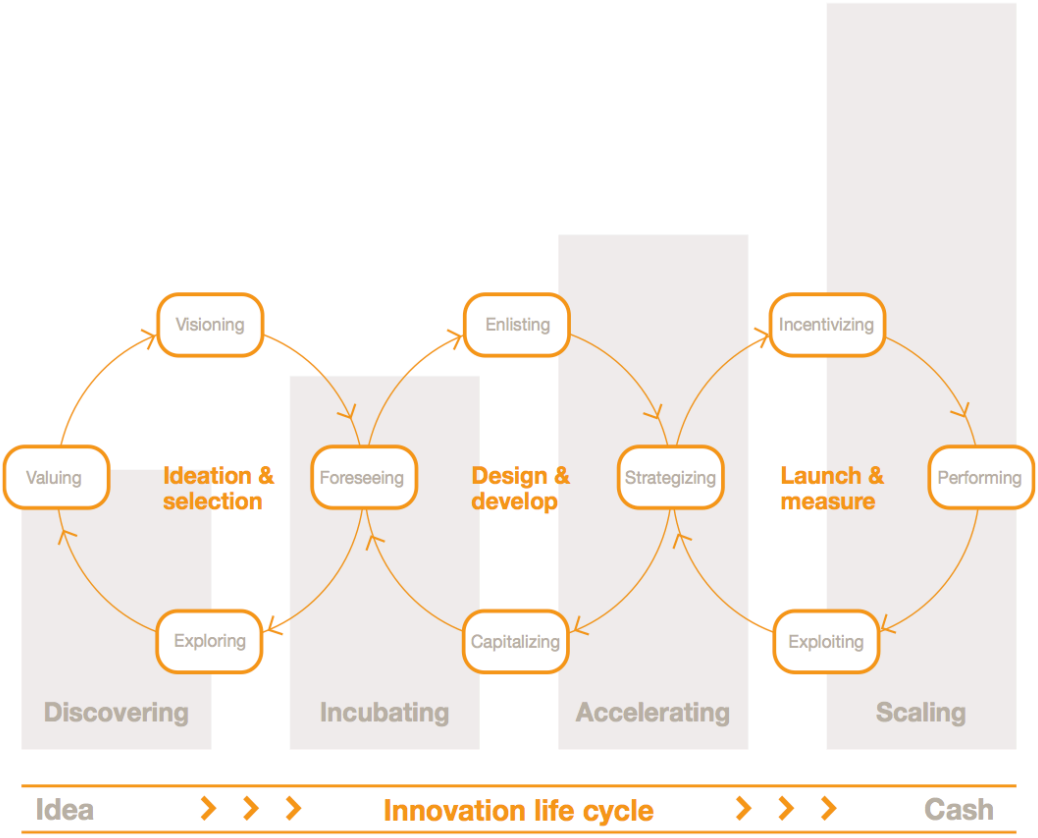

Fig. 2.5 PriceWaterhouseCoopers Innovation Life Cycle (reprinted from PWC 2011)

In 2011, PriceWaterhouseCoopers released the Technology Forecast study "Decoding innovation's DNA" (PWC 2011). In the report, a multi-domain, empirically supported innovation process model is proposed that blends aspects of linear and cyclical innovation models. PWC defines 4 stages: Discovery, Incubation, Acceleration, and Scaling, which are supported by 3 problem-solving loops: Ideation & Selection, Design & Development, and Launch and Measurement. The study further maps information technologies to the various stages of innovation, and thus provides a very useful overview of the contemporary knowledge infrastructure in the context of innovation. However, the intricacy of the actual knowledge in the innovation process is limited to illustrations and cases, leaving room for further exploration and

improvement of how exactly knowledge can be integrated in distributed innovation environments.

2.3.5. INNOVANET (Paukert et al. 2003)

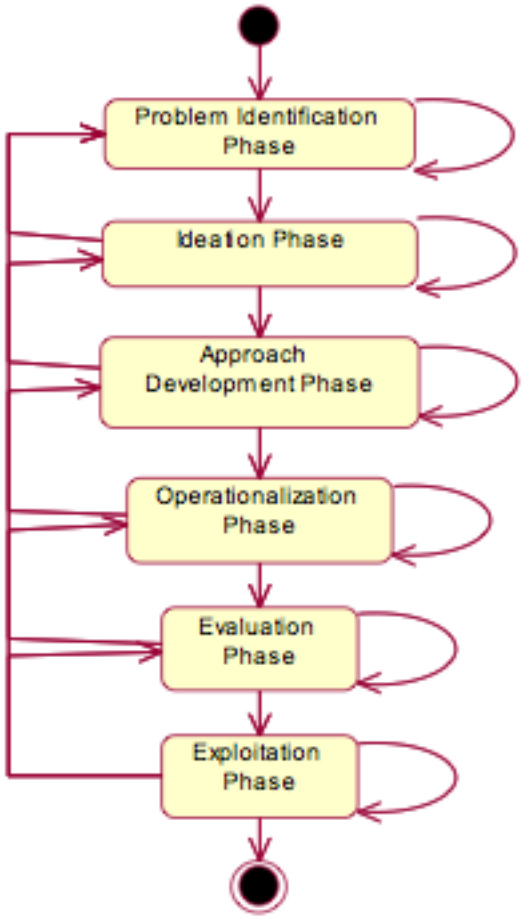

Fig. 2.6: INNOVANET innovation process model (reprinted from Paukert et al. 2003)

The INNOVANET project was a European project focusing on knowledge in the innovation process. The project defined (a) an innovation process model, depicted above, and (b) an innovation knowledge life cycle, discussed further below. The six stages of the innovation process model are problem identification (defining the problem proactively or reactively); ideation (developing the central idea for the innovation); approach development (solidifying the idea towards an implemented solution); operationalisation

(transferring the approach to an operational form), evaluation (validation and evaluation of results); and exploitation (commercial or other type of deployment). The INNOVANET process model's merits and shortcomings are best discussed in conjunction with its innovation knowledge life cycle, which is done in section 2.5.

2.3.6. Funnel Model (Dooley and O'Sullivan 1999)

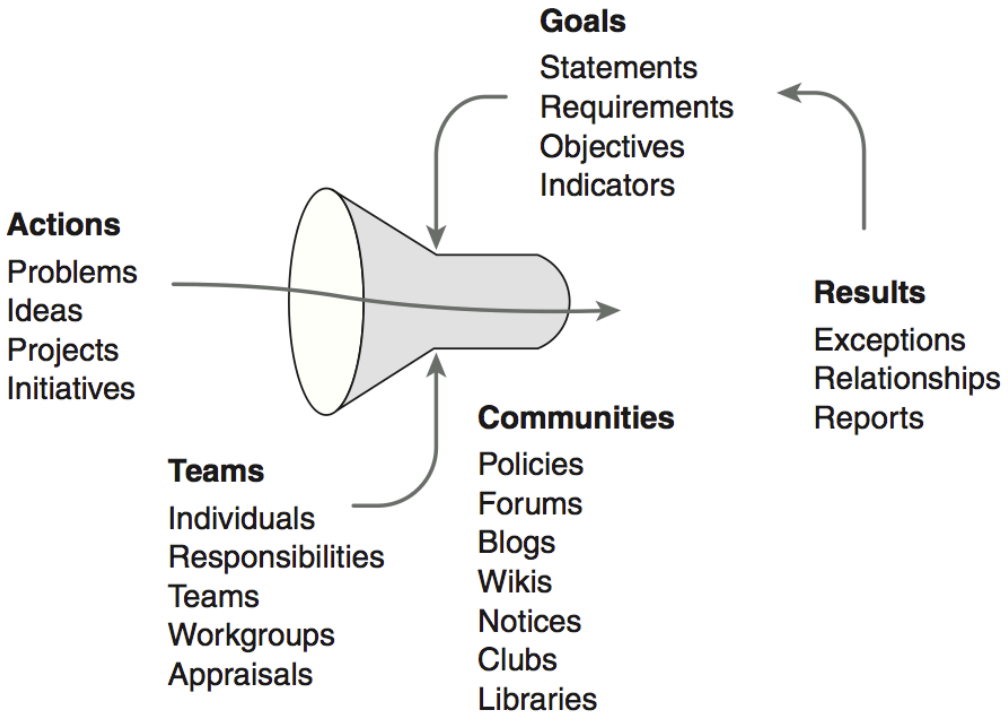

Fig. 2.7 Innovation Funnel (reprinted from O'Sullivan and Dooley 2009)

The innovation funnel is a well-known and broadly used concept for "managing innovation by controlling the interaction of goals, actions, teams, and results used in the innovation process" (Dooley and O'Sullivan 1999). The arrows in Fig. 5.6 represent the flow of goals, actions teams and results towards the neck of the funnel. The model basically represents an idea selection mechanism based on two constraints: *goals* and *teams*. Goals can be statements, requirements, objectives, and indicators, and their purpose is to ensure alignment of ideas with what is desired and/or envisaged. Teams can be individuals, teams, working groups, roles, and appraisals, and they

constrain the ability to actuate ideas based on the capacity of the actors: the neck of the funnel can be 'loosened' if more people are available to do the job. Where the famous funnel model falls somewhat short, is the question where the ideas come from. There is a dynamic of divergence preceding the convergence (discussed for example in PWC 2011), which this model does not capture convincingly (although one could posit the emanation context is contained within the goals/requirements, since they drive the need for innovation in the first place). Another consideration one could make is that the model is very rudimentary: although it is a useful metaphor for guiding actions within a domain, it does not provide a lot of decision support.

2.4. Open Innovation and Co-Creation

The last years have seen a shift from more closed, traditional innovation processes towards more open models for innovation under the impetus of the seminal work on open innovation by Chesbrough (2003). Trott and Hartmann (2009) argue that the concepts of open innovation presented in Chesbrough's work are nothing new, and that innovation had hitherto rarely taken place in 'closed innovation' models as defined by Chesbrough. A networked model of innovation was indeed advocated as early as 1985 by Rothwell and Zegveld (1985), and earlier work to advance the thinking in this field can be traced back to Pearson et al. (1979), and Griffiths and Pearson (1973). One could even posit that the important innovation framework TRIZ and its principles (see Section 3), which was conceived as early as 1948 and is the result of a thorough study of international patents and problem-solving patterns between them, was a form of open innovation since it relies on knowledge (and resulting patterns) outside of the scope of an individual firm (Altshuller 2000). Criticisms notwithstanding, Chesbrough's work has led to the widespread adoption of the notion of open innovation in research, practice and thinking about innovation in the enterprise (Trott and Hartmann 2009) that continues to this day.

With the notion of more open models for innovation also came the advent of customer co-creation techniques that strive to involve the customer in innovation processes.

Such techniques include:

- Participatory method;
- Empathic design;
- Co-designing;
- Use of artefacts and prototypes;
- Personas and avatars;
- Laddering techniques;
- Living labs;
- Lead user approach; etc.

These techniques (Mukhtar et al. 2012) attempt to integrate customer perspectives, and formalise customer knowledge to the point where it becomes relevant for an enterprise in the context of innovation. This falls within the broader scope of the aims of the knowledge-creating enterprise to formalise individual and tacit knowledge to a level where it can be shared within the organisation (Chesbrough and Kusunoki 2001, Nonaka et al. 2000, Scharmer 2001, Takeuchi 2001).

2.5. Knowledge Creation and Sharing

As the life cycles of products and services shrink, companies need to constantly develop new products and/or services in order to grow revenue (Hartley 2000). The pace of innovation in companies is accelerating, and product engineering teams need to keep up. Engineering teams around the world are constantly trying to develop that next disruptive innovation because it is this type of product that generates the greatest profits (Bower et al. 1995). In order to develop relevant, useful products organisations are becoming more and more market-oriented and try to integrate market and user knowledge into their business processes (Day 1994). However, a constant

number of approximately 80 percent of all new products or services fails within six months or falls significantly short of forecast profits once brought to market (Morwitz et al. 1997). Part of this failure rate can be attributed to factors involving poor market information processing and poor decision making based on incomplete and/or erroneous information. In a perfect world, product properties, functions, pricing and marketing would be based on perfect information and thus succeed, but in reality this knowledge is imperfectly shared over time and across people, organisations and industries (Hagardon and Sutton 1997).

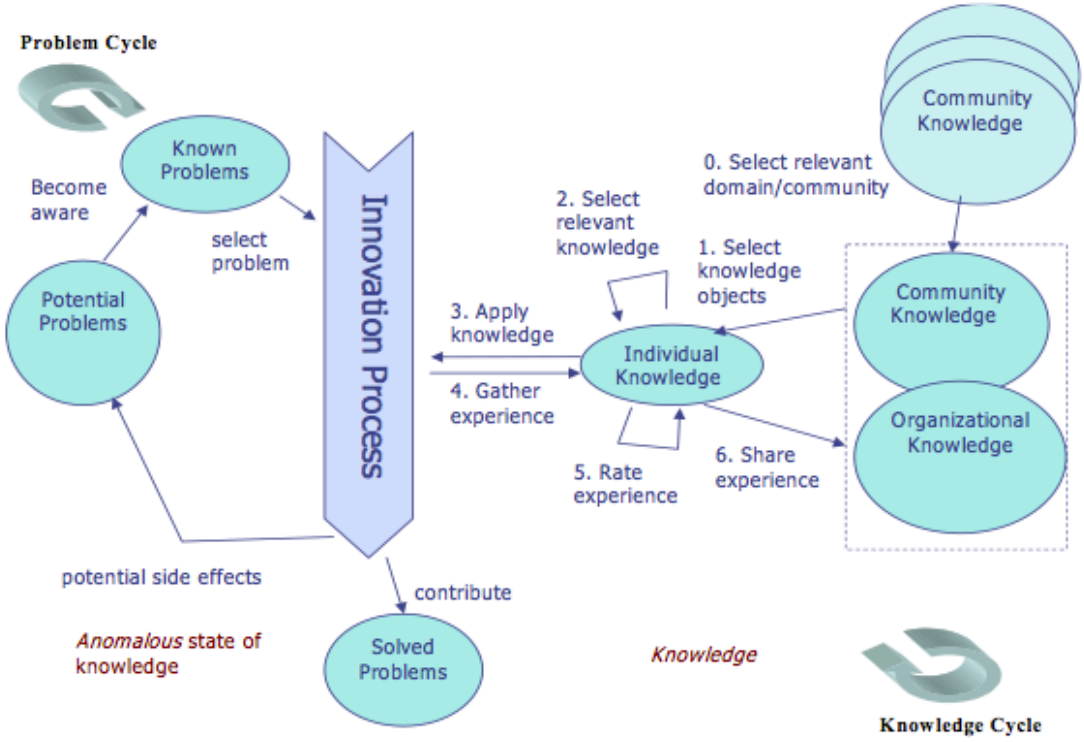

Fig. 2.8 Innovation Knowledge Life Cycle (reprinted from Paukert et al. 2003)

In this context it is interesting to revisit the INNOVANET project, which included a knowledge life cycle to accompany the innovation process (Fig. 2.8). The stages of the knowledge life cycle are: select domain; select knowledge objects; select relevant knowledge; apply knowledge; gather experience; rate experience; and share experience. What we can discern from this model is that it is very coarse in a number of ways. First of all, the exact interactions of the knowledge with stages in the innovation process are

insufficiently explicated (indeed, the process is represented merely as a homogeneous arrow). Secondly, the "apply knowledge" stage does not do much in terms of bringing to bear how knowledge is manipulated, used, transformed, etc. in the context of innovation. Finally, the inherent coarseness of the model suggest it is actually concerned more with the social aspects of knowledge creating and sharing in the school of thought of Nonaka et al. (2000), rather than the life cycle of the actual knowledge itself. Taken together, the INNOVANET innovation process model and knowledge life cycle fall short in sufficiently defining the role of knowledge in the innovation process.

Popadiuk & Choo (2006) suggest that knowledge creation is focussed on the invention and use of knowledge that leads to new capabilities for the organisation, whereas innovation is concerned with how these new capabilities may be transformed into products and services that have economic value in markets. They posit that different types of knowledge are required for different types of innovation. The knowledge required as a foundation in an innovation context includes not only a cognisance of customers and their preferences, but also a detailed understanding of products and processes, and a comprehension of the organisation's competitors and value network. In this context, boundary spanning has also been identified as an important principle in knowledge acquisition for innovation (Beckett and Hyland 2009, Rosenkopf and Nerkar 2001).

2.5.1. Ontology

An ontology is commonly defined as: *a [formal,] explicit specification of a [shared] conceptualization* (Gruber 1995). Ontologies are necessary to enable semantic interoperability between information systems and services on the Web (Guarino 1998). In collaborative environments, the knowledge acquisition, creation, and sharing process between different entities in the network has been supported by ontologies for a number of years (De Leenheer et al. 2010, Dietz 2006, Gordijn et al. 2001, Gunasekaran and Ngai 2004, Uschold et al. 1999, Uschold and Gruninger 2004, Vernadat 1996). Ontologies are shared and agreed-upon conceptualisations of real-world

entities, and how these entities can be identified and grouped within a higher-level structure, family or hierarchy. Ontologies are comprised of classes, attributes and relationships that provide a shared understanding of a given domain. Recent efforts to construct a customer relationship management (CRM) business ontology (Magro and Goy 2008, Magro and Goy 2012) propose a common semantic model of CRM that can be shared by companies involved in CRM such as client firms and software houses, essentially providing a customer-centred shared business conceptualisation.

In a business context, enterprise ontologies have been created to support the flow and exchange of information within and between enterprises. O'Leary (2010) discusses a number of these ontologies: ARIS, SAP, REA, TEO, TOVE, and EO.

- ARIS (Architecture of Integrated Information Systems) (Scheer 1998) consists of multiple frameworks that are integrated into a meta-model consisting of twelve classes: Machine, Hardware, Event, Environmental Data, Input, Output, Application Software, Event, Goal, Human Output and Organisational Unit.
- SAP Glossary is a widely-used glossary for defining and managing the business concepts within an enterprise. Whilst this does fall within the scope of Master Data Management (Fischer 2007), such a glossary could be seen as a precursor to an enterprise ontology with meaningful semantics (Meersman 2002).
- REA (Resources – Events – Agents) (McCarthy 1979, 1982) is an enterprise ontology that has grown out of the accounting domain and supposedly constitutes the basis for the ISO Open-edi standard (O'Leary 2010). In any case, REA and Open-edi have been recently unified into OeBTO (Open-edi Business Ontology) and OeBTO is being formailsed using OMG's SBVR (Semantics of Business Vocabulary and Business Rules) to introduce a hitherto largely absent service-centricity (Zdravkovic et al 2011, Zdravkovic and Ilayperuma 2010).
- TEO (The Enterprise Ontology) (Uschold et al. 1998) originated from the artificial intelligence community in the UK. It has five high-level

classes: MetaOntology, Activities and Processes, Organisation, Startegy, and Marketing (O'Leary 2010).

- TOVE (Toronto Virtual Enterprise) (Fox and Gruninger 1998, Gruninger et al. 2000) is an extensive enterprise ontology that satted off as a shared terminology and gradually added components. It consists of a number of sub-ontologies such as Activity, Resource, Quality, Time, Product Design, etc.
- EO (Enterprise Ontology) (Dietz 2006) constitutes the theory and methodology for modelling an enterprise on a high level of abstraction (its unchanging core), where an enterprise is considered an artefact that needs to be modelled like any other artefact. Dietz's work on EO finds its origins in DEMO (Design and Engineering Methodology for Organisations), which is focused on transaction modelling.

2.5.2. Product Ontology

Because products and their components are one of the common denominators in a business network with heterogeneous partners (Meersman 2007), product ontologies form a formidable candidate as a central interface for data integration in various stages of value creation.

The problem of product data integration has been addressed by the Semantic Web community by the development of product ontologies. The most important product ontologies today are eClassOWL, PRONTO, SWOP and GoodRelations.

1. eClassOWL is a product ontology that is derived from the eCl@ss product classification standard that is widely used in the manufacturing industry (Hepp 2006)
2. PRONTO is geared towards product information regarding production, storage, sales and distribution (Vegetti et al. 2005)
3. SWOP is a product ontology developed by the Semantic Web Open engineering Platform project. It is an extremely powerful and very

granular product modelling ontology for expressing product and component properties (Böhms 2006)

4. GoodRelations is a lightweight product ontology for representing product information that is relevant to the e-commerce domain (Hepp 2008)

The above ontologies do a good job of representing product and component properties. Properties such as product shape, material, colour, family and other manufacturing and sales related concepts are covered, in some ontologies to very great detail. However, in the context of open innovation the main shortcoming of these ontologies is that product, component and property functions are not included. Hence they are to be regarded more as very important and valuable assets in the modelling, manufacturing and commerce process, rather than tools to drive innovation.

Many well-known and successful systematic innovation approaches such as TRIZ in traditional, goods-dominant environments rely at some point on the function of components (Altshuller 2000, Dewulf 2011). In these approaches, innovation is achieved when new functions are found for existing properties, or vice versa. A well-known example of this principle in innovation is found in the Swiffer cleaning device, a billion dollar household brand (Ticoll et al. 2007). In this case the property 'suction' was replaced with 'static electricity' for the function 'cleaning'.

Functions drive the existence of product properties in innovation, and are a crucial part of the representation of products in the context of innovation. One cannot represent functions using GoodRelations, PRONTO, eClassOWL or SWOP. Therefore, a product innovation ontology that represents functions was proposed in Meersman and Dillon (2010), and Meersman and Debruyne (2011).

2.6. Product, Service and Platform Innovation

2.6.1. S-DL and Service Science

Vargo and Lusch authored a series of papers on Service-Dominant Logic (S-DL), announcing and creating a paradigm shift away from Goods-Dominant Logic (G-DL) as a framework for understanding economic exchange and value creation (Vargo and Lusch 2004a, 2004b, 2006, 2008a, 2008b). SD-L forms the foundation for the emerging field of Service Science, which proposes an interdisciplinary approach to the study and creation of service systems with no real demarcation between products and services (Maglio and Spohrer 2008, Maglio et al. 2009, Vargo and Akaka 2009). In this view, products are vehicles for service delivery and services are the application of competences for the benefit of others. The view of products as mere vehicles for delivery was already proposed by Pine and Gilmore (1998) in their study of the 'experience economy', and further clarified in Vargo and Akaka (2009). But the prevalence of traditional GD-L in the large body of contemporary product innovation approaches, practices, and research suggests that this vision has not been completely carried through to the intricate level of product engineering.

2.6.2. Service Value Networks

The Service Science view of services as applications of competences is further embodied in the research field of service value networks. A Service Value Network (SVN) is an open network of enterprises and customers who establish relationships between each other for selecting, creating, bundling and delivering value-added services (Allee 2002, Hamilton 2004, Lovelock and Wirtz 2011, Razo-Zapata et al. 2012). Whereas value chains were sequences of activities that add each value to a production process, in SVNs the value is co-created in a networked setting.

The key issue of SVN technology research is to automatically match customer needs with competencies on the market (Meersman and De Leenheer 2012). In

other words, SVN composition aims to bundle relevant competences in a network such that they deliver value in such a way that they answer a customer need. Suppliers, as well as customers can deliver these competencies. This value co-creation happens usually in different tiers: at B2C side, service providers make sure they offer relevant competences in fulfilment of a customer need; at B2B side service enablers make sure the technology space can make these services possible (Basole and Rouse 2008).

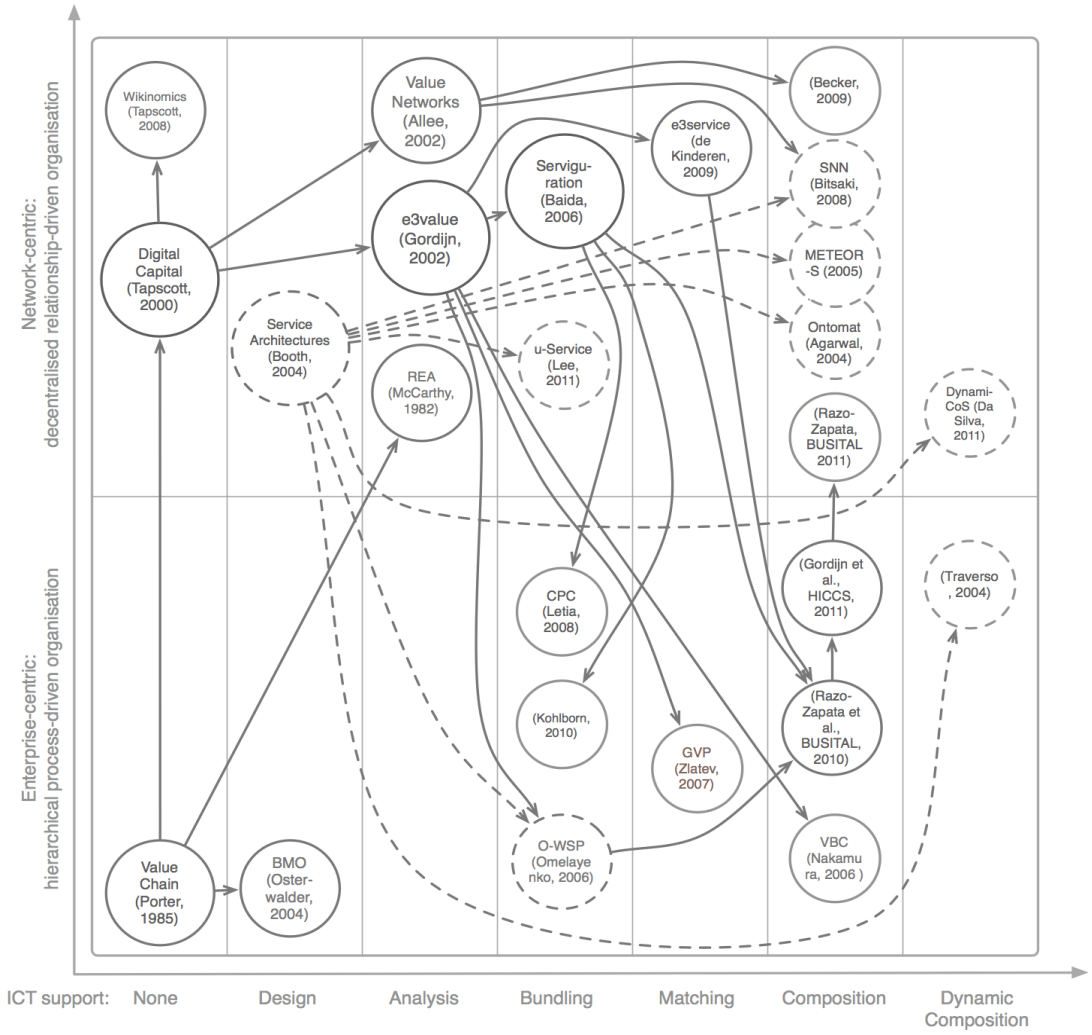

Fig. 2.9 Service Value Network approaches (reprinted from Razo-Zapata et al. 2011)

Fig 2.9 shows how the innovation space in which different SVN approaches have emerged from business research (Porter 1985, Tapscott 2000) and influenced each other. Solid circles represent business-oriented approaches taking into account value aspects of services, whereas dotted circles stand for process-oriented approaches hence focusing more on software aspects of services (see Razo-Zapata et al. 2011). The axes of the space indicate how these approaches co-evolve with changing business practice trends and increasing demand for ICT support: vertically, there is the economic context, which is evolving from a hierarchical process-driven organisation to a decentralised and relationship-driven organisation. Horizontally, there is the support of ICT in the different activities of SNs in these organisations.

A promising direction for advancing the state of the art lies in the dynamic composition of service value networks in decentralised business environments. This corresponds to the upper-right corner of the SVN innovation space in the figure. These trends are confirmed in business research literature by, i.a., Tapscott (2006), Van Heck and Vervest (2007), and Chesbrough (2011).

A reference should be made here to e3value (Gordijn and Akkermans 2003, Akkermans et al. 2004), which is the SVN approach that was adopted in this research. E3value provides ontologies to analyse and model perspectives of customers and providers on service needs. Inspired by service marketing and management theory, the conceptualisation of services focuses on value aspects, rather than merely computer-technical aspects as found in most service-oriented computing paradigms (e.g. WSDL, SOAP). As depicted in Fig. 2.9, e3value has been evolving since 2002 taking up different related service network approaches.

2.6.3. Service Innovation and Servitisation

Michel et al. (2008) provide a study on the application of the intricacies of S-DL to discontinuous innovations and open up the discussion for reframing and rethinking the hitherto G-DL dominated field of innovation. One of the corollaries of such rethinking is the recently rejuvenated idea of

'servitisation'. Servitisation is a term that is increasingly used in the discussion on the transformation from products to services, encompassing the generation of value to customers by adding or integrating services to products. Vandermerwe and Rada (1988) and Oliva and Kallenberg (2003) are some of the pioneers in this area researching the increase in importance of the role of services in a packaged solution to meet customer problems and raise customer satisfaction. Thoben et al. (2001) present a four-staged extended product concept, connecting products, product related services and the needs of customers through the four stages of Tangible Product, Product and Supporting Services, Product and Differentiating Services, and Product as a Service (see Fig. 2.10).

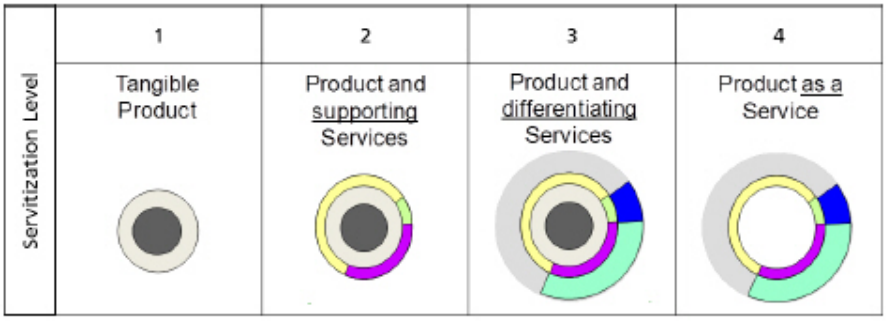

Fig. 2.10: Extended Product Concept (reprinted from Thoben et al. 2001)

The transformation of the product into a service can be seen by the gradual enlargement of the outer service circles. In level 1 the product is the only entity, in level 2 an additional outer circle represents supporting services related to the product, in level 3 differentiating services to provide competitive advantage are added to the periphery and in level 4 the product as a separate identifiable object disappears and becomes part of the service.

This model clearly illustrates the development of services, but does not reflect the continuation of the base product or platform upon which the services are founded. The concept of an innovation cycle as proposed by Freitag et al. (2012) comprises a Service Innovation Phase followed by a Servitisation Phase, with Thoben's extended product concept forming an integral part of the Servitisation phase. Whereas Freitag's Service Innovation Phase (phase 1)

focuses on idea generation and selection, the Servitisation Phase (phase 2) reflects the interdependence between product and service as the innovations will be product-related services. In this context service innovation will trigger servitisation processes, which can result from either adding a supportive service to an existing product or adaption of the physical product. The main shortcomings in this conceptual approach are that services are exclusively product-related, and that the notion of a platform that enables service delivery and innovation is not clearly explained, whilst this platform provides the essential foundation for the generation and delivery of services and subsequently the sought-after profitability, value and customer satisfaction.

2.6.4. Platforms and Platform Innovation

The platform as defined by Gawer (2009) consists of a system that is divided into core components that exhibit a low variety, and 'peripheral' components that exhibit a high variety. In the same publication, Gawer (2009) presents a new typology of platforms, distinguishing internal, supply chain, industry, and multi-sided platforms.

Internal platforms are in a sense 'the original platform' as they reflect the first business setting where the word 'platform' was widely used in the context of NPD (New Product Development). The platform in this case is within the firm, and represents products that satisfy a group of consumers, but are easily modifiable to introduce variety in order to answer other segment needs efficiently and at low cost. Examples are car manufacturers who use a common platform for different models of the same brand of car.

Supply chain platforms are shared by several firms in a supply chain and exist to increase productive efficiency along the supply chain and for the same variety and customisation cost reductions of internal platforms. Examples are car manufacturers who form an alliance to produce a single platform over multiple brands, thus further reducing production costs (as compared to internal platforms) due to shared investments.

Industry platforms exist as the basis of an industry ecosystem, where several firms participate who do not necessarily sell to each other, but where their individual products and/or services must function together as part of a joint offering. Industry platforms are often also the stage for open innovation initiatives involving multiple companies with complex trade-offs and constellations of open and closed innovation models and intellectual property arrangements.

Multi-sided platforms or markets are similar to industry platforms and concern several firms or groups of firms who are engaged in some form of transactions with each other. However, multi-sided platforms can also only be occupied with the facilitation of transactions, and do not consist of the common building blocks that are found in industry platforms. Gawer (2009) makes the distinction between both as follows: all industry platforms are involved in the facilitation of innovation, whilst not all multi-sided platforms are.

Meyer and DeTore (2001) discuss the importance of applying platform concepts to innovation, highlighting areas such as inventiveness in market segmentation, cognisance of the perceived and latent needs of current and new users, and creating subsystems and interfaces linking different services, products and product lines. Innovation processes will then use these subsystems and interfaces as operational platforms.

The platform innovation life cycle is typically slower because it involves hardware engineering, high investment costs and the need for a relatively stable service environment, whereas service innovation has a more dynamic nature (more responsive and with faster iterations) and can thus respond to emerging customer needs faster (Eisenmann et al. 2007).

2.7. Chapter Summary

This Chapter provided an overview of key literature relevant to this research. Several gaps for improving the State of the Art have been identified. Current innovation process models lack to a varying degree the following: (a) clear

integration of knowledge-based aspects, and (b) suitability for distributed teams consisting of actors with varying expertise collaborating in online environments. It has also been identified that there is a need for an ontology or semantic model that is geared towards innovation by covering in a suitable way all attributes that are relevant in an innovation context. Finally, there is a lack of clarity on the nature of and difference between product, service, and platform innovation, which inhibits the development of a unifying innovation framework.

'Are we meddling with things we don't understand, Ponder?'

Ponder looked up at the gnomic bulk of the machine. It didn't seem threatening, merely... *other*.

He thought: meddle first, understand later. You had to meddle a bit before you had anything to try to understand. And the thing was never, ever, to go back and hide in the Lavatory of Unreason. You have to try to get your mind around the Universe before you can give it a twist.

Terry Pratchett

Discworld 17 'Interesting Times'

3. Chapter 3: Research Methodology

3.1. Chapter Preface

Appendices pertaining to this chapter are:

- Appendix I: Hybrid Research Methodology

This chapter describes how the hybrid methodology for this thesis came to fruition, and explains the various components and planning of the methodological approach.

3.2. Introduction

Inevitably, this was to become a T-shaped[1] thesis. From the onset, I wanted to demonstrate that the principles resulting from this research would be applicable to every industry domain. Of course, constraints of reality and sanity do not allow one to explore and validate the artefacts in every domain in the world, but the need for a multi-domain approach became apparent. These domains became real estate CRM, scuba diving equipment, online travel, and ambient assisted living, which amongst them represent an array of product and service innovation; traditional and online business innovation; and B2B and B2C innovation. Early on, it was clear that I would need depth and breadth in order to achieve my results. Depth refers to the meaningful interaction with a domain, whilst delivering value to the actors in the domain. Breadth refers to the applicability of the research results, but also to the quality of the results themselves: in hindsight, I know now that I would not have reached my results had it not been for the broad variety of industry domains, reflecting a different 'nature of innovation' between them.

[1] As remarked by Jim Spohrer in a personal conversation at IBM Almaden Research Centre, San Jose, California, on 14 January 2013. T-shaped refers to boundary spanning competencies crossing many disciplines, systems and domains, with depth achieved in at least one domain and system. Visualisation available at http://www.ceri.msu.edu/wp-content/uploads/2010/07/TshapedProfImage.pdf

To a certain degree, the variety between domains takes on an almost eclectic nature when brought together in a single framework. Certainly, the relevance overlap between domains was not always there *on the level of the domain*. Even on the meta-level, the insights and connections between domains and disciplines sometimes only became apparent long after the work in a domain was done.

In any case, the need to (a) research and build 'something' that improves the reality at that time, and (b) transition between domains whilst eliciting useful, reusable artefacts from those domains, calls for a multifaceted methodological approach that is integrative, creative ('designerly'), reflective, and adaptive over time.

3.2.1. The case for a broad approach

Innovation takes place in inherently dynamic, social, and context-dependent environments. Collaborative innovation multiplies the number of (partially overlapping) contexts involved in the innovation process. This presents problems in terms of transposability, validity and replicability of results.

An absolute proof of the transposability (and corollary validity) of the resulting framework would be to transpose it to every domain and every situation of the world and measure its utility in each scenario. Reality constraints implore a more practical approach: to apply the framework and/or components thereof in as many domains and scenarios as possible. In the case of this thesis, I have limited the research to the four domains that have yielded demonstrable results from the application of the principles, techniques, and technologies of the framework: real estate CRM in Malaysia, scuba diving equipment manufacturing in Australia and the USA, online travel in Europe, and Ambient Assisted Living in Australia and Europe. The domains are described further in section 3.4.1.3 of this chapter, and in their respective domain chapters 4A-4D.

Replicability is a bit harder to capture because of endogenous and exogenous factors.

Endogenously, the framework itself has evolved over time, and initial assumptions about how it would generally work were disproven in practice. In a strict sense, one could state that the initial conceptualisations of the framework (Meersman 2007, and Meersman and Dillon 2009) have already been disproven by the later iterations. For clarity's sake, any claims regarding replicability and generality pertain only to the final version of the framework presented in this thesis.

Exogenously, the actors, objects, processes, and non-documented elements in an inherently social innovation process change over time. Therefore it becomes very difficult – if not impossible – to replicate the *exact* circumstances under which a certain innovation took place. In recognition of this reality, business research has since long proposed alternative research methodologies such as action research, soft systems, design science, and case studies to document realities that might prove useful irrespective of the possible need to tailor them to a different future reality. Still then, 'survivor bias' skews business literature since describing failed projects is generally not found – or is not – interesting for publication (Cohen 2009). For example, this thesis does not describe a two-year effort with one of Australia's largest telecommunications providers in which a lot of participatory action research was performed, but where the design stage was never reached because of external circumstances.

I wanted to go beyond case descriptions and implementations of known artefacts, and rather design and implement artefacts whilst studying their interactions with *different* industry domains. This multi-domain approach has repercussions on the depth of research, or more specifically, on the evaluation of the approach and execution (on the level of the domain). Only the artefacts that are transposable and reusable have been evaluated because to do otherwise would have left 'dead ends' that do not contribute to the central thesis. To put it with a metaphor: instead of using different (existing) glasses to look at the same landscape and learn about that landscape, I have used the same (yet evolving) pair of glasses to look at different landscapes in an effort to continuously improve the glasses themselves.

3.2.2. The case for a deep approach

Because innovation is different from domain to domain, the level of abstraction that applies to all domains, witnessed for example in innovation process models, contributes mainly to explaining how things work on a general level, and to structuring the efforts of actors and processes around the known stages of innovation. Part of the motivation behind undertaking this thesis was a frustration with this generality. Many innovation approaches and models lack *intricacy*: what must one do then, in a real-world setting, to successfully innovate? It seems that for every rule, there were many more exceptions. When knowledge is discussed, it is generally presented largely as a given, without sufficient consideration for the short but dense space between the atomic (in a sense, semiotic) level of knowledge and the subsequent decisions that needed to be made to progress the innovation process.

What I intended to do with the research methodology, was to delve into the details of each domain and participate in their respective innovation processes. In particular, the focus is on *knowledge-based* aspects of innovation and surfacing these from the ground level of the domains to a more general level. This would result in a knowledge-based, collaborative innovation framework with more detail than generic process models in terms of the type, form, and timing of knowledge vis-à-vis the innovation process and its actors.

The design science research approach employed for work within a domain is described in section 3.4.2 of this chapter. It follows the usual project stages from problem to solution.

3.2.3. Limitations of the subject

The first reflex I had when thinking about evaluation was to evaluate the artefacts by measuring the success of the innovations I was to help produce. But there are several issues and limitations with this approach. Firstly, bringing innovations to market to the point where they can be measured for success *exceeds the duration* of a PhD project if you take (a) the duration of the

design stages of the artefacts (which precede the actual innovation process) and (b) the objective of tackling multiple domains into account. Secondly, in case of success or failure, it is very difficult to reliably measure what part of the success or failure is attributable to the artefacts introduced by my research *in relation to other employed artefacts*. Finally, there are many *external variables* that define whether a product or service will be a success. Literature is rife with cases of successful innovations that are basically improved or posterior copies of less successful earlier versions, often made by a different entity. Therefore innovation success is not a reliable measure for the individual utility, value, and applicability of the embedded individual artefacts and their overarching framework resulting from this thesis, or any thesis for that matter.

3.3. Background of Employed Research Methodologies

3.3.1. Design Science Research

Pfeffers et al. (2008) describe Design Science Research (DSR) as a methodology for information systems (IS) research that produces "explicitly applicable research solutions", in juxtaposition with theretofore largely descriptive research methodologies (but also recognising the older roots of design science in IS). Venable (2006) succinctly states that DSR is "research in which a new or improved solution technology is invented", where solution technologies can be systems, methods, procedures, practices, or other technologies. DSR emphasises the duality between knowledge and practice: one aims to answer scientific knowledge questions by designing 'things' that solve a practical problem (Hevner et al., 2004).

Venable (2006) describes 4 reciprocal activities in DSR: problem diagnosis, technology invention/design, technology evaluation, and theory building (Fig. 3.1).

The **Problem Diagnosis** activity concerns the analysis of a problem, understanding the problem space, what cause the problem and what the consequences of said problem are.

The **Technology Invention/Design** activity concerns the creation/design of artefacts that are expected to solve the problem, that offer an improvement towards solving the problem, or that offer an improvement in utility or performance with regards to existing technologies. Technologies can be methods, products, services, systems, practices, techniques, or other technologies.

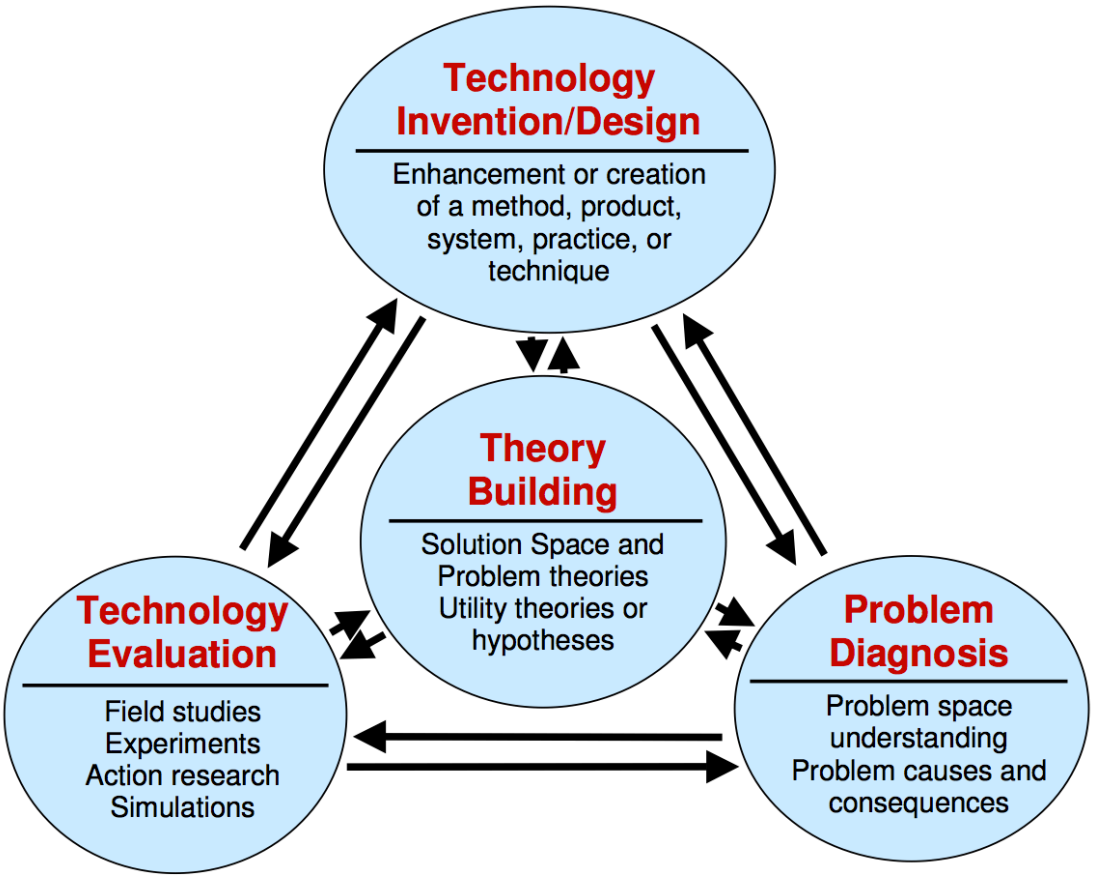

Fig. 3.1: An Activity Framework for DSR. Reprinted from Venable (2006)

The **Theory Building** activity is concerned with defining the solution space on a general level, but also infusing the problem diagnosis activity with *problem theories* about what the nature of the problem is, and offering input to the Technology Invention/Design activity in terms of *utility theories* ('what could work well to solve this problem?').

The **Technology Evaluation** activity as it is described here falls somewhat short and this has been recognised by Venable in workshops given at ACIS 2012 and Curtin University. In principle *any* evaluation method that can measure some dimension of the artefact and how it is used is valid. In a later version of the diagram in Fig. 3.1, the "Field Studies / Experiments / Action research / Simulations" has been replaced with "Artificial Evaluation / Naturalistic Evaluation" which refers to Venable et al. (2012), discussed further below.

Furthermore, I am not convinced that relegating full-fledged research methodologies such as field studies, action research, focus groups, etc. to an activity that is part of DSR provides a proper representation of the interrelation between the prescriptive DSR and the mostly descriptive aforementioned methodologies. It could be a matter of perspective, but I would posit that the inquisitive nature of research takes precedence over the creative or designerly aspect of research. One steps into an environment to learn about that environment *out of curiosity*. One creates solutions to improve that environment and to study the interactions of that environment with the artefacts in terms of the utility, value, performance, etc. of the artefacts *only when necessary, useful, or desirable*. This could translate to the observation that the space of the former will always be larger than that of the latter. In multi-disciplinary, multi-domain, T-shaped research, the leg of the T hangs (or should hang) from the arm, rather than the other way around, because the leg is driven only by necessity, utility, and/or desirability.

Granted, Venable's diagram (Fig. 3.1) does represent the interrelation between the methodologies comprised under evaluation and the other design science activities. Because of these bidirectional arrows, one could interpret the 'technology evaluation' activity as a guiding activity for the other activities, but its nomenclature and of course the fact that it is situated *within* a DSR activity framework suggest an alternate preferred reading by the author.

DSR itself *is* concerned with the arm of the T through theory building and reflection. Comprehensive frameworks that capture the role of theory and design theory in DSR are provided in e.g. Nunamaker et al. (1991), Walls et al.

(2002), and Venable (2006). March and Smith (1995) do not consider theory to be a part of DSR, but relegate that aspect to the realm of 'natural sciences' – which Venable (2006) presumes to include social and behavioural sciences.

One of the limitations of Design Science is that there is currently no clear methodological path between domains. Apart from the inclusion of theory building and evaluation stages in most frameworks, there does not seem to be a suitable DSR model for the interaction of theory with problem analysis, solution design, and evaluation *between and across domains*. Cycles generally refer back inwards, or lead to a dead end outside of the model.

3.3.2. Action Research

Action research (AR) is a methodology that aims to combine theory with practice by the intervention of the researcher to improve a given situation (Susman 1983, Babugorlu and Ravn 1992), Baskerville and Wood-Harper 1998). Its origins can be traced back as far as the 1940s (Collier 1945, Lewin 1946, Lewin 1948).

Baskerville (1998) formulated 5 main stages in the AR process cycle for information systems: diagnosing, action planning, action taking, evaluating, and specifying learning (Fig. 3.2).

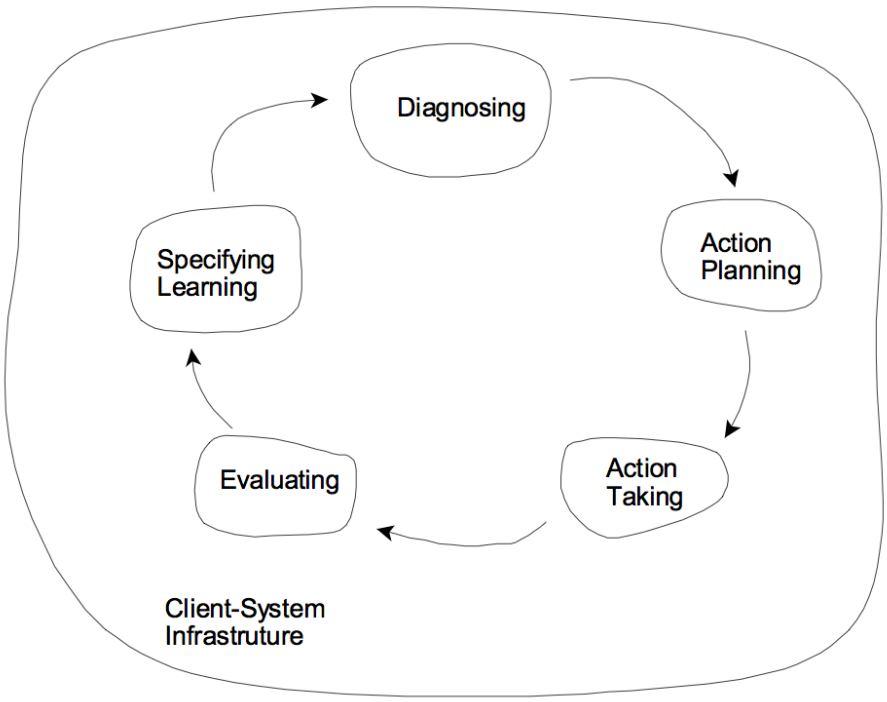

Fig. 3.2: The Action Research Cycle. Reprinted from Baskerville (2008)

1. Diagnosing corresponds to Venable's (2006) DSR stage of problem identification, where the problem is analysed and conceptualised not through simplification but in a holistic manner.

2. Action Planning is defined by Baskerville as the collaborative specification of organisational activities to be undertaken. This would correspond to solution requirements and project planning stages in a DSR process.

3. Action Taking refers to the actual collaborative activity undertaken by the participants. This corresponds to the design/building/execution stages of the DSR process.

4. Evaluating corresponds to the DSR stage of evaluation, and informs the cyclical process.

5. Specifying Learning concerns the channelling of the gained knowledge into three channels: to the organisation via 'double-loop learning' (Argyris and Schön 1978); in case of unsuccessful change, to practitioners and AR

researchers as a basis for diagnosis for future projects; and to the scientific community in the form of scientific publications and formalised knowledge.

Out of the above, we see that Baskerville's AR Cycle has a lot in common with DSR. The key differences are, firstly, that DSR more clearly works the IT artefact at its heart, whilst AR is broader in specifying 'action' as something that can take many forms. Secondly, DSR is dependent on other research methods for the evaluation of its artefacts, whilst AR is stand-alone. What further emerges here is the aforementioned image of DSR as the technical leg, and AR as the social arm of the T-shaped research project.

The application of AR specifically to innovation processes in organisations has been discussed by Kaplan (1998) under the moniker of Innovation Action Research (IAR). IAR follows an only somewhat similar approach to DSR with the main cycle stages being: (1) *Observing and Documenting Practice*, where shortcomings in current practice are observed and documented, providing cases for; (2) *Teaching and Speaking* about the Innovation, where social settings for feedback and learning by the AR researchers are created, and a further codification and generalisation takes place, leading to; (3) *Writing Articles and Books*, in order to generate excitement for the innovations, which leads to invitations to; (4) *Implement the Concept in a New Organisation* as an advanced, intermediate, initial, or base case implementation. This then again leads to observations, completing the cycle.

Whilst Kaplan's IAR is an interesting conceptualisation, it reads more like a retrospective of performed AR research than as a replicable method because of inherent and external constraints, such as for example time (it takes a long time to complete the process, making it less suitable for fast-paced innovation domains) and reputation (the assumption that publications will lead to invitations depends in part on the stature of the researcher).

A method that comes close to but falls short of the approach I have followed, is the Action Design Research (ADR) method (Sein et al. 2011). In this method, that consists four stages comprising seven principles, a blending of AR and DSR is proposed.

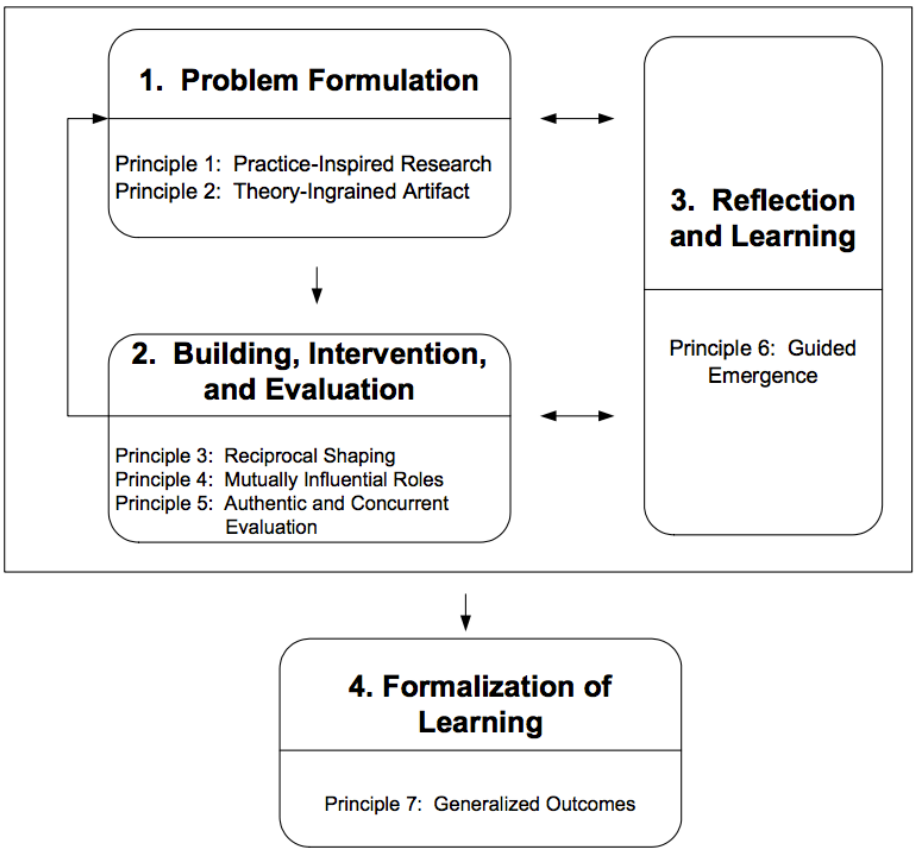

Fig. 3.3: ADR Method: Stages and principles. Reprinted from Sein et al. (2011)

Stage 1 – Problem Formulation is 'triggered' by a "problem perceived in practice or anticipated by researchers" (Sein et al. 2011). The authors quite loosely describe various inputs for the *initial* problem formulation, none of which are represented in their overview diagram in Fig. 3.3. Principle 1 – *Practice-Inspired Research* emphasises the approach to practical problems as knowledge-creating opportunities. Principle 2 – *Theory-Ingrained Artefact* states that the artefacts that are (to be) created are "informed by theories" (Sein et al. 2011), namely problem structuration, solution identification, and design guiding theories.

Stage 2 – Building, Intervention, and Evaluation employs the premises of Stage 1 to design and develop the artefact. This stage is described as an iterative BIE process combining *building* (B) the artefact, *intervention* (I) in the organisation, and *evaluation* (E) of the artefact. The intervention sub-process is one of the elements that set ADR apart from DSR. Principle 3 – *Reciprocal*

Shaping concerns the interaction between artefact and organisation and how they mutually shape each other. Principle 4 – *Mutually Influential Roles* concerns mutual learning between the project participants, with AR researchers bringing structure, technology and theory to the table, whilst practitioners bring hypotheses from practice and organisational knowledge to the table. Principle 5 – *Authentic and Concurrent Evaluation* refers to evaluation as a process that is embedded *within* the building sub-process, which sets it apart from traditional DSR approaches.

Stage 3 – Reflection and Learning concerns the bridge between the instance levels of any built solution and the broader class of problems it could apply to. It also involves the input for adjustment of the research process based on intermediate evaluations. Principle 6 – *Guided Emergence* refers the "interplay between two seemingly conflicting perspectives" (Sein et al. 2011), being the preliminary design of the artefacts and the way it evolves in an organisation due to a variety of factors.

Stage 4 – Formalisation of Learning concerns the stage where knowledge and learning are further developed in to general, applicable knowledge for a range of certain problems. Principle 7 – *Generalised Outcomes* refers to a generalisation process on three levels: (1) problems and (2) solutions are essentially brought from an instance to on ontological level, and (3) design principles (or rules) are derived from the research outcomes.

Interesting to note is that Stage 4 is a 'dead end' in the model: it has one arrow leading to it but does not offer any input to the ADR process. This can mean one of two or both things: (a) Stage 4 constitutes the finality and (hence) purpose of ADR. (b) The model does not cater for Stage 4 offering input to the process because the model is incomplete.

One can ask oneself: "In what scenario is formalised knowledge applicable to an ADR process, knowing that initial input knowledge, intrinsic knowledge, and emanating knowledge are contained within stages 1, 2, and 3?" The answer is a different class of problems with a partial overlap either in the nature of the problems or the utility of the projected solution. This points in

the direction of the observation that ADR is not particularly suited – in its current form – for multi-, inter-, and trans-domain research.

3.4. Hybrid Research Methodology

A hybrid methodology of action research (AR) and design science research (DSR) was used for this project. The AR acts as a guiding framework for selecting and interacting with the industry domains. The DSR approach is employed to collaboratively build information systems that practically solve innovation problems in participating business domains. Fig. 3.4 provides an overview of the hybrid methodology for the four domains of this research. The first stage relates to the current state of the art, where the thematic scope for the action research is defined. The action research project is designed and an industry domain is entered where a system is built. Following the DSR cycle, the innovation framework is advanced, and theories are formulated for the next domain cycle, and so on. A description of the three main components of the hybrid research methodology follows.

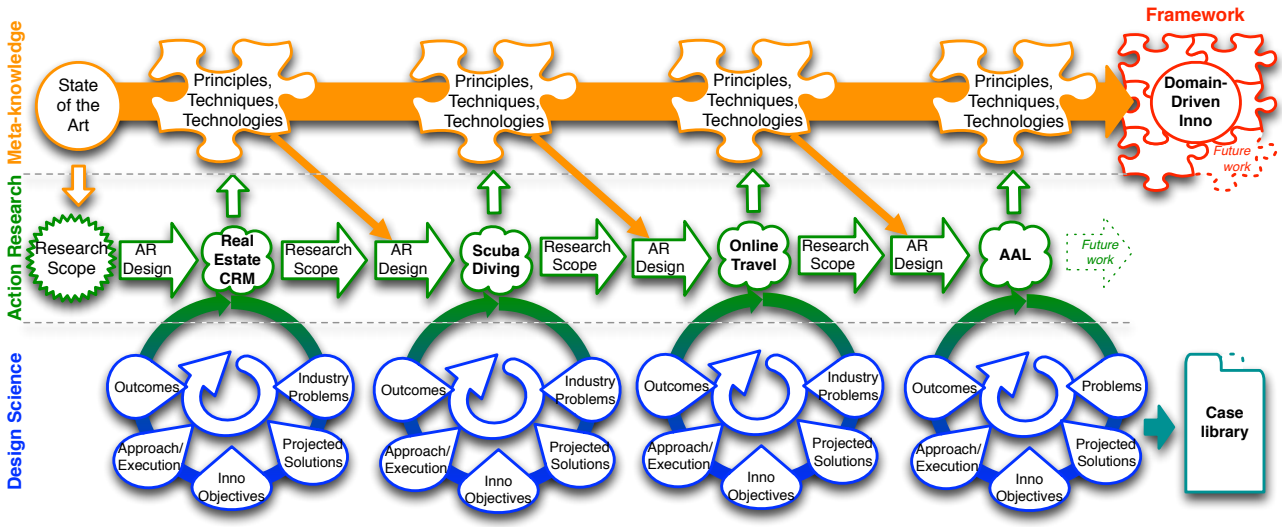

Fig. 3.4 Hybrid Research Methodology (larger version in appendices)

3.4.1. Action Research

Participatory action research was used as a way to structure collaboration with industry partners, and to shape the research agenda going forward. It was also used as a form of mediation between the ivory tower of concept and theory building, and the groundwork undertaken in the design cycles. Meta-level concepts are applied during the design process, using the meta-level as an interpretative framework for the design outcomes. As a result the domain driven innovation framework that sits on top of the meta-level is continuously evolving.

3.4.1.1. Research Scope

The research scoping stage embodies the delineation of the issues to be studied in the industry domain. The scoping stage allowed me to specify aspects that I wanted to research whilst acting as a participatory action researcher in industry domains. The result is that unexplored research questions regarding the meta-level framework could be researched whilst participating in the industry projects. Although Fig. 3.4 presents the hybrid methodology in a linear fashion, it should be understood that projects were to a certain extent undertaken concurrently (see timeline in Table 3.1), and that the research scoping was a dynamic process. Inputs for the thematic scoping stage were literature review and outcomes of previous engineering cycles (in terms of what they meant for the meta-level).

3.4.1.2. AR Design

Based on the aspects defined in the research scope and the practical availability of willing industry domain partners, a design for the action research project was devised. The design stage incorporates decisions on data collection methods, partner roles and responsibilities, envisaged outcomes and objectives, general outlines of the DSR projects, and decision points on the innovation principles, techniques and technologies.

3.4.1.3. Industry Domains

In this section a brief background is provided of the 4 industry domains that were involved in the research scope of this thesis. Additional domain descriptions can be consulted in the respective domain chapters 4A-4D. The following paragraphs should be considered as an introduction to the domains, including clarifications on the industry partners and data collection processes.

Real Estate CRM

In the real estate CRM domain, a collaboration took place with a Malaysian CRM service provider that was at that time primarily active in the real estate and insurance industries in Kuala Lumpur. The company had recently migrated to a cloud-based solution for their CRM system, and were looking for ways to innovate their business model, including adding business intelligence capabilities and the capacity to easily migrate legacy CRM systems of their clients to their cloud service. In this project the collaborators other than myself were a manager and a systems engineer from the industry partner. The data collection for this project comprised of the data structure and instances of the CRM system, the product manual, and interviews with the CRM service provider via email and in person in Perth and Kuala Lumpur.

Scuba Diving Equipment

The scuba diving equipment manufacturing domain project was initiated by myself by approaching key industry partners. I mainly collaborated with a technical diving centre in Perth, Australia. Perth has a sizeable diving industry because of the climate and beautiful underwater surroundings. However, there are no equipment manufacturers in Perth, only diving training and tourist centres, equipment resellers, and equipment repairers. The data collection process for this project comprised of a video interview with a technical diving expert, hands-on technical diving certification courses and expeditions, various product and training manuals, online message

exchanges with a US-based technical diving equipment manufacturer, and online conversations on the world's largest scuba diving forum.

Online Travel

The online travel domain represents the largest research project in terms of committed resources. I was able secure sizeable government funding of 500.000 euros for this project in collaboration with a Belgian group buying company and Belgian research group. The project aimed to build a platform for Requests For Proposals initiated by communities of users for online products and services. The platform doubles as a system for bottom-up innovation via the integration of user feedback. I was not completely free to define the entire project design as I was working according to industry partner requirements. This is for example reflected in the domain ontology, which was part of the work of a Belgian research group, and has a different structure and approach than the models in other domains. The data collection process consisted of examining existing systems and industry standards, building the platform, and then running a pilot in the online travel domain. For this pilot, the consortium collaborated with the largest winter sports community of the Netherlands, wintersporters.nl. Data was collected from consumers participating in the pilot platform, and they also had the opportunity to comment on the experience in a designated forum (which in the end totalled about 100 posts).

Ambient Assisted Living

The ambient assisted living domain represents exploratory research in platform and service innovation in sensor-driven healthcare. This was done as part of a broader product innovation effort our research institute was preparing with a large Australian telecommunications provider who was looking to develop and market a smart home platform and a range of wireless sensors in the energy, security and healthcare domains. The project falls into two main streams, product innovation and service innovation, which – as I will go on to discuss in the analysis chapter – are different yet not as separate as one might think. Partners in this project were the telecommunications

provider, a service value network research group from the Netherlands, a European ambient assisted living service provider, the Curtin Health Innovation Research Institute, the Curtin School of Pharmacy, and the Curtin Department of Computing. Data collection for this project was quite multi-faceted, ranging from meetings with the telecom company, smart home product data sheets, AAL personas provided by the European partner, National Health and Medical Research medical practice guidelines, Medicare Benefits Schedule listings, to expert interviews for validation.

3.4.1.4. Timeline

Table 3.1: Project Timeline

Year	'09			'10				'11				'12			
Quarter	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
CRM															
Scuba															
Travel															
Health															

This timeline is provided mainly to aid understanding of the evolution of the work by giving a chronological overview of the projects and their overlaps. Although the domains are described consecutively in this thesis, their partial concurrency means insights from one domain unavoidably influence progress in another. It is hoped this clarification will help reduce potential preconceptions by the reader of the degree of domain disparity as we go through the domain chapters and into the analysis.

The travel domain project kicked off in May 2009 and ended in May 2011. The real estate CRM domain ran from July 2009 until December 2009, with some additional research, evaluation, and a publication from September until November 2012. The scuba diving equipment domain started in March 2010 and concluded after a presentation of results in November 2010. The ambient assisted living domain was initiated when my research institute was approached by the industry partner in May 2011, with the bulk of the

domain-specific work commencing in November 2011 and continuing into present time and the future.

3.4.2. Design Science Research

The activities of the DSR projects on the domain level align with Venable's DSR Activity Framework, but are spread along the lines of a project process with following stages:

3.4.2.1. Industry Problems

Through an iterative and collaborative process, industry problems that are within the scope of competency of the industry partners are detected and articulated.

DSR activities:

- Problem diagnosis: problem space understanding, problem causes and consequences
- Theory building: problem theories

3.4.2.2. Projected Solutions

These problems are then paired to projected solutions, or ideal scenarios that solve or contribute to the solution of the problems.

DSR activities:

- Theory building: solution space, utility theories

3.4.2.3. Innovation Objectives

In this stage the projected solutions are broken down in terms of what is needed from a technological and business standpoint. This is crystallised further into tangible innovation objectives.

DSR activities:

- Theory building: utility theories
- Technology invention/design: technology selection/design

3.4.2.4. Approach and Execution

After the innovation objectives are clear, a plan of approach is devised and executed.

DSR activities:

- Technology invention/design: solution creation
- Technology evaluation: cyclical, intermediate evaluation

3.4.2.5. Outcomes

In the final stage, the artefacts are evaluated and results are analysed. Significance of problems/solutions for meta-level framework is assessed.

DSR activities:

- Technology evaluation: software testing, system testing, user testing, requirements alignment analysis (ex ante, ex post, naturalistic, artificial)

3.4.3. Meta-Knowledge

3.4.3.1. Theory and innovation framework

One of the key elements in this thesis, and ultimately also one of the key outcomes, is the modular innovation framework of which the evolving increments served as an overarching, guiding theoretical anchor, ultimately leading to the final state named the 'domain-driven innovation framework' that is being presented in the synthesis chapter of this manuscript. The incremental and dynamic nature of the framework translates to the fact that the theoretical framework and the applied components were different in every industry domain project, although careful consideration was made to ensure every final component was validated in some way by the entirety of the domains.

3.4.3.2. Innovation Process Model

The innovation process model that has been created in this research is a practical blend of the innovation process models discussed in the state of the art, as well the TRIZ principles of segmentation and merging (see below). The innovation process model is not to be confused with the DSR stages, although there is some congruency. The innovation process model serves as both a guiding and interpretative framework that serves as a vehicle for connecting domain-specific knowledge across domains. In a sense it is an ontology that serves as the backbone for the domain-driven innovation framework. It is also an artefact that is evaluated on a supra-domain level. The description of the process model will take place mainly in the domain chapters (as part of an instantiation) and the synthesis chapter (as part of the resulting framework). Nevertheless a succinct overview is presented here for clarity purposes.

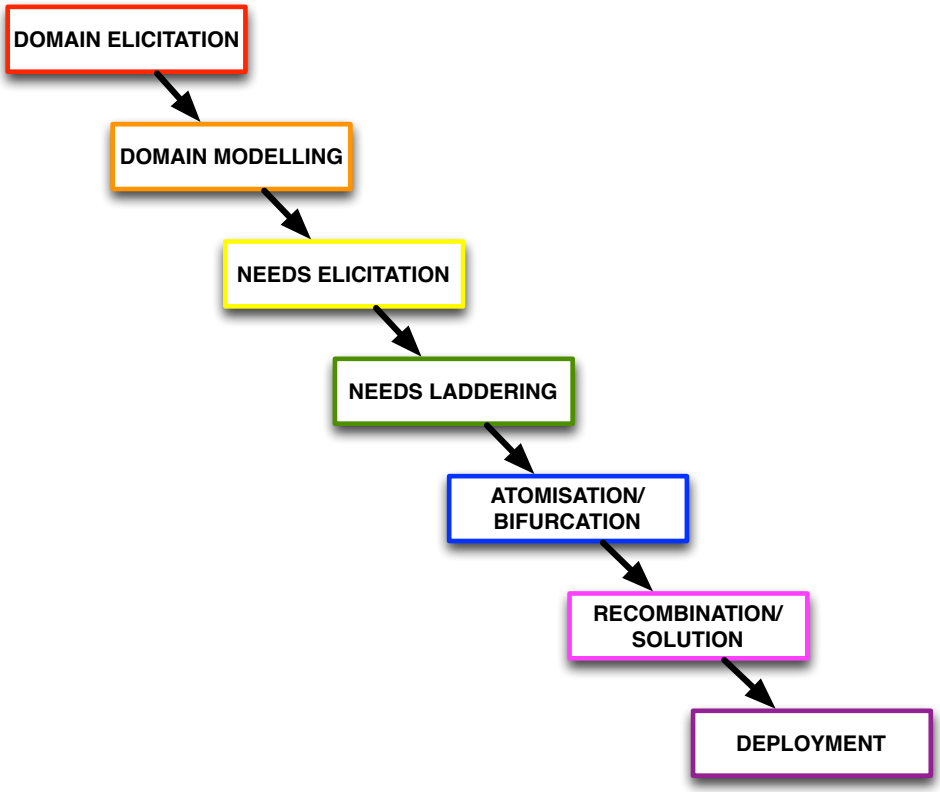

Fig. 3.5: Innovation Process Model.

Domain Elicitation:

The initial step is the analysis of different industry source documents such as reports, design documents, manuals, personas, interviews, etc. Based on the initial analysis, a preliminary model of what we think the domain model might look like is developed.

Domain Modelling:

In this stage the domain is hierarchically structured and various relations between all domain concepts are added, further refined and validated with the help of domain experts. This results in a large 'lexon base' that contains all concepts and relations of the domain. The DOGMA methodology (Developing Ontology-Grounded Methods and Applications) (Jarrar and Meersman 2009) is used for the domain modelling process. DOGMA stands out for its grounding in linguistics and near-natural language fact types. DOGMA knowledge building blocks are expressed in natural language, and because of this, are relatively easily obtained and agreed upon (as inspired by database modelling methodologies such as NIAM (Wintraecken 1990) and ORM (Halpin 2008)). As a result, domain experts and knowledge engineers can use natural language to communicate and capture knowledge. These building blocks - called lexons (Jarrar and Meersman 2009) - only need in principle to express "plausible" facts (as perceived by the community of stakeholders) in order to be entered into the Lexon Base, a repository containing large sets of such lexons. A lexon is formally described as a 5-tuple $\langle \gamma$, head term, role, co-role, tail term), where γ is an abstract context identifier. The context identifier is assumed to unambiguously identify the concepts denoted by the term and role labels.

Needs Elicitation:

In this stage needs in the domain are elicited based on the domain model and user data in the form of usage data, market research, CRM data, etc. These take the shape of 'actionable patterns', or areas of interest for innovation.

Needs Laddering:

In this stage laddering techniques are used to link specific product properties to high-level values, resulting in 'functional consequences'. In essence this process translates customer needs to the language of the competence domain of the producer or provider.

Atomisation/Bifurcation:

At this point properties and functions related to concepts of interest in the domain are extracted. Possible interesting combinations are evaluated collaboratively by actors in the domain. This stage follows the principle of Segmentation (Altschuller 2000), where an object is divided into independent parts, or where the degree of fragmentation or segmentation is increased.

Recombination/Solution:

Successful candidate patterns are recombined into a new entity. This stage follows the TRIZ principle of Merging (Altshuller 2000), where identical or similar parts are brought closer together, merged, or synchronised, i.e. making whole again in a different configuration that what has been segmented in the previous stage.

Deployment:

A single candidate entity or selection of candidate entities is deployed and the performance of the innovation is monitored and measured. The monitoring data can serve as further input for the definition of actionable patterns.

3.5. Notes on Evaluation

Apart from cross-fertilisation between domains, the multi-domain approach applied in this thesis really shines in the evaluation and analysis stages. It allows for a multi-level evaluation: one on the level of the domain, and one on the supra-domain level. In a domain, artefacts created and/or applied in that domain are evaluated. On the supra-level, the innovation process model is evaluated in terms of its utility in interaction with the artefacts from that

domain. This way, a pattern of utility is enabled to emerge on a general level, which contributes (or should contribute) to the applicability of the final framework.

The evaluation method is chosen through the application of the DSR Evaluation Strategy (Fig. 3.6) and Method (Fig. 3.7) Selection Framework (Venable 2006). This translates to the following domain-level evaluation method categorisation for the domain artefacts:

- Real Estate CRM domain: Ex Ante Naturalistic
- Scuba Diving Equipment domain: Ex Post Naturalistic
- Online Travel domain: Ex Post Naturalistic
- Ambient Assisted Living Domain: Ex Post Artificial

For the supra-level process model evaluation, all evaluation is Ex Post Naturalistic as projects were real-world, multi-stakeholder projects.

DSR Evaluation Strategy Selection Framework		Ex Ante	Ex Post
		•Formative •Lower build cost •Faster •Evaluate design, partial prototype, or full prototype •Less risk to participants (during evaluation) •Higher risk of false positive	•Summative •Higher build cost •Slower •Evaluate instantiation •Higher risk to participants (during evaluation) •Lower risk of false positive
Naturalistic	•Many diverse stakeholders •Substantial conflict •Socio-technical artifacts •Higher cost •Longer time - slower •Organizational access needed •Artifact effectiveness evaluation •Desired Rigor: "Proof of the Pudding" •Higher risk to participants •Lower risk of false positive – safety critical systems	•Real users, real problem, and somewhat unreal system •Low-medium cost •Medium speed •Low risk to participants •Higher risk of false positive	•Real users, real problem, and real system •Highest Cost •Highest risk to participants •Best evaluation of effectiveness •Identification of side effects •Lowest risk of false positive – safety critical systems
Artificial	•Few similar stakeholders •Little or no conflict •Purely technical artifacts •Lower cost •Less time - faster •Desired Rigor: Control of Variables •Artifact efficacy evaluation •Less risk during evaluation •Higher risk of false positive	•Unreal Users, Problem, and/or System •Lowest Cost •Fastest •Lowest risk to participants •Highest risk of false positive re. effectiveness	•Real system, unreal problem and possibly unreal users •Medium-high cost •Medium speed •Low-medium risk to participants

Fig. 3.6: DSR Evaluation Strategy Selection Framework. Reprinted form Venable et al. (2012)

DSR Evaluation Method Selection Framework	Ex Ante	Ex Post
Naturalistic	•Action Research •Focus Group	•Action Research •Case Study •Focus Group •Participant Observation •Ethnography •Phenomenology •Survey (qualitative or quantitative)
Artificial	•Mathematical or Logical Proof •Criteria-Based Evaluation •Lab Experiment •Computer Simulation	•Mathematical or Logical Proof •Lab Experiment •Role Playing Simulation •Computer Simulation •Field Experiment

Fig. 3.7: DSR Evaluation Method Selection Framework. Reprinted form Venable et al. (2012)

3.1. Chapter Summary

This Chapter has provided an overview of and motivation for the methodological choices underlying the research design. Section 3.2 provided a scoping of the research and how this translates to methodology, design, and evaluation. Section 3.3 provided an introductory background to the employed research methodologies in the context of the hybrid research methodology (Section 3.4), which further detailed the research design on the different levels of the methodology. Finally, notes on evaluation were provided in Section 3.5.

"That's all the motorcycle is, a system of concepts worked out in steel. There's no part in it, no shape in it, that is not out of someone's mind."

Robert M. Pirsig

Zen and the Art of Motorcycle Maintenance

4. Chapter 4A: Real Estate CRM Domain

4.1. Chapter Preface

This Chapter is based on the following publication:

- Meersman, D. (2012). Domain Bifurcation as a Customisation and Business Intelligence Strategy in Domain-Driven Innovation. *IADIS, IST Proceedings*, 11-18.

Appendices pertaining to this chapter are:

- Appendix II: CRM Domain Model
- Appendix III: Real Estate Domain Model

This domain relates to a Malaysian CRM service provider that had faced problems with expanding into new domains. Because of the high cost associated with CRM customisation, a large investment had to be made whenever a client from a hitherto unserviced domain would be added to their portfolio. In several sessions in Australia and Malaysia over the course of three months, the problems were articulated further and paired with possible technological solutions. The project was divided into two smaller projects: ontologies and data mining. The ontology project was carried by the company itself, whilst the data mining project found funding through the Malaysian Brain Gain Fund. This chapter concerns the ontology project.

4.2. Introduction

At the core of information systems is the representation of a reality that is agreed upon by the stakeholders of that system (Shanks 1999). In the case of a Customer Relationship Management (CRM) system, the reality of customer interactions in an industry domain is represented in the data structures, instance data, and functionalities of the system. When examined closely, one can discern two distinct domains in a CRM system: the customer relationship management objects, processes, and actors; and the objects, processes, and

actors of the industry domain in which the CRM system is used. This disparity between domains helps explain the sizeable customisation costs associated with any deployment of a CRM system, as CRM systems will look very different between domains notwithstanding shared functionality. The cost of customisation ranges from a ratio of 4:1 (4 dollars for every dollar spent on purchase costs) in traditional, on-site CRM systems, to 1:1 (1 dollar for every dollar spent on purchase costs) in cloud-based, software-as-a-service (SAAS) systems (Dickie 2000). Whilst SAAS has reduced the cost of entry into new domains by CRM service providers, the associated customisation costs offer continuous challenges.

Another challenge posed by the domain disparity in CRM is on the level of business intelligence. When mining and analysing the aggregated data contained in the system for opportunities for innovation and improvement, the domains' intertwined data and processes potentially obfuscate emerging patterns. Patterns arising from the data mining process might be relevant to CRM service actors, but irrelevant to industry domain actors, and vice versa.

In this chapter, a bifurcation approach using semantic technology to separate CRM knowledge from industry domain knowledge in a CRM system deployed in the Malaysian real estate industry is introduced. The method, process and rationale for constructing the two separate domain models is discussed and the models are analysed using examples. Finally, the usefulness and implications of the approach for CRM customisation and business intelligence are discussed, followed by and innovation process analysis and future directions for the research.

4.3. Background

The context of this research was a Malaysian CRM service provider that was facing a number of problems in expanding into new domains, and in providing added value to its clients. Because of the high cost associated with CRM customisation and migrating from legacy on-site systems to a cloud-based solution, a sizeable investment had to be made whenever a client from a previously unserviced domain would be added to the portfolio. The

company was at that point predominantly active in the real estate services domain managing large assets in the Kuala Lumpur administrative and financial districts, but was increasingly entering the insurance domain. A major issue was that every new client, even within the same domain, would need customisations and migrations of legacy on-site systems to a cloud-based solution. This calls for an approach that allows for interoperability and integration of disparate databases and information systems.

Another issue is that the company was having problems optimising the system and was looking for a business intelligence solution to mine for patterns that could indicate 'areas of interest' for improvement. Envisaged improvements ranged from churn detection and process optimisation to HR performance monitoring and anomaly detection. Some of the anticipated improvements would pertain to the CRM provider, but some would pertain to their clients, creating the opportunity for an added-value service. For example, if a certain operator consistently takes much longer than others to solve a problem, it might indicate a problem in staffing; if problems with the same property section of a real estate asset consistently reoccur, this might indicate problem with the building itself. CRM functionalities are quite generic, but will often be named differently depending on the system and domain of application, and their active usage by users will vary depending on the requirements of the reality of the application domain. This translates to similar functionalities with varying nomenclature and varying usage levels across domains.

Based on these background factors, and several sessions in Australia and Malaysia with the industry partner over the course of three months, the problems were further articulated and paired with possible solutions. With the solutions clear, a compartmentalisation process would take place where the solutions are translated in technological building blocks with a development schedule.

A two-fold solution for the array of problems faced by the company was formulated. First, a bifurcation method to build two separate domain models would be used: one generic CRM domain model, and one industry domain

model. Next, these models could be used for migrating legacy systems to a cloud-based environment; for interoperation and integration of disparate systems; and for driving the business intelligence process for both the CRM service provider and its client base. The focus here is specifically on the bifurcation process of the domain models.

4.3.1. Innovation Objectives

The following objectives were worked out with the partner company:

1. To develop the CRM system so that it can be implemented in any domain with minimal customization. *This objective shall be achieved by implementing a generic CRM domain model and a domain model for various verticals. By combining the CRM domain model and real estate domain model to create a real estate CRM domain model, an adaptive overarching domain model that can be applied to other verticals is created.*

2. To develop an advanced tool that can be marketed overseas as well as provide end user benefits to users within Malaysia. *The system will be considered an advanced tool with the addition of semantic intelligence and data mining technology. The product will be deployed on the global market by implementing the application as a Software-as-a-Service (SaaS) model using grid computing technology.*

4.4. Approach

Three stages were defined for reaching the objectives. The *domain elicitation* stage concerns the process of extracting knowledge from industry sources, in this case the real estate CRM system, the product manual for the system, and initial expert interviews. In the *domain modelling* stage, the extracted domain knowledge is modelled according to a set methodology. In the *bifurcation* stage, the domain model is split up into two distinct domain models. These stages will now be explored in greater detail.

4.4.1. Domain Elicitation

The initial step concerns gathering the prerequisite information and holding expert interviews to validate assumptions, clarify terminology, and fill in any gaps. In this case information gathering consisted of a data dump for quick analysis and remote access to the CRM system for further inspection. Software manuals were also provided, but were used only sporadically when needed. Based on the initial data analysis, a rudimentary hierarchical classification of the concepts of the system was made using FreeMind mind mapping software. This was further discussed with 2 experts from the company (a manager and an engineer), after which further concepts were added.

4.4.2. Domain Modelling

The DOGMA methodology (Developing Ontology-Grounded Methods and Applications) (Jarrar and Meersman 2009) was adopted for the ontology engineering process. For structuring the domain knowledge, the OPAQ principle was implemented. The OPAQ principle allows an ontology engineer and/or core domain expert to model any domain into mutually exclusive and collective exhaustive classes. This principle has been previously successfully applied in the car industry domain (De Leenheer et al. 2010), the scuba diving equipment industry (Meersman and Dillon 2010), the higher education industry (Acknowledge 2008), the online travel industry (Meersman and Debruyne 2011), and the ambient assisted living domain (Meersman and De Leenheer 2012). With OPAQ, the highest level of the domain model features the following classes:

- *Object*: products and components used in processes by actors and objects
- *Process*: any process in the domain, executed by an actor with the use of objects
- *Actor*: any actor using objects in any process in the domain

- *Quality*: concepts that define how, to what extent, when etc. something happens; properties and functions of objects, actors and processes.

After classifying all concepts as an Object, Process, Actor, or Quality or a subclass thereof, the end result was a very large domain model that covered the knowledge contained in the information system, being the concepts, their relations, the resulting fact types and constraints. The domain model will be discussed in greater detail in the following section.

4.4.3. Bifurcation

In the bifurcation process stage the CRM domain model was separated from the real estate domain model. The process involved three confidence categories: 'sure', 'confident' and 'don't know'. The 'sure' category comprises of concepts of which the ontology engineer is sure that they fall in one of the two domain models. The 'confident' category is tagged for input from a domain expert, but can be classified confidently into one of two domain models. The 'don't know' category requires input from a domain expert prior to classification. Both domain models were reviewed and validated in their entirety by two domain experts.

The bifurcation process resulted in two OPAQ domain models ('CRM' and 'real estate'). The CRM domain model consists of 119 concepts with 7 types of relations, and a total of 360 facts. The real estate domain model consists of 140 concepts, 6 types of relations, and a total of 310 facts. Interesting to note here is that we used two underlying practices to create and encourage a controlled vocabulary. Firstly, the widely applicable OPAQ model structures two different domains following a congruent structure, bringing to bear similarities and overlaps between the domains. Remarkably, both domains were quite distinct, with only an approximate 5% overlap of concepts. Secondly, previous experience shows that limiting the number of types of relations between concepts is 'best practice' for creating and maintaining a controlled vocabulary, adding to interoperability.

4.5. Case Study

In both domain models, about 60% of relations are isa/subsumes relations, effectively constructing the subsumption hierarchy. As stated above, the top levels of the hierarchy are Object, Process, Actor, and Quality. We will now have a more detailed look at other aspects of the two domain models.

4.5.1. CRM Domain Model

The top-level Objects in the CRM Domain Model (CDM) are `SalesArtifact`, `Document`, `MarketingArtifact`, and `SupportArtifact`. These break down further into sub-objects such as for example `ServiceContract` and `SupportTicket` for `SupportArtifact` (see Fig. 4.1).

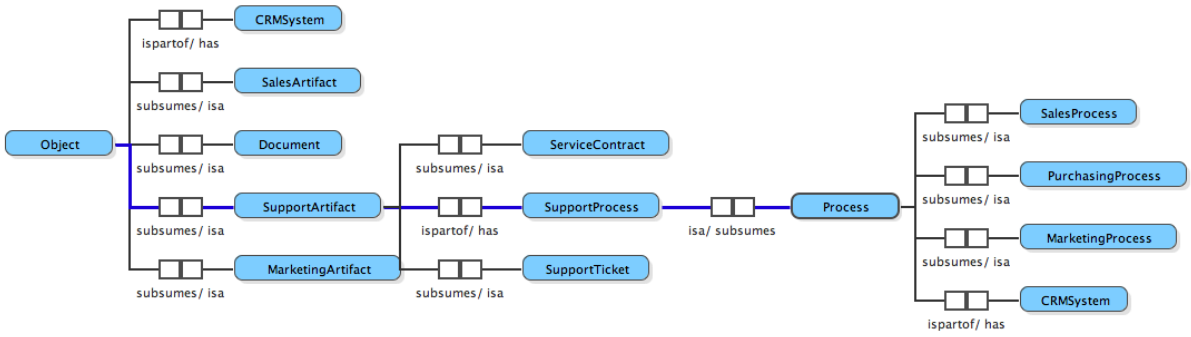

Fig. 4.1: Example Object Pattern in the CDM.

We further see that the `SupportArtifact` is part of a `SupportProcess`. Top-level processes in the CRM domain are `SalesProcess`, `PurchasingProcess`, `MarketingProcess`, and `SupportProcess`, each with their own `has/ispartof` relations for `Objects` used in the respective processes.

`Processes` also involve Actors. In Fig. 4.2 we see the representation of a system `User` interacting with a `SupportTicket` in a `SupportProcess`.

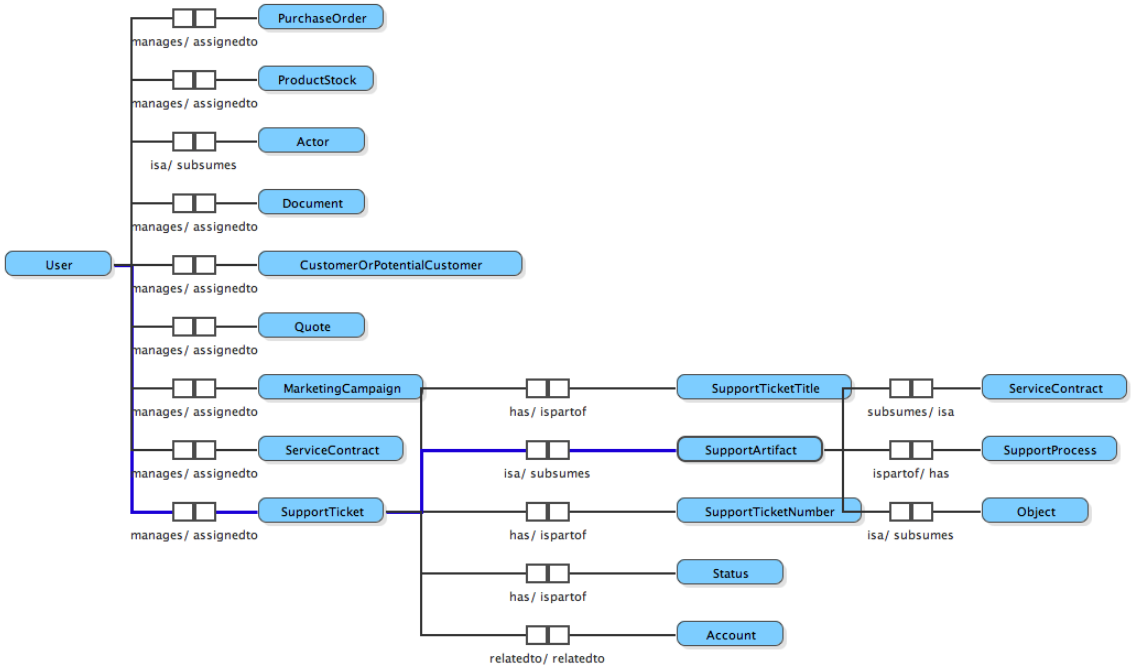

Fig. 4.2: Example User Pattern in the CDM

Interesting to note in the example in Fig. 4.2 is that the `SupportTicket` has a `Status`. A `Status` is a `Quality`. Examples of `Qualities` in the domain model are `Status`, `Progress`, `TimeAndDate`, and `Number`. There are many types of `Numbers`: `ProductNumber`, `PurchaseOrderNumber`, `NumberOfMarketingItemsSent`, `InvoiceNumber`, `ExpectedRevenue`, `ProductQuantity`, `SalesOrderNumber`, and `Price`.

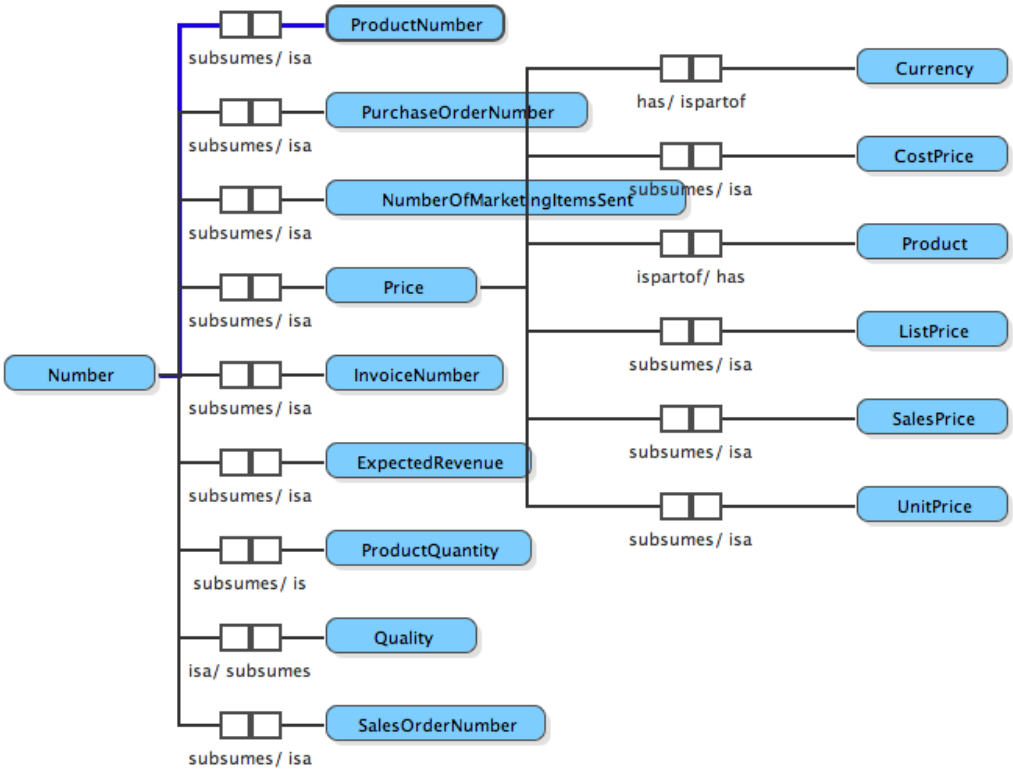

Fig. 4.3: Example Number Pattern in the CDM

In Fig. 4.3 we see how the `Price` of a `Product` breaks down further into different types of Prices such as `CostPrice`, `ListPrice`, `SalesPrice` and `UnitPrice`.

The relations between concepts in the CDM are:

1. `subsumes/isa` indicating subsumption relations
2. `sells/soldby` indicating `Actors` selling `Objects`
3. `relatedto/relatedto` indicating non-exclusive associations between `Objects`
4. `sentto/receives` indicating the physical sending of `Objects` between `Actors`
5. `assignedto/manages` indicating `Objects` falling under the responsibility of `Users`
6. `madeby/makes` indicating production of an `Object` by an `Actor`

7. has/ispartof indicating part/whole relations

4.5.2. Real Estate Domain Model

Interestingly, there are only 2 top-level `Objects` in the Real Estate Domain Model (RDM): `Property` and `PropertyDevelopmentCompany` (Fig. 4.4).

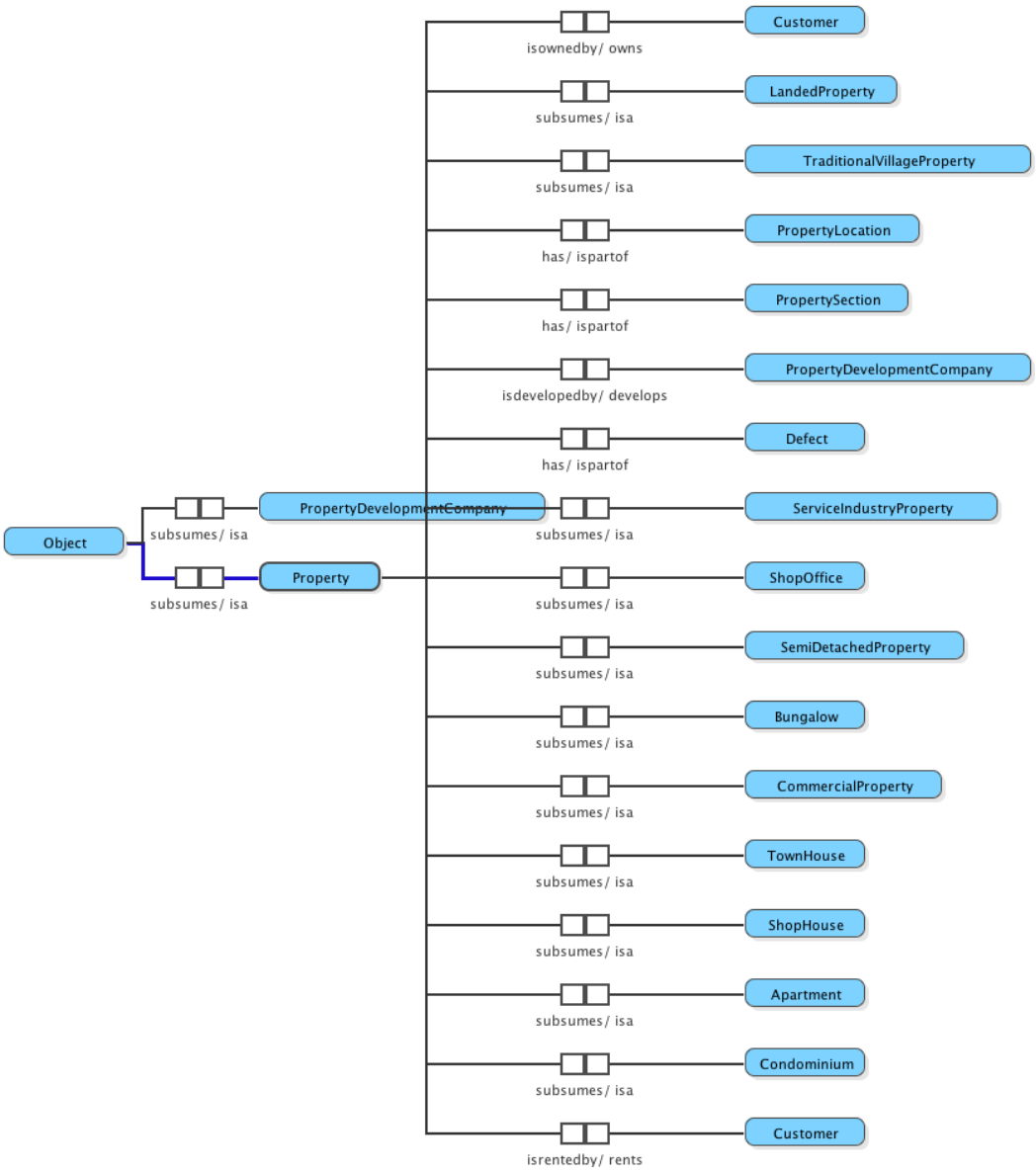

Fig. 4.4 Example Object Pattern in the RDM.

We see that, naturally, `Property` breaks down into many types of real estate properties: `Apartment`, `Condominium`, `TownHouse`, `Bungalow`, `CommercialProperty`, `ShopHouse`, `TraditionalVillageProperty`, `ServiceIndustryProperty`, `ShopOffice`, `LandedProperty`, and `SemiDetachedProperty`. Of particular interest to note here is that we are dealing with a Malaysian context: the types of properties reflect this specific context. For example a `TraditionalVillageProperty` would not be a standard way of classifying Australian properties, whilst the Malaysian domain experts ensured that this is a commonly used category in their industry.

In Fig. 4.4 we also see that a Property has `PropertySections`. There are too many `PropertySections` to list here, but they include all possible parts of a Property, such as for example `Roof`, `Hallway`, `Lobby`, `PrayerRoom`, `Playground`, `Wardrobe`, `LivingRoom`, and `Kitchen`. `Kitchen` breaks down further into a `WetKitchen` and `DryKitchen`. Notice again the specificities of the Malaysian context.

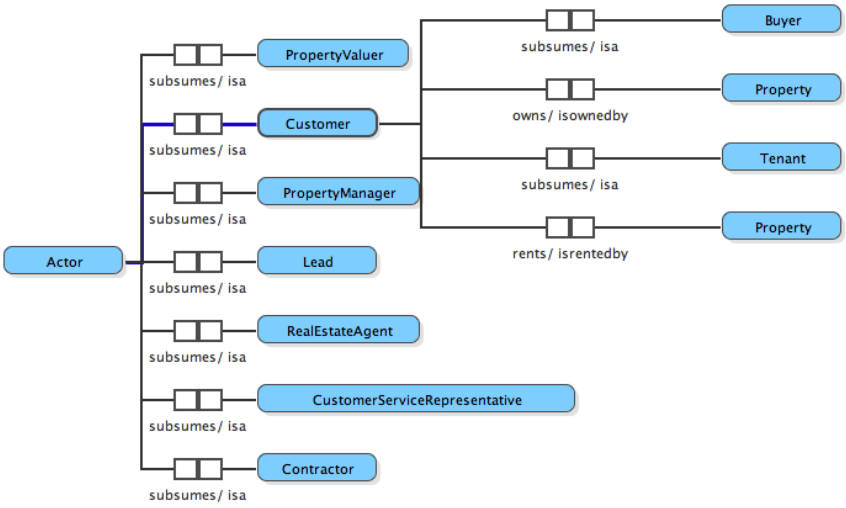

Fig. 4.5: Example Actor Pattern in the RDM.

The top-level `Processes` for the RDM are only two processes: `DefectsManagement` and `PropertyDevelopment`. Top-level `Actors` for

the RDM are `Customer`, `PropertyValuer`, `PropertyManager`, `Lead`, `RealEstateAgent`, `CustomerServiceRepresentative`, and `Contractor` (see Fig. 4.5). Note that the `Customer`, `Lead` and `CustomerServiceRepresenative` concepts are shared between the CDM and RDM. We further see in this example that a `Customer` can be a `Tenant` and a `Buyer`, and can own or rent a property.

There are three top-level concepts for `Quality` in the RDM: `Number`, `Location`, and (perhaps somewhat ironically) `Defect` (Fig. 4.6). `Number` subsumes concepts such as `HallwayNumber`, `LivingRoomNumber`, `FloorOrStoreyNumber`, `BedroomNumber`, and so on. `Location` can refer to a `DefectsLocation` and a `PropertyLocation`. Additional concepts such as GPS location or other descriptors can be added here. `Defect` breaks down into the most common defects found in the real estate domain.

The relations between concepts in the RDM domain model are:

1. `subsumes/isa` indicating subsumption relations
2. `rents/isrentedby` indicating `Actors` renting `Objects`
3. `owns/isownedby` indicating `Actors` owning `Objects`
4. `manages/ismanagedby` indicating `Objects` falling under the responsibility of `Users`
5. `develops/isdevelopedby` indicating production of an `Object` by an `Actor`
6. `has/ispartof` indicating part/whole relations

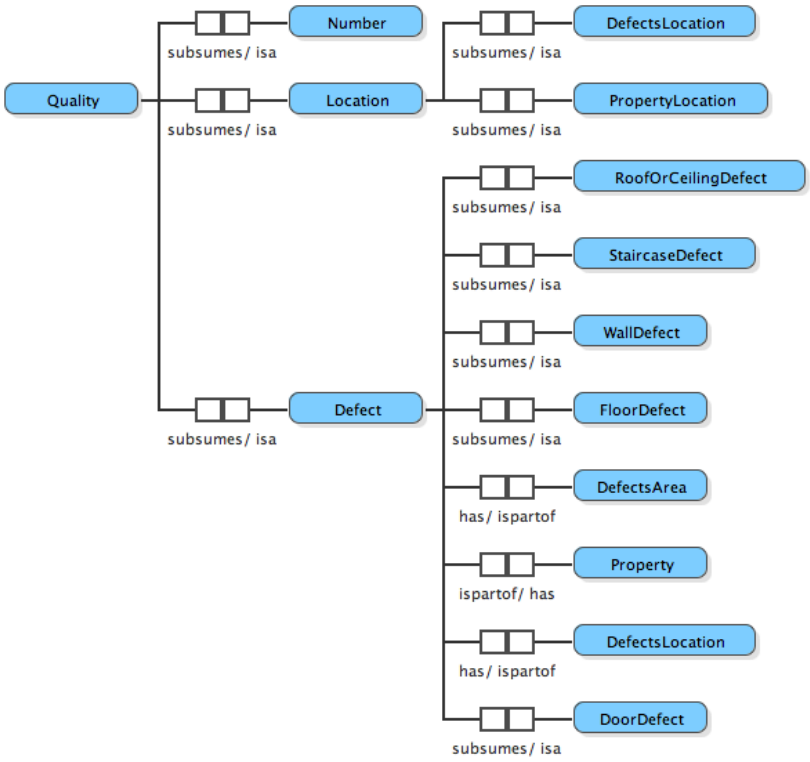

Fig. 4.6: Example Quality pattern in the RDM

4.6. Intermediate discussion

4.6.1. Limitations

The CDM is currently based mainly on one CRM system, with some concepts added from another consulted system. A larger dataset and more CRM systems resulting in various additional objects, processes, and actors would result in a more generic domain model than is now the case. The expectation is that the model will naturally grow as new clients with different systems are added by the industry partner, but a survey of existing CRM systems would certainly make sense to speed up the process. The next client to be migrated to the industry partner's cloud-based system is an insurance company. The bifurcation would in this case be followed by a recombination stage in which an insurance domain model would be added to provide full concept coverage. Interestingly, it can be expected that data mappings of the legacy

system to the CDM would bring to bear most concepts of the insurance domain model (as we can assume that the vast majority of whatever remains unmapped will constitute that which is not the CRM domain, hence constitutes the insurance domain). So it seems there are advantages to the approach developed in this project beyond mere interoperability and integration.

Although the RDM contains most concepts that are relevant as defined by the stakeholders of that particular real estate domain in Malaysia, the specificities of the domain for the Malaysian context, as indicated in the analysis, point in the direction of future improvements to the model. Although the RDM was developed by multiple stakeholders, the top-down domain model will require bottom-up input to further complete it. The quality of the initial domain model is thus not assured beyond the current usage context. Ideally the real estate domain model would be made public. This way, the domain model can evolve to decent quality ontologies once enough organisations start to use them and add to them. This would however invoke a plethora of issues regarding versioning, evolution and alignment. Would it for example make sense to have a generic, catch-all real estate domain model, or would it be preferable to keep them for example country-specific? In any case, not much of the RDM could be considered commercially sensitive information. In the end, it is a representation of a reality most, if not all, people are a part and aware of.

4.6.2. Further use

One of the more interesting uses for the bifurcated domain models is for business intelligence. The next steps would be to use the domain models separately in domain-driven data mining processes. Not only will the separation bring clarity when analysing patterns, the commercial reality must also be taken into account: there where CRM optimisations apply to the provider and can bring costs down, optimisations based on patterns discovered in the industry domain constitute value that can be offered as a service to the respective client base.

4.7. Real Estate CRM Domain Innovation Process

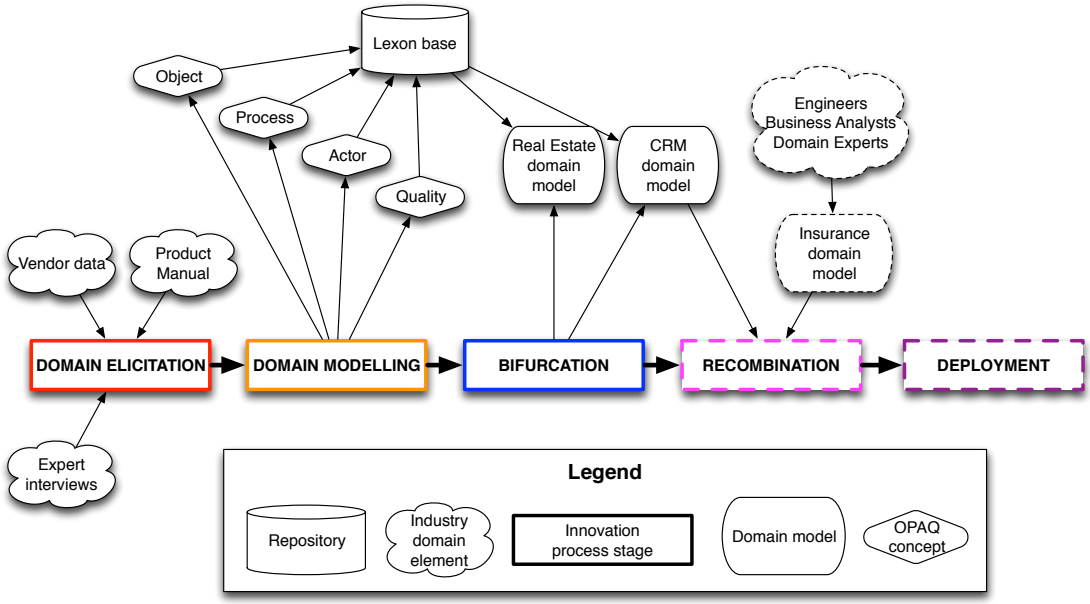

Fig. 4.7 Real Estate CRM Domain Innovation Process

The application of the innovation process model (see section 3.4.3.2) to the case study of the real estate CRM domain results in a process model with five stages and some knowledge interactions (Fig. 4.7). The process steps of needs elicitation and needs laddering were appended since the research project did not concern the discovery of customer needs nor did it go beyond the scope of a B2B information system innovation project. The recombination of the CRM domain model with another vertical (e.g. insurance) and the corollary deployment also fell outside of the scope of the project, but these stages did drive the design logic of the preceding stages, hence they are represented theoretically in the model.

In this particular project, the activities within the project align very closely to the innovation process model depicted in Fig. 4.7. For this reason the following discussion will be kept brief.

The input for the **Domain Elicitation** stage (see section 4.4.1) was mainly the data (and interface) of the CRM system of the partner company, supplemented with conversations with the domain experts and a product

manual of the CRM system. A rough initial domain model of the entire system was constructed with a mind map, which served as input for the **Domain Modelling** stage further discussed in section 4.4.2.

The **Bifurcation** stage (see section 4.4.3), which as indicated comes conceptually after the modelling stage but in reality runs concurrently. The output for this stage, which follows the TRIZ principle of Segmentation (Altschuller 2000), are two domain models, the real estate domain model and the CRM domain model.

The CRM domain model would then be used further in a **Recombination** stage with a domain model from another vertical, in fact creating a new semantically enriched model for the Insurance CRM domain, resulting in a **Deployment**.

"A property is that which not at all
Can be disjoined and severed from a thing
Without a fatal dissolution: such,
Weight to the rocks, heat to the fire, and flow
To the wide waters, touch to corporal things,
Intangibility to the viewless void."

Titus Lucretius Clarus

On The Nature of Things (55 BCE)

5. Chapter 4B: Scuba Diving Equipment Domain

5.1. Chapter Preface

This chapter is based on the following publication:

- Meersman, D., & Dillon, T. (2010). The Open Innovation Paradigm and the Semantic Web: An Ontology for Distributed Product Innovation. *On the Move to Meaningful Internet Systems 2010: OTM 2010 Workshops*, Springer Lecture Notes in Computer Science, Berlin, 49-52.

The roles of the co-authors were as follows:

- Myself: author, researcher
- Tharam Dillon: supervisor

Appendices pertaining to this chapter are:

- Appendix IV: Scuba Diving Equipment Domain Model
- Appendix V: Scuba Domain Expert Interview Transcript
- Appendix VI: Scuba Domain Expert Interview Screenshots

This chapter describes the development and application of a formal domain model of the scuba diving equipment domain in the context of an innovation process. The scuba diving equipment manufacturing domain was chosen for a variety of reasons. First of all, the scuba domain is very well defined. If a user breathes using a self-contained underwater breathing apparatus, it is scuba, if not, then it is not. Another consideration is that mainstream scuba has only been around for about fifty years. It is a very young sector that has had a limited number of innovations for this reason. A search for patents containing

the word 'scuba' comes up with only about 4300 patents[7]. A third factor that contributed to the domain choice was the fact that in order to participate in scuba diving activities, a user has to get trained and certified. This means that instructors, essentially domain experts, are available in large numbers. For the construction of the domain model we are working together with equipment manufacturers, service technicians and instructors. Besides the above-mentioned practical considerations, it was found that industry professionals are more willing to share and co-operate in a sector that essentially sells life support equipment. And last but not least, scuba industry leaders have experienced a significant slowdown in the pace of innovation in the sector. Designs of the majority of equipment have barely evolved in the last ten years (Gilliam 2009).

5.2. Introduction

Information and knowledge are the most important objects in an innovation process. But what information and what knowledge? In what form? At what stage? In which quantity? At what level of detail? A major problem is that people generally do not sufficiently grasp the concept of innovation to answer these questions. Innovation is still largely regarded as the result of a bright idea, or as just an organic improvement on an existing product. Generic innovation process models such as for example the Innovanet model (Paukert et al. 2003) do not deal with the intricacies of knowledge, but treat it as a given and as a result. Clearly there are more dimensions to it.

In order to tackle the issue of knowledge intricacy in innovation processes one must:

1. Study and understand the concept of innovation and information in innovation;
2. Develop a conceptual framework to support this knowledge;

[7] http://www.freepatentsonline.com/result.html?query_txt=scuba&sort=relevance&srch=top&search= Accessed 20 June 2010.

3. Embed the framework in a prototype for adaptation and validation purposes.

The type of information that is most important in an innovation process is how the user perceives a product and what it will *do* for him or her. This information is essential in moving the product, but is also the exact type of information market input in innovation processes should consist of. Manufacturers think in terms of properties or features, whilst consumers think in terms of *functions*, or the 'job they want to get done' by using the product or service (Christensen 2007).

5.3. Background

5.3.1. Open Innovation and Heterogeneity

The open innovation paradigm can be understood as the opposite of the traditional vertical integration or closed model of innovation. In an open innovation environment, companies search for solutions to their innovation problems outside the boundaries of their and their partners' R&D departments. The advent of this paradigm has caused innovation to evolve from an internal business process to a collaborative process that involves multiple stakeholders, value life cycle partners, customers, consultants and even competitors (Chesbrough et al. 2006). The open innovation paradigm has changed the way businesses innovate, but its inherent inter-organisational nature implies a versatility of participating agents and systems, heterogeneous information formats and differing semantics. This has introduced many communication, interoperation and integration challenges, not the least in product information management and design systems.

The most important product ontologies today are GoodRelations for e-commerce (Hepp 2008), PRONTO for production, storage and sales (Vegetti et al. 2005), eClassOWL for manufacturing (Hepp 2006), and SWOP for product modelling (Böhms 2006). As discussed in Chapter 2 these ontologies do not include product, component, and property functions, which affects their usability in innovation processes. They are to be regarded more as very

important and valuable assets in the modelling, manufacturing and commerce process, rather than tools to drive innovation. It can be argued that for ontologies to be valuable in innovation processes, the idea of product ontology needs rethinking.

5.3.2. Innovation Objectives

Objective 1: artefact for reasoning in a product innovation context

This objective concerns the development of a domain model that contains all relevant facts about a product aspect in a format that can be used of reasoning by humans or machines.

Objective 2: artefact for the semantic annotation of web resources

This objective concerns the development of an artefact that can be used to annotate web resources concerning a particular product domain, allowing for knowledge discovery and classification in the context of innovation.

5.4. Approach

5.4.1. Product Innovation Specifics

A major conceptual component of the approach is that product, component and property functions are integrated in a granular product representation. Besides listing which products have which components and properties, it is defined which components, which sub-components and even which properties have a certain function. Because the existence of properties in a component is driven by the function they perform, i.e. the fulfilment of initial requirements and in some cases posterior cost considerations, the inclusion of functions and their linkage to products, product components and product properties is crucial in the context of ideation. Why is something there?

Another big difference between a regular product ontology and an ontology geared towards product innovation, is that the entire domain of product application is included in the product innovation ontology, as the usage of the product has a great influence on the reasoning behind feature introduction.

By formalising the entire domain in the broadest sense possible, one can for example gain valuable insight in how certain functions that are performed by users today can be taken over by technology tomorrow. User appeasement is the main driver of innovations and that certainly plays a role in the interpretation of the domain model, but on a semantic level the user is just another concept that participates in a process.

5.4.2. Class Level and Instance Level

The advantage of using an ontology to represent domain and product knowledge for innovation processes is that the instance level can stay hidden from potentially competitive industry partners. Because the mechanics of product functioning are expressed on the class/property (concept/relation) level, no instance information is shared between users of the domain model. The domain model only really means something to the users with respect to their own instances in product engineering databases. This feature of the framework encourages users to share engineering knowledge, which makes sense, and helps them avoid accidentally over-sharing potentially sensitive information. The separation of the instance and class level is what is actually already being done today on a case-by-case basis by open innovation tender firms such as Nine Sigma. In this case an industry problem is stripped of all instance information and sent out to research groups who can then respond with possible solutions.

5.4.3. Ontology Engineering Methodology

The ontology engineering methodology used in this research consists of five main steps.

5.4.3.1. Industry source document analysis

The initial step is the analysis of industry-sourced information provided by industry representatives. This encompasses manuals; design documents; training manuals; and sales inventory structures.

5.4.3.2. Initial knowledge formalisation

Based on the initial domain knowledge, a high-level domain model with a low granularity (OPAQ classification) is developed. After breaking up the domain in these main building blocks, general concepts and relations are added without delving into the specifics too much. The domain is divided into practical blocks according to time of interview constraints and expertise domains. A paper version of the initial domain model is used as a basis for the domain expert interviews (see e.g. Fig 5.6).

5.4.3.3. Domain expert interview

The domain expert is contacted and a meeting is set up. The main gist of the research approach (the properties/functions perspective) is introduced and agreement is reached on which part of the domain model will be discussed. Time to think about the subject is given. The interview itself is about a limited subject, and in case of product discussions, design diagrams and actual products are brought, which are disassembled as the interview progresses (see Fig 5.1-5.6).

Fig. 5.1 Domain Expert Interview – Screenshot 1

Fig. 5.2 Domain Expert Interview – Screenshot 2

Fig. 5.3 Domain Expert Interview – Screenshot 3

Fig. 5.4 Domain Expert Interview – Screenshot 4

Fig. 5.5 Domain Expert Interview – Screenshot 5

Fig. 5.6 Domain Expert Interview – Screenshot 6

Everything is recorded in high definition video so that the footage can be used for future reference with sufficient zoom capabilities for small product details. After the interview, a full transcript is made and annotated with terms from the initial domain model, whilst indicating properties and functions as well as new terms and sameas relations.

5.4.3.4. Domain modelling

In the domain modelling stage, the interview annotations are formalised as lexons, according to the DOGMA approach. The facts are added to the domain model until the representation for that part is complete, based on the provided information. Assumptions from the initial domain model are trumped by domain expert statements.

5.4.3.5. Domain model validation

In the final stage the domain model is validated by sending the fact types out to domain experts, who can evaluate them with simple true/false answers. This way potential errors are traced and new insights and additions arise.

5.5. Case Study

5.5.1. Domain model overview

In the subsumption hierarchy the top level concepts are Actor, Object, Process and Quality. There are currently approximately 250 concepts and relations in the domain model, which at the moment equates to about 1500 fact statements about the second stage regulator and how it inter-plays with other classes and relations. The second stage regulator is the part of the breathing apparatus that is held by the diver in his or her mouth. Its main function is to deliver breathing gas tot the diver at ambient pressure.

The second stage regulator is classified in the subsumption hierarchy as follows:

```
T
- Object
-- ScubaGearComponent
--- Regulator
---- SecondStageRegulator
```

The following classes have the second stage regulator as a part:

OpenCircuitBreathingGear haspart/ispartof SecondStageRegulator

ClosedCircuitBreathingGear haspart/ispartof SecondStageRegulator

SemiClosedCircuitBreathingGear haspart/ispartof SecondStageRegulator

The second stage regulator has following components:

```
SecondStageRegulator haspart/ispartof Piston
SecondStageRegulator haspart/ispartof Spring
SecondStageRegulator haspart/ispartof PurgeDome
SecondStageRegulator haspart/ispartof ExhaustTee
SecondStageRegulator haspart/ispartof CoverRing
SecondStageRegulator haspart/ispartof SpringAdjustKnob
SecondStageRegulator haspart/ispartof HeatSink
SecondStageRegulator haspart/ispartof Nut
SecondStageRegulator haspart/ispartof Deflector
SecondStageRegulator haspart/ispartof Diaphragm
SecondStageRegulator haspart/ispartof TieWrap
SecondStageRegulator haspart/ispartof MouthPiece
SecondStageRegulator haspart/ispartof Housing
SecondStageRegulator haspart/ispartof Pin
SecondStageRegulator haspart/ispartof VenturiControlLever
SecondStageRegulator haspart/ispartof SeatingSeal
SecondStageRegulator haspart/ispartof ExhaustValve
SecondStageRegulator haspart/ispartof ValveTube
SecondStageRegulator haspart/ispartof DiaphragmCover
SecondStageRegulator haspart/ispartof BalancingCylinder
SecondStageRegulator haspart/ispartof Orifice
```

```
SecondStageRegulator haspart/ispartof Lever
```

5.5.2. Examples

The components of the second stage regulator in turn often have sub-components. For example the valve tube has an inlet coupling sub-component in Fig. 5.7:

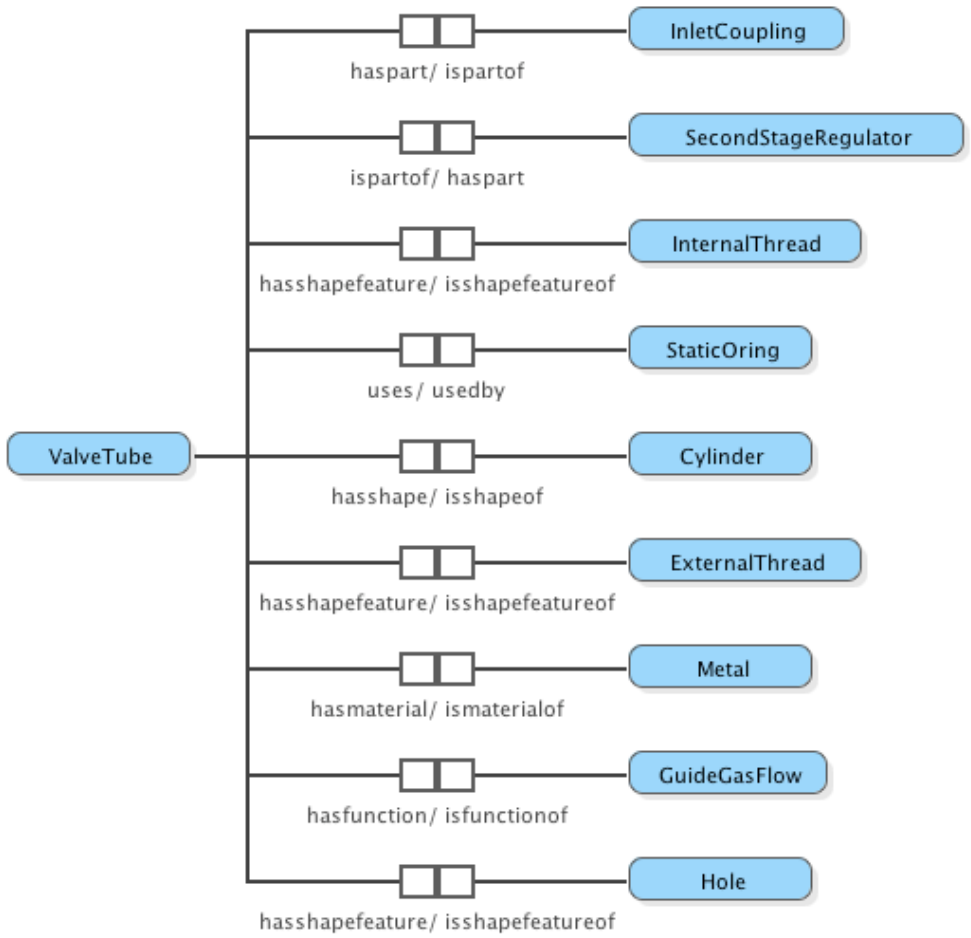

Fig. 5.7: Valve Tube with Components, Properties and Functions.

In this example we can also see the main function of the valve tube: to guide the gas flow.

The properties of components are expressed in a variety of ways. Each component has a shape and a material. Because the relatively simple shape description is often not a good approximation of the real world shape, the

shape feature property was introduced. These are properties that specify certain features of the shape, such as holes, threads, grooves, etc. In this example the cylindrical valve tube has both an internal and external screw thread and a hole.

The various properties are classified in the subsumption hierarchy as follows:

```
T

- Quality

-- ComponentFunction

-- ComponentProperty

--- Material

--- Shape

--- ShapeFeature
```

Sub-components have functions as well, as shown in Figure 5.8:

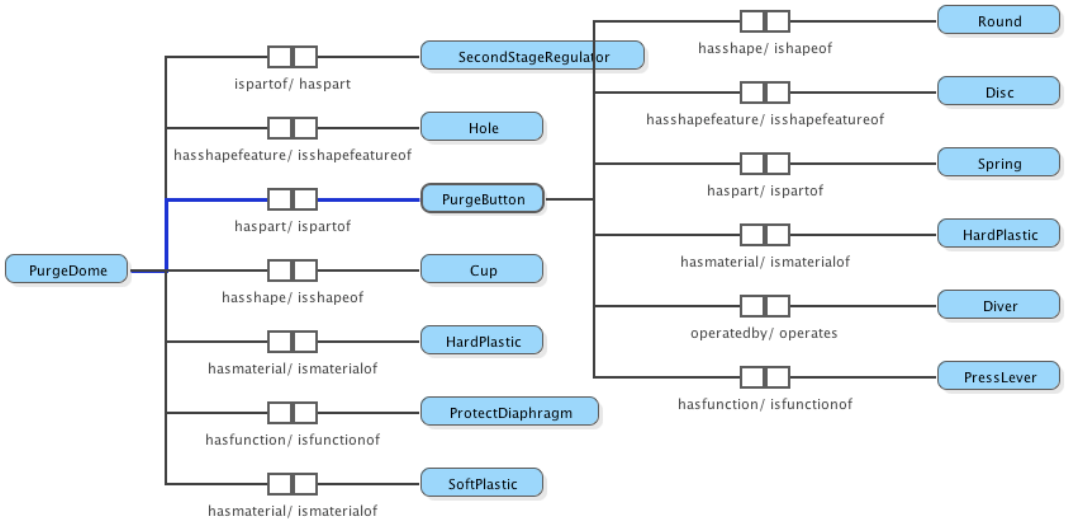

Fig. 5.8. Purge Dome with Components, Properties and Functions.

In this case the function of the sub-component 'purge button' of the purge dome is to press the lever that moves the piston. This causes gas to flow in and the regulator to purge.

Although most of the times the component function is the result of an interplay between material, shape and shape features, a shape feature can also have a distinct function. In Figure 5.9 we see an example of this:

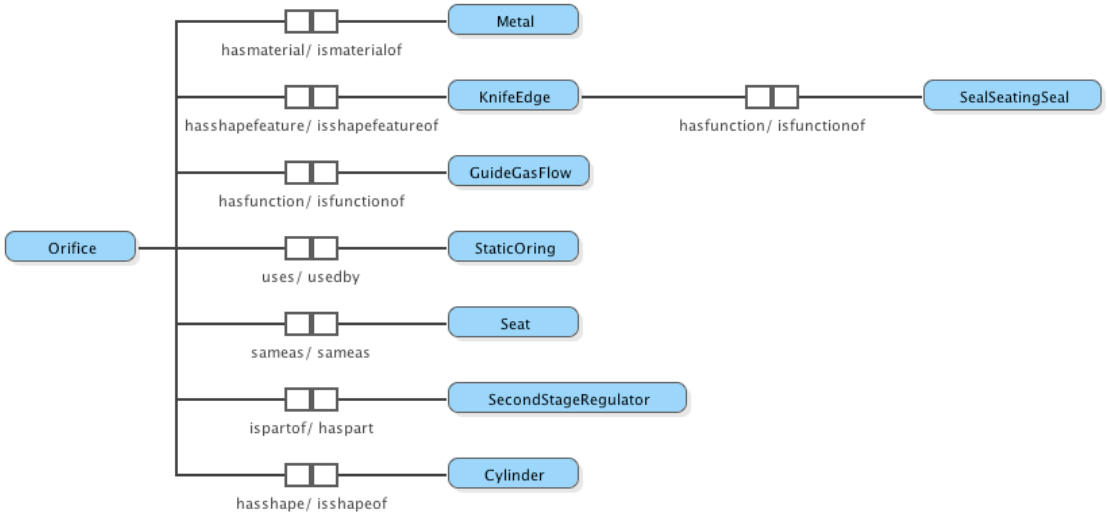

Fig. 5.9 Orifice with Properties, Functions, and Shape Feature Function.

The conceptual difference is that a shape feature inherits material properties and the general function from its parent, but can offer additional specific functions. In this case the 'knife edge', which is the accepted way of expressing the very sharp edge of one side of the orifice or seat, ensures that the orifice seals against the seating seal of the piston.

A final aspect discussed here is the operation of components versus their general working. Two roles and co-roles are distinguished: `uses/usedby` and `operates/operatedby`. The difference between the two is that `uses/usedby` refers to (sub-)component or (sub-)process dependencies and `operates/operatedby` refers to where components are or can be operated by an actor. In the example of Fig. 5.8, we see that the diver operates the purge button. This distinction in relations allows one to see at what point exactly gear interfaces with the diver. This is done out of product engineering considerations. One is able to track every point in the domain model where an actor interacts with a concept.

In the case of the second stage regulator these points are:

```
Diver operates/operatedby MouthPiece

Diver operates/operatedby SpringAdjustKnob

Diver operates/operatedby PurgeButton

Diver operates/operatedby VenturiControlLever

Diver operates/operatedby Diaphragm

Diver operates/operatedby ExhaustValve
```

Of course some actors such as service technicians will interact with every component. We do not include this information in the domain model. Instead we confine the `operates/operatedby` relation to participants of the process in which the components perform their intended function. In the case of the second stage regulator, this would be the breathing process. This process has the following place in the subsumption hierarchy:

```
T

- Process

-- DiveProcess

--- Breathing
```

These are the current properties of the breathing process:

```
Breathing performedby/performs Diver

Breathing uses/usedby BreathingMix

Breathing uses/usedby BreathingGear
```

As we see the diver is the only actor in this process and thus the operates/operatedby relation in any sub-component of breathing gear (which includes the second stage regulator) is reserved for the diver.

5.5.3. Application

The domain model was used in conversations with domain experts on the largest scuba diving forum on the Web, in a series of conversations in June 2010. The discussions concern the detailed discussion of parts of the second

stage regulator, and the questions and discussions are focussed on unearthing possible improvements to the design. The main idea of the application of the domain model was to ascertain whether a non-domain expert (me) could reason and interact with experts on the web based on the concepts and relations contained in the domain model, and whether the level of granularity of the domain model was sufficient for use in a collaborative, web-based innovation process.

Of the participants in the discussions, **Cerich** is a manufacturer, and **Divor** is the username of Davor Meersman. Most other users are diving professionals and senior divers. All forum threads were initiated by the researcher.

The format of the discussions is as follows:

> **Username** Date, Time
>
> *Forum post in italics with domain model concepts (or their synonyms)* ***underlined and bold****.*

All discussions are reflected in their entirety and in their original state, with the exception of some spelling and grammar errors that were corrected to improve readability.

5.5.3.1. Forum thread: "Why is there no thread on a heat sink?"

Divor June 21st, 2010, 07:45 AM

Why is there no thread on a ***heat sink****?*

I don't really understand how the ***heat sink*** *works, really, and it seems such a simple part.*

herman June 21st, 2010, 09:25 AM

Which ***heat sink****? In general they provide a* ***surface*** *area for* ***heat*** *to* ***transfer*** *to/from a device. The amount of* ***surface*** *area, sink* ***material****,* ***air****/****water flow*** *around it and differential* ***temperature*** *around it determines the amount of* ***heat*** *that is* ***transferred*** *and which way it* ***flows****.*

*I am guessing here but if you mean on a **second stage**, as **air pressure** decreases from the **IP** to **ambient pressure** as the **diver breaths**, there is a **cooling** effect that in the right **conditions** can cause the **water** around the **seats** to freeze, bad thing if it freezes your **stage** open or shut. The **heat sink** absorbs **heat** from the **water** and **transfers** it to the **seat** area to help **warm** the **area** and overcome the **cooling** effect of the expanding **air**.*

Divor June 21st, 2010, 09:59 AM

*Thanks. I did mean the **second stage heat sink**. Wouldn't a **threaded heat sink** have more **surface area** than one with a **sleek** inside?*

fppf June 21st, 2010, 10:14 AM

What is your PhD in?

*If your talking about **ribbing** or **threading** the inside to try and **warm** the **gas**, that really is not the **purpose** of the **heat sink**.*

*The **goal** of this design is to keep the **seats warm** enough to prevent ice formation. If the **seats** are above freezing they wont build ice and the **gas temperature** is not important.*

*Also, the volume of **gas** moving through the **regulator** has to high of velocity and adiabatic **cooling** for the **heat sink** to greatly affect the **temperature**. Keep in mind **regulator** free **flow** is not a huge issue until the **water temperatures** start to get below 50 degrees or so depending on design and **flow** rates. As the **ambient water temperature** decreases the amount of **heat** moved in the system decreases due to the **temperature** delta drop.*

Divor June 21st, 2010, 10:22 AM

Thanks a lot for that. PhD is in information systems, with an application in the scuba equipment domain. I'm interviewing domain experts in real life and checking up on bits that we didn't cover or that I wonder about afterwards here. So your info is really valuable to me and much appreciated.

5.5.3.2. Forum thread: "Uses of the spring adjustment knob"

Divor June 21st, 2010, 09:10 AM

*What are the **uses** of the **spring adjustment knob**?*

I've only found two:

*1) with heavy exertion you want less effort **breathing***

*2) in strong **currents** you want a bit more*

*Are there any other **uses** of the **spring adjustment knob**?*

Peter_C June 21st, 2010, 09:14 AM

*I would consider my main use that of keeping them from **free flowing** when not in use, but when in my **mouth** I open them up so they **breathe** nice and easy. Both my **primary** and my bungeed **backup** have **adjustment knobs.***

Divor June 21st, 2010, 09:19 AM

Thanks for your answer.

*Doesn't the dive/pre-dive **venturi control lever** serve that purpose?*

awap June 21st, 2010, 09:27 AM

*The **venturi control** does not prevent **free flow** but does reduce the severity of a **free flow** should one occur.*

*With a cracking pressure **adjustment knob**, you can be more aggressive when tuning the **reg** for top performance and **control** any small problem that may occur as the **seat** takes a set.*

Divor June 21st, 2010, 09:57 AM

*With **'cracking'**, do you mean an **adjustment knob** that has a **ratchet**?*

awap June 21st, 2010, 10:03 AM

*The term "**cracking pressure**" refers to the amount of force required to pull the **LP seat** away from the **orifice** and start **gas flowing** through the **2nd stage**. That **pressure** is **regulated** by the string **pushing** the **LP seat** into the **orifice**.*

Divor June 21st, 2010, 10:05 AM

Thanks for clearing that up.

fppf June 21st, 2010, 10:20 AM

*The **"venturi" switch** does help **prevent** inadvertent **free flows** when the reg is not in your **mouth**. It does this by making a small restriction and causing a small **pressure** increase in the **body** of the **regulator** when it starts to **flow**. This **pressure** increase will **close** the **seat**.*

*With no restriction most **regulators** are designed to induce a **pressure** drop in the **body**, which causes the **seat** to open more and then **free flow**. But, this same effect helps **reduce** **breathing** effort when the **regulator** is in use and the **exhale** keeps the **reg** from **free flowing**.*

*That is why they allow you to **turn** the **"venturi" switch** on and off.*

herman June 21st, 2010, 11:25 AM

*I see you are posting a lot of questions of **reg** design- great thing IMO- so I have a suggestion for you. Order this book and read it- "Regulator Savvy" by Peter Wolfinger, I have you a link below. It will answer the questions you have and the ones that will come later once you learn more. The book is well worth the cost and if I had to bet darn near everyone who has answered you has a copy. It is pretty much the bible for those of us who really want to know how these things work.*

Scuba Tools - Regulator Savvy Book

Divor June 21st, 2010, 11:52 AM

Thanks so much for the pointer.

Doc Ed June 24th, 2010, 04:54 AM

*Another use is that by reducing the **pressure** on poppet **seat**, there will be less of a **groove** on it, theoretically prolonging the life of the seat.*

5.5.3.3. Forum thread: "Disadvantages of the spring adjustment knob"

Divor June 21st, 2010, 09:14 AM

Hi,

*Since Mares has no **spring adjustment knobs** on its **2nd stage regulators**, I reckon there are disadvantages to this part of the regulator. What are they?*

Thanks in advance.

c5diver June 21st, 2010, 12:03 PM

*I see you posted a similar post in regulators. the short answer is personal preference. Mares **regs** are classic down stream regs with no **air adjustment valve**. They have fewer part and are easy to adjust/repair the inhalation adjustment on say a Scubapro s600 properly adjusted with the **adjustment knob** set to as easy breathing as it can, should breath pretty close to the same as any other reg. and it should not **free flow** at that setting.*

a22shady June 21st, 2010, 12:53 PM

*The other advantage I would see is besides the ability to adjust the breathability is to custom it. If your in **warmer waters** you may want it fully out to make it **breath** as easily as possible. For some who do **cold waters** you may want to **reduce** the amount for a less likely chance of **free flow**. As you will hear it's personal preference. For me my **primary** was adjustable and **back-up** was not, Until recently I upgraded it and both are adjustable.*

c5diver June 21st, 2010, 04:24 PM

*And here my kid dives a pair of s600's and I had the adjustment taken off the **octo** so it just works when you grab it. I like to keep it simple. less to go wrong if somebody needs it and doesn't know how it works.*

Ontwreckdiver June 21st, 2010, 07:53 PM

*Why would you a **regulator** that needs to be adjusted for **pre-dive**, **dive**, **warm water**, **cold water**? That is a lot of unnecessary fiddling around with a reg. That was one of the main reasons I went with Mares regulators is because they aren't adjustable.*

c5diver June 22nd, 2010, 10:12 AM

*my mares reg works the same in the **cold quarries** as it does in the **warm waters** of coz. I went this way and never looked back.*

jakobon June 22nd, 2010, 03:32 PM

*I have a Mares Abyss 42, and I have no need for a **knob** to adjust the **cracking resistance**.*

*Among the reasons why I chose a Mares **regulator**, was that the **regulator** automatically **adjusts** the supply of **air** according to the **divers** demands - no **knob** required.*

*And I have not been disappointed, even when **diving** in strong **current** - and having high demand of **air**. I have not yet used it during a winter, but I cannot imagine this would make any difference in the **regulators breathing** comfort.*

For me personally, the high quality, the simplicity of having fewer part and the use of advanced technologies makes me prefer Mares regulators over others brands.

But agreed, what "talks" to me doesn't have to be the only right thing for you. Take a look around, read reviews and visit you LDS to try it out.

*In the end though, I do not believe that you will ever miss the **adjusting knob** while **diving** with any Mares regulator in any **condition**.*

Best regards,

Jakob

5.5.3.4. Forum thread: "Ribbed heat sink"

Divor June 21st, 2010, 09:17 AM

Hi

*Why is the **heat sink** on the HOG **2nd stage** **ribbed**? Aesthetic/symmetric purposes?*

*Also why are there never any **threads** in **heat sinks**?*

Thanks in advance.

cerich June 21st, 2010, 09:27 AM

*I actually don't think of it as a **heat sink** but as a spacer that is needed there, and the **ribs** are for aesthetic reasons.*

*I have no idea why there are never **threads** on **heat sinks**.....*

Randy43068 June 21st, 2010, 09:28 AM

How about bathroom sinks?

Divor June 21st, 2010, 10:03 AM

*Thanks, cerich. I assumed it was a **heat sink** because I took apart a **second stage** and compared it to a Zeagle **second stage** service manual, which had an almost identical part labelled **'heat sink'** there.*

This is all part of my PhD project, will PM you when I have a more solid prototype ready, if interested. It's an innovation support system for scuba equipment manufacturers, amongst other things.

5.5.3.5. Forum thread: "Implications of the spring adjustment knob"

Divor June 21st, 2010, 10:17 AM

Hi,

*I was just wondering: as opposed to a **regulator** without **a spring adjustment knob**, does a **regulator** that has one have a different design on the inside because there is a range of **air flows** (from min to max) that introduce variability in obtaining a **laminar flow**?*

Thanks in advance.

fppf June 21st, 2010, 10:24 AM

*I'm not aware of any **reg** that can claim to have **laminar flow**.*

*Having an **adjustment knob** does not drive the overall design. Most designs incorporate an **adjustment** method.*

cerich *June 21st, 2010, 10:25 AM*

You do know that what you wrote above is one of those things you need to read a couple times and you'll still not be sure you follow the drift? :D

*The **air flow** isn't really impacted so much as **cracking** effort*

Is there a EDGE and/or HOG specific question in this?

Divor June 21st, 2010, 10:27 AM

*I'm sorry, I didn't mean to burden you, it's just that it was your **reg** that I took apart, so it would have been easier to visualise. It is indeed a more general question. Cheers*

Peter_C June 21st, 2010, 10:46 AM

*There are other brands than HOG that offer the same **reg body** and internals without the external **adjustment knob** for less money. Effectively charging much more for adding in the external **adjustment**. HOG does not do this and offers a top quality adjustable **reg** for one of the most reasonable prices out there.*

herman June 21st, 2010, 11:14 AM

Let me take a shot at this, I think I see where he is going.

*First off, the **cracking pressure knob** has no effect at all on **case** design, **gas flow** within the **case** or for that matter total overall **flow** rates of the **second stage**, basically all it does is vary the **spring pressure** on the internal parts of the **LP seat**. For all intents and purposes, removing the internal **spring** and replacing it with a stiffer/lighter one would have the same effect, just not externally accessible. This will only cause the **cracking pressure**- the amount of force needed to open the **LP seat** to vary but it has no effect on the amount of **gas** the **reg** is capable of **delivering**.*

*On the other hand, the **venturi control lever** does have an effect on **case** geometry and hence the **flow of gas** within the **case** (but not on total available **flow**). Set to max, the **flow** is directed from the **LP seat outlet** into the **mouthpiece** of the **reg**, this creates a **venturi** effect and **reduces** the **pressure** under the **diaphragm**, **reducing** the effort needed to hold the **LP seat** open. If the **reg** is started **flowing** (**purge button** pressed) and there is no back **pressure** (i.e. no one **breathing** on the **reg**) the effect will likely be high enough to keep the **reg free flowing** and **increase** until the **reg** is in full **free flow**. Set to the minimum position, the **airflow** between the **LP seat outlet** and the **mouthpiece** is disrupted causing less of a **venturi** effect and less **vacuum** behind the **diaphragm**.*

*Neither the **cracking pressure knob** nor the **venturi assist lever** have any effect on the **volume** of **gas** the **reg** can **flow**, they just make getting it easier for the **diver**. Does that help or did I just muddy the water more. :)*

Divor June 21st, 2010, 12:05 PM

No you cleared it up, this is a great answer to my question. I'll pick up that book you mentioned in the other thread and read it before bothering you guys again :)

Thanks for taking the time to write such an extensive answer.

herman June 21st, 2010, 02:47 PM

Happy to help and it's no bother; I really encourage divers to learn about their gear. The book has so many good illustrations and examples that are hard to reproduce here that really help you understand the internal working of a regulator. It delves into the how and whys of regs but at a level most anyone with a little technical background

can grasp. I reread it every so often to brush up on what I know; it's worth rereading from time to time.

5.6. Intermediate discussion

The value of the domain model is demonstrated in the observation that a non-domain expert can use it to engage with domain experts on a fairly intricate level. Questions such as "As opposed to a regulator without a spring adjustment knob, does a regulator that has one have a different design on the inside because there is a range of air flows that introduce variability in obtaining a laminar flow?" would be difficult to construct without a basis for reasoning, whether this is an external domain model or an internalised body of knowledge. The difference between both sources of knowledge (external/internal) exemplifies the potential of the demonstrated approach in *broadening the scope of collaborative innovation:* it allows a broader base of people to collaborate in a (web-based) product innovation process. In this case the potential innovation candidates could have been in the realm of e.g. a threaded heat sink, a non-ribbed heat sink, or an automated spring adjustment knob.

The application of the domain model in the context described above has to a certain extent demonstrated that it satisfies *Innovation Objective 1: artefact for reasoning in a product innovation context.* We have not applied the domain model as an annotation artefact (Innovation Objective 2: artefact for the semantic annotation of web resources) apart from the non-automated annotation of the forum discussions above. Based on the annotated concept density in the (very limited number of) forum posts, the domain model coverage does seem to be satisfactory for a prototype.

On the level of the domain model, there are a number of issues that still need to be addressed.

First, the component material property should be elaborated further. Classifications like `HardPlastic`, `SoftPlastic` and `MoldablePlastic` do not represent a good approximation of the state of the art in materials

science. Often the slightest change in a material property, which has not been elaborated greatly in this version of the domain model, will enhance the performance of a function. Although we do have sufficient quality properties to cope with these kinds of slight enhancements on a conceptual level, this granularity is lacking on the materials side.

Secondly, the possible level of granularity is virtually endless. The expectation here is that an optimal level can be found only after some iterations of the domain, the commitment of product engineering databases and the execution of some innovation processes.

A third point of attention is that the process realm of the domain model currently assumes a best-case scenario, i.e. a textbook perfect process. However, often functions are in place to prevent problems, which could prove catastrophic in this particular industry domain. The addition of critical failure processes would be a useful addition.

5.7. Scuba Diving Domain Innovation Process

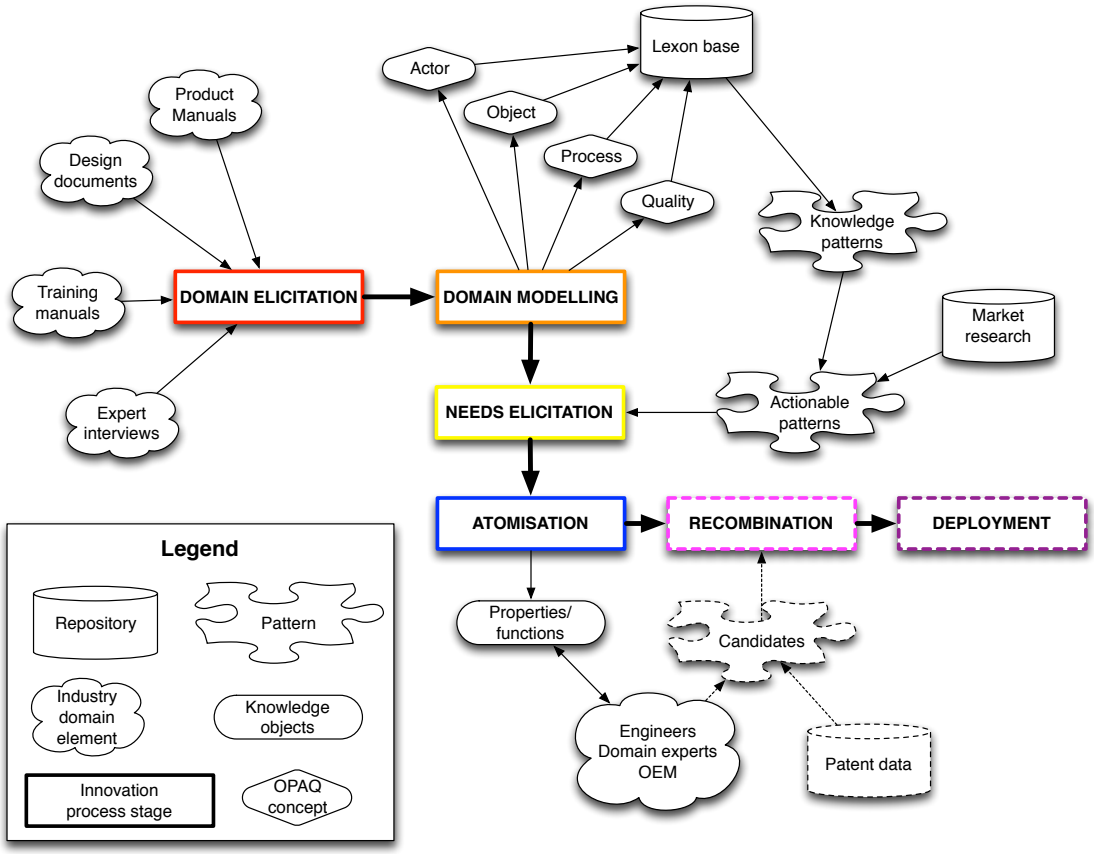

Fig. 5.10 Scuba Diving Equipment Domain Innovation Process

The application of the innovation process model (see section 3.4.3.2) to the case study of the scuba diving equipment domain results in a process model with six stages and varied knowledge interactions (Fig. 5.10). The needs laddering stage was appended in this case because there was no explicit market need that needed to be translated into the competency realm of the providers. Rather, the area of interest in the domain (the second stage regulator) was selected based on the academic qualities of the subject (such as degree of complexity). Additionally, considering the case study did not involve the actual engineering and deployment of new scuba diving equipment, the recombination and deployment stages are represented conceptually without having been executed (although they would have been the next step in the innovation process).

The input for the **Domain Elicitation** stage were product manuals, design documents, training manuals, and of course the expert interviews. This initial set of documents was used to elicit the main concepts of the domain. The output was a rudimentary domain model and the annotated transcript of the expert interview, which formed the input for the Domain Modelling Stage.

The **Domain Modelling** stage resulted in a domain model following the OPAQ principle (see above), with the lexon base as the main output. The lexon base in turn contains relevant domain knowledge patterns. It should be noted here that the output of the Atomisation stage (the atomisation of an actionable pattern into properties/functions) further offers input to the lexon base (i.e. those facts are also added).

The input for the **Needs Elicitation** stage were – depending on how one wants to define it – one or more 'actionable patterns' or areas of interest, in this case the second stage regulator (one pattern), or all components of the second stage regulator (multiple patterns).

Once the area of interest was defined, it was atomised into its properties and functions in the **Atomisation** stage. It should be noted here that the bidirectional arrow means domain experts can/should be further involved in this stage in order to validate the resulting properties and functions and their relations (in my case questions regarding the properties/functions that did not result from the interview were clarified further with the domain expert over the phone). The outputs for this stage were the properties and functions of the second stage regulator. In the forum discussions, what was essentially an ideation process was held with various actors such as a manufacturer (engineer/OEM) and senior divers (domain experts). Interesting to note here is that the ideation stage, which typically takes place in the first stage of innovation process models, is something that (a) occurs after the 4th stage, and (b) is not part of the core of this innovation process model. Observation (a) suggests that the 4 antecedent stages might be useful as an addition to other, more established process models already in place in various innovation settings. Observation (b) correctly suggests that the approach used in this research is partial to formalised knowledge on the level of that knowledge,

and is mainly interested in the explicated outputs of internalised knowledge. Those outputs would be candidate patterns with a different configuration of properties and functions (such as a non-ribbed heat sink, a threaded heat sink, or an automated spring adjustment knob – as discussed above). Patent data could also be included here as a possible input to rule out (in case of exact matches) and/or discover candidates (in case of similar property/function configurations from other industries).

The successful candidate property/function patterns would then be essentially recombined into a new, tangible product in the **Recombination** stage.

Ultimately, the innovation would be deployed in the market or to a test audience in the **Deployment** stage, after which its success could be measured and evaluated.

"You come to me for advice, but you can't cope with anything you don't recognise. Hmmm. So we'll have to tell you something you already know but make it sound like news, eh? Well, business as usual, I suppose."

Old man on a pole (Douglas Adams)

A Hitchhiker's Guide to the Galaxy

6. Chapter 4C: Online Travel Domain

6.1. Chapter Preface

This Chapter is based on following publications:

- Meersman, D. & Debruyne, C. (2011). Purchase Intent, Online Offers and Product Innovation: Misunderstandings in the Ménage à Trois. *BIS (Workshops) 2011: Springer Lecture Notes in Business Information Processing*, 132-143.
- Debruyne, C., Meersman, D., Baert, M., & Hansenne, R. (2011). Community Driven Requests for Proposals - Applying Semantics to Match Customer Purchase Intents to Vendor Offers. *Proceedings of WEB-IST 2011*, 525-530.

The roles of the co-authors were as follows:

- Myself: Initiation and conceptualisation of the proposal, and in charge of overall requirements, research design, and management of the project.
- Christophe Debruyne: main semantics expert, in charge of defining and developing the ontologies and overlooking the semantic data integration within the project.
- Mathias Baert: lead developer of the group buying company. In charge of integration, interface development, and deployment.
- Rami Hansenne: semantic matching expert, in charge of the design and development of the matching engine.

Appendices pertaining to this chapter are:

- Appendix VII: Online Travel Domain Model
- Appendix VIII: Online Travel Domain Software Descriptions

A Belgian group buying company identified several industry problems relating to the state of online commerce. The group buying company is an internet company with offices in Antwerp (Belgium), Amsterdam (Netherlands), and Dusseldorf (Germany). It was founded in 2008 and has rapidly grown into a rather large player in the group buying industry in Europe, with group buying actions of up to 60.000 participants. The industry problems identified by the company pertained to aspects such as lack of usability of unstructured online data, high advertising costs and low conversion rates, personal online privacy, lack of reciprocity between demand and supply, and the cost of customisation.

In several sessions over the course of two months, the problems were articulated further and paired with possible technological solutions. As a side-process, discussions were held with field experts from business and academia to compartmentalise the possible technical solutions in more granular building blocks.

The building blocks were then integrated in a project proposal that was submitted to the Flemish Institute of Science and Technology (IWT) for funding approval. The COMDRIVE RFP (Community Driven Requests For Proposals) project was awarded an AA rating by IWT, and subsequently executed by the project participants. The project ran for 18 months, with two development cycles and a pilot study in month 15 of the project. The team was distributed over Belgium, the Netherlands and Australia. Contact was held with three-weekly teleconference meetings, half-yearly physical meetings, email and telephone.

6.2. Introduction

When consumers want to buy a certain item on the Web today, they have to browse through hundreds of offers and results and this number is expected to increase in the future. In this model, the vendors drive the process by publishing products and providing means to buy these online. For example travel agencies in the Netherlands need to query many different tour operators to find holiday packages meeting their customers' requirements.

They often have an API that facilitates this process, but the granularity of the specific search is often limited due to the heterogeneous nature of all vendor databases.

A solution to this problem would be to allow the consumers to specify their requirements and to match these to offers of different vendors. The COMDRIVE RFP project (Debruyne et al. 2011) resulted in a platform enabling consumers to drive the requirements process by expressing their intent to buy a certain product in a tool and language they are comfortable with. This platform sends out the request to a distributed vendor infrastructure, which responds to the request with offers.

For this solution to be effective, a common vocabulary between the consumers and the vendors has to be established. Such a vocabulary can be captured in an ontology. An ontology is commonly defined as: *a [formal,] explicit specification of a [shared] conceptualization* (Gruber 1995). Ontologies are necessary to enable semantic interoperability between information systems and services on the Web (Guarino 1998). In general, interoperability is defined as the ability of two or more information systems or their (computerized) components to exchange data, knowledge or resources and to interpret the information in them (De Leenheer 2008), in this case the COMDRIVE RFP platform and the different vendor applications.

The pilot partner for the project was the publisher of the largest winter sports platform in the Netherlands, with an average reach of 600.000 visitors per month. The content of the platform is characterized by current information regarding winter sports areas and a large amount of community generated information. Participants in the project were the director and the technical lead of the platform, and hundreds of end-users. The examples used in this chapter stem from the domain of winter holiday packages (including winter sports, accommodation, facilities).

6.3. Background

6.3.1. Problem Scope

Based on initial conversations with the group buying company, I articulated 6 problems in the marketplace, and paired those with solutions.

Table 6.1 Problems and projected solutions

1	**The online world is largely flat**
Problem	Purchasing on the internet is still in its infancy. As more and more vendors turn to the internet for selling their goods, the internet holds an ever increasing amount of unstructured product data, which makes it harder for users to find what they are looking for and more difficult and for search engines to filter search results. Basically a vendor flattens out the (previously structured) product data to represent it in a web mark-up language (e.g. HTML). This is a major source of loss of information, which causes great inefficiency and which no search algorithm in the world can fix.
Solution	*We will build an RFP prototype which keeps vendor product data intact by natively supporting product semantics and by adhering to international product classification standards. The product semantics will be defined by community stakeholders. The semantics underpinning data structures of a certain product domain will be generated by the community itself. [Company3] will develop a semantic matching engine which will be able to match rich semantic product data to standard vendor product data (i.e. matching RFP's to product offerings and their vendors), with the option to take into account non-product related factors. We will also introduce an innovative way of browsing product concepts through node cloud navigation, which merges the ease of use of bottom-up dynamic tag clouds and the processability of top-down structured data. Our approach will reduce search inefficiency and*

increase retrieval speed for internet users. We will research what the best visualisations and configurations are for the node cloud navigation with regard to speed and usability.

2	**Advertising is expensive and inefficient for vendors**
Problem	There is an enormous amount of money spent on advertising ("the attention economy"), whilst conversion rates (the rates of advertising-induced website visits converting into a sale or other desirable action) are at an all-time low: they are currently only somewhere between 1 and 3 percent. The reason behind these low conversion rates is that advertising uses the shot of hail technique: you fire a lot of messages into peoples' lives, hope some stick, hope some people consider buying and at the end of the funnel, hope to make a sale. The problem lies in the fact that you are often merely dealing with passers-by, who are not necessarily interested in your product.
Solution	*We will turn this model around by offering intentions to purchase (expressed by communities or individual users) to vendors, who can then act upon these qualified leads in a more efficient and less resource consuming way ("the intention economy"). Whilst the primary focus of our company is to improve the user experience of online purchasing, our approach constitutes a reduction of operational costs and increased profitability for vendors, creating a win-win model.*

3	**Personal privacy is gaining importance**
Problem	Whilst people surf the net in search for product (and other) information, they are constantly monitored in a way that would not be acceptable in real life, and are often required to submit

	personal data to access certain information. New legislation and the enforcement of existing legislation in Europe and the United States are expected to increasingly prohibit current user monitoring and behavioural targeting practices.The collected data is used to make assumptions about user preferences and behaviour, but is in the end worth nothing more than... assumptions. Also, because the user is not in control of his or her data, erroneous assumptions can be introduced and cannot be filtered out.
Solution	*For users, our model enhances user privacy by only sharing relevant personal user data with the winning vendor. For vendors, we will offer some community metadata, which will provide community-specific information in a meaningful way. This semantic layer will ensure that our platform does not become yet another silo, but can in fact connect with other standards adhering communities.*

4	**Demand and Supply have no reciprocal relationship**
Problem	Currently there are little to no tools available for users to engage in a reciprocal relationship with vendors online. Vendors carry the full burden of maintaining CRM systems, whilst users cannot change the content of these systems. Our company is a leading participant in Project VRM, which is led by the Harvard University Berkman Center. Vendor Relationship Management (VRM) is the next big thing and aims to develop tools to improve the relationship between Demand and Supply by providing new and better ways for the former to relate to the latter.
Solution	*VRM intends to improve markets and their mechanisms by equipping customers to be independent leaders and not just captive followers in their relationships with vendors and other parties on the supply side of*

the marketplace. Our company is driven by this impetus and has a proven track record in improving user relations with vendors by aggregating user intentions for leverage purposes. Our company has already built up a solid and growing user base of 2500 active and recurring households in group buying initiatives for heating oil, and we have expanded this model to gas and electricity in Q1 2009. Based on current statistics, we expect an even bigger uptake and are working diligently to create a snowball effect. Some outcomes of our model are a significant price reduction (for heating oil more than a quarter of a million euros in three months) and improved buying conditions for our users (for electricity and gas, all participating vendors agreed to drop the flat fees from their pricing structure and just let people pay for what they use, which is unprecedented in Flanders). We now want to expand this model to individual users using state-of-the-art technology, which will be developed in this project.

5	**Setting up communities sometimes costs more than the potential revenue**
Problem	The sudden success of our company has led to increasing overhead when setting up new communities. The current group-buying model, which is a solid web-based application, needs automation and additional functionality with regard to scalability of new community portal set-ups. Besides being able to cater for more communities faster, by implementing a fully automated system the threshold for the types of products that can be bought will drop and hence the product portfolio can expand towards 'long tail'. Every time a group buying initiative and auction is executed, set-up costs need to be deducted from made revenues. For heating oil, electricity and gas, the revenues cover the set-up costs, but for gasoline cards, although in high demand by the

	community, the margin is too low and thus currently out of reach. The types of communities [Company3] is working with vary from purpose-driven communities (which are set up specifically for group buying) and budding communities (largely off-line communities that are moving towards an online presence) to fully fledged online community portals (who need group buying functionality built into their portal).
Solution	*We want to make it extremely easy and fast to set up a group buying initiative and wants to cater for different community needs with regard to various functionality such as auctions, calendars, user management with specific attention to privacy and not-another-silo techniques, blogging, forums, visual customisation, etc. Our company will develop an additional Facebook application interface using the Facebook API and also intends to offer native support of OpenID and OpenSocial, so that existing communities and social networks can simply connect to our platform to create additional revenue streams as the current advertising crunch is cutting into their budgets.*

6	**The e-commerce market is growing, but crowded and lacking incentive**
Problem	Our research clearly shows that although there is a rise in the number of vendors selling through the internet and an overall increase of internet sales in terms of revenue, the market share of e-commerce with regard to traditional commerce is still very low, given the high internet connectivity rates of households in Belgium. Some barriers for the adoption of e-commerce include low levels of trust and lack of a perceived necessity of the concept of e-commerce. The vast majority of current e-commerce platforms uses the metaphor of online stores, trying to mimic a real life shopping experience and presents itself as a mirrored

alternative of a real-world setting (i.e. atomic stores with a limited offering).

Solution	*The COMDRIVE RFP platform will resolve the issues above through a variety of mechanisms. The community and group buying approach has a considerable 'pull' effect for users who have never before engaged in e-commerce activities: paper applications for our group buying initiatives (aggregated by community leaders) are sometimes as high as 80 percent (as opposed to online applications). The leverage effect of the group buying concept itself allows vendors of less obvious products, such as heating oil, gas and electricity, diapers, etc. to expand their activities onto the net and tap into new markets. The RFP approach does away with atomic vendor structures and integrates vendors in a network. The metaphor of the online store is absent in the model, where the internet medium is used for defining RFPs, initiating group buying processes and systems communication. In a more advanced model of the RFP prototype, we will include vendor trust barometers, which aid users in choosing the right proposing vendor.*

6.3.2. Innovation Objectives

The project aimed to develop a fully automated, flexible, extensible and adaptive RFP prototype that allows (community) users or groups of users to express their intent and request proposals from a dynamic vendor network. The problem-solution scope was translated into following measurable innovation objectives:

Objective 1: Integrated Personal RFP prototype

A fully automated, flexible, extensible, semantic and adaptive RFP prototype that allow users to express their intent and request proposals from a dynamic vendor network and allows communities to generate additional revenue streams.

Objective 2: Personal RFP Meta-model

A semantic, extensible and interoperable conceptualisation of RFP. The meta-model describes the upper ontology for domain-specific Personal Requests for Proposals, allowing communities to contribute product- and domain specific concepts through a collaborative knowledge engineering platform.

Objective 3: AGB Module

A fully automated group buying (AGB) module that allows community leaders to initiate and organise their group buying activities online with their community members (with support for member group buying process initiation). Community plug-ability support and social networking components development and integration to be able to accommodate both highly developed and budding or purpose driven online communities. Support for OpenSocial and development of additional Facebook application interface.

Objective 4: Semantic Matching Engine

Matching of customer intent and vendor offering based on shared, personal customer purchasing profile and community profile for accurate offerings based on pre-defined and implicit criteria. Matching of semantic product data and flat vendor data for vendor offering relevance assessment within context.

Objective 5: Rapid Semantic Node Cloud Navigation

Dynamic node cloud underpinned by semantic product data for fast navigation through correlated product concepts. Combination of ease of use of tag clouds and processability of structured data.

6.4. Approach

The COMDRIVE RFP project developed a platform where consumers can express their intent to buy a certain product (Personal Request For Proposals) in a tool and language they are comfortable with. This platform sends out the request to a distributed vendor infrastructure, which responds to the request with proposals. The Personal RFP system is composed of a web application

that uses a rapid node cloud navigator to create RFPs for which offers are found by a matching engine, using an ontology which queries different vendor databases.

Fig. 6.2 shows how the different components interact within the platform. Users are able to express their purchase intent through the portal, which has a dynamic interface (Fig. 6.1), using the ontology. When requests are entered, the matching engine interprets the request and annotated vendor databases to find matches, which are sent back to the customer. The whole platform is driven by the request and product ontology and is semantically underpinned in that sense.

Fig. 6.1: The interface, driven by the ontology, aids the user in expressing their intent. In this example, the user is asked to give one (or more) possibilities for Ski Area ("Skigebied" in Dutch), Auto-completion relies on accessing the data through the application commitment.

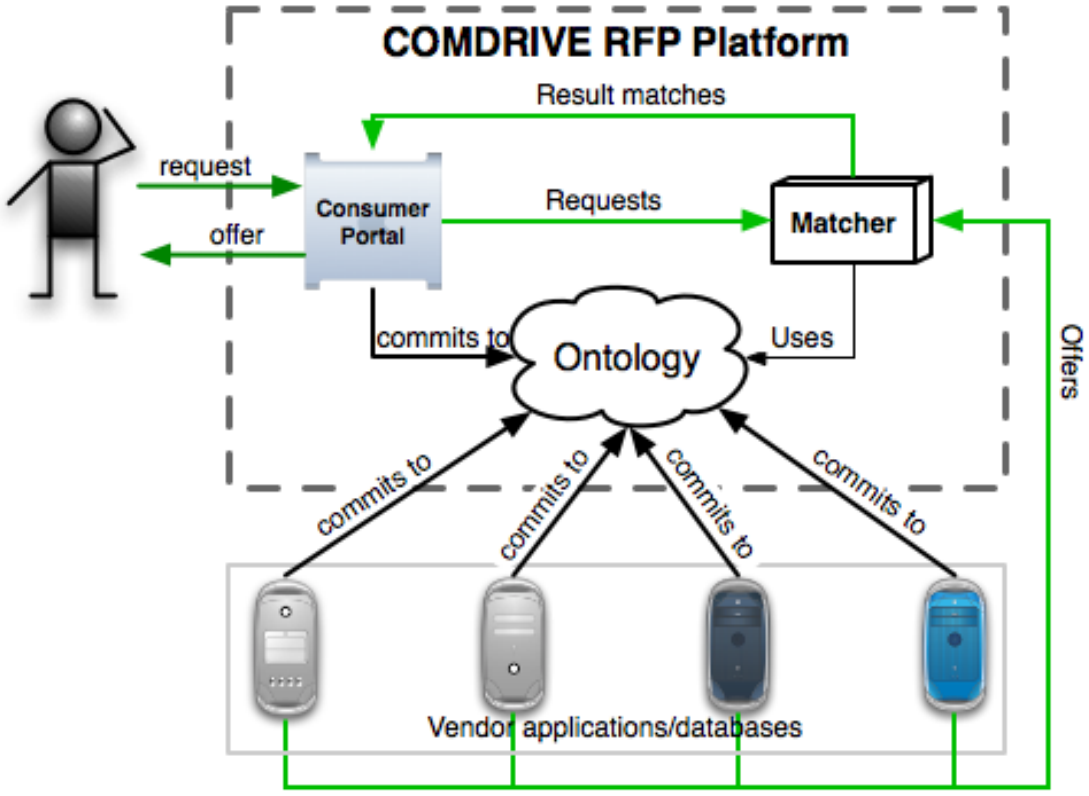

Fig. 6.2: The interaction between the COMDRIVE RFP Platform's different components.

The ontologies do not emerge by themselves, buyers and vendors need to share and reach an agreement on a common vocabulary of the domain. More specifically, software agents need to interpret the information in the customer's purchase intent to automatically match this information with vendor offers based on their semantics. A conceptualisation provides a shared agreement on the semantics of core concepts and the relationships between them, imposing a structure on the domain that is readable by both humans and machines.

6.4.1. Meta-Model

Customers express their intent in their own language. Vendors offer their offers in different formats with varying conceptual coverage. Both sides need to share a common vocabulary to be able to interact through the system. In our platform, software agents interpret the information in the Requests for

Proposals and match them to vendor data streams. Out of the many collaborative ontology engineering methodologies that exist today (Sure et al. 2009), DOGMA was adopted (Jarrar and Meersman 2009), which stands out for its groundings in linguistics. DOGMA relies on the fact that knowledge building blocks, expressed in natural language, are easily obtained and agreed upon (as inspired by database modelling methodologies such as NIAM (Wintraecken 1990) and ORM (Halpin 2008), allowing domain experts and knowledge engineers to use natural language to communicate and capture knowledge. The knowledge building blocks - called lexons - in principle only need to express "plausible" facts (as perceived by the community of stakeholders) in order to be entered into the Lexon Base, a repository containing large sets of such lexons. A lexon is formally described as a 5-tuple `<G, head, role, co-role, tail>`, where `G` is an abstract context identifier (e.g., a document on the Web) and used to identify unambiguously (to human users at least) the concepts denoted by the term and role labels. Ontologies in DOGMA are selections of such lexons with constraints on their usage (e.g., "A person can have at most one Name").

It should be clear that DOGMA is only the method to reach agreements amongst different stakeholders. Ontologies in DOGMA are actually "representation agnostic": they can be implemented with other formalisms such as RDF(S) and OWL. DOGMA thus precedes the implementation of ontology, and can be repeated to incrementally grow and refine the ontology. Once agreement has been established and an appropriate mapping of (for instance GoodRelations) has been given, the concepts in the DOGMA ontology can be integrated with that particular schema by generating the necessary classes and properties.

Before building an ontology from scratch, one has to assess existing meta-models that describe products (not necessarily implemented with Semantic Web technologies) (Hepp et al. 2007). Four important product meta-models

were analysed and compared: eCl@ss[1], UNSPSC[2], EOTD[3] and RosettaNet Technical Dictionary[4]. Both eCl@ss and UNSPSC are broad: the first was created by and driven by the German industry and is thus a "de facto standard", whereas the United Nations Development Programme drives the development of latter. Both UNSPSC and eCl@ss provide very little detail for the travelling domain. The others were designed for more technical industries and did not fit the scope of this project.

Travel industry meta-models include Hi-Touch[5], OnTour[6], Harmonise (Dell'Erba et al. 2002) and the Open Travel Alliance specification[7]. Harmonise focuses on accommodation and events (e.g., sports and conferences), but its main aim is to transfer data between tourism industry partners. Hi-Touch is a commercial thesaurus implemented in OWL to align different vendor databases. OnTour, a recent initiative, mainly covers accommodation and activities. Open Travel Alliance provides a structure for electronic messages, e.g., concerning flights, insurance, etc. Hi-touch and OnTour ontologies were developed based on international standards whereas Open Travel Alliance and Harmonise provide their own.

The product ontology was bootstrapped drawing inspiration from the existing meta-models and vendor applications, which were then refined and completed by several domain experts. Domain experts with different views on the domain, such as tour operators for the vendor perspective and a community of skiers for the buyer perspective, were consulted. Fig. 6.3 shows few of the hundreds of lexons created for the purpose of this project.

[1] http://www.eclass-online.com/
[2] http://www.unspsc.org/
[3] http://www.eccma.org/
[4] http://www.rosettanet.org/
[5] http://www.mondeca.com/
[6] http://e-tourism.deri.at/ont/index.html
[7] http://www.opentravel.org/

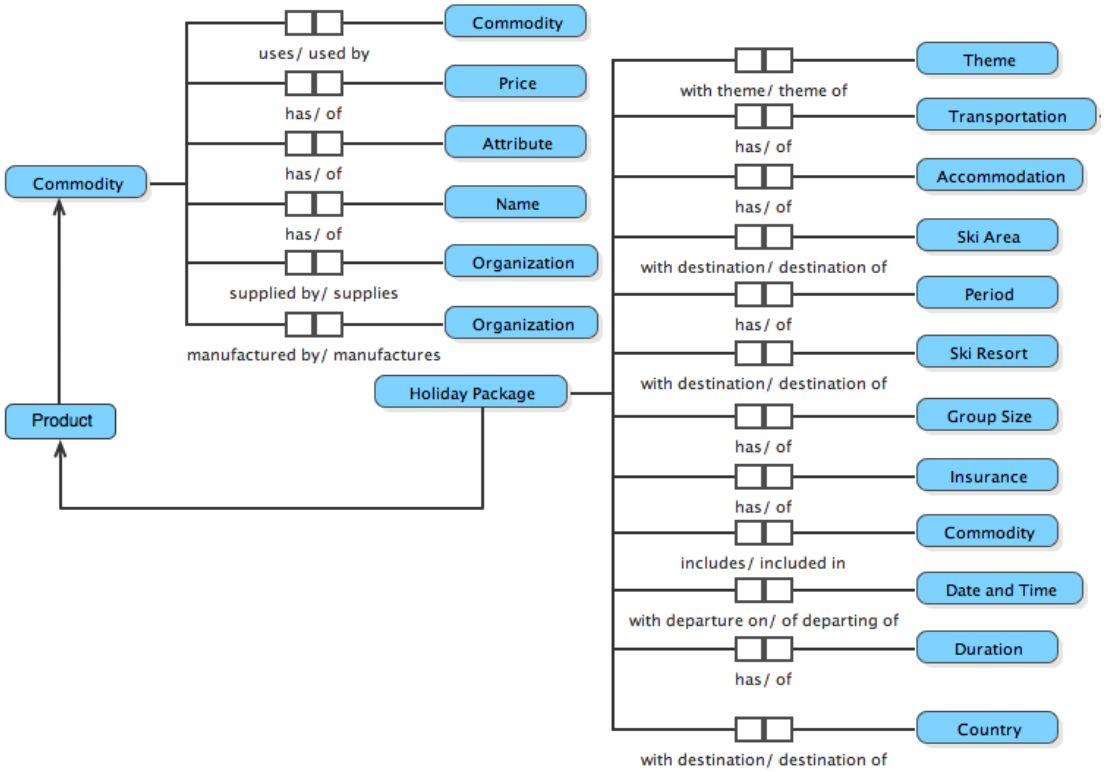

Fig. 6.3: Some lexons describing domain knowledge developed during the project. These lexons describe holiday packages and commodities, and how holiday packages inherit the properties of commodity by the is-a relationship denoted by the arrow.

The ontology was developed in a modular way, as shown in Fig. 6.4. The *Upper Common Ontology* contains the conceptualizations and semantic constraints that are common to and accepted by a general domain, in this case `Product`. For instance, the lexon `<G, Product, with, of, Price>` is true for all applications of stakeholders within that domain and therefore belongs to that layer. The *Domain Application Ontology* contains lexons specific to a certain application domain. In the case of COMDRIVE RFP, these lexons will contain the terms `Holiday Package` and `Accommodation`. The *Lower Common Ontology* represents the interpretation of the domain from the perspective of an organization or community. For instance, the representation of a `Price` might change depending on the community: from a buyer's perspective it is represented by a `Range`, whereas from a Vendor's perspective it is represented as a `Value`. Whilst the ontology evolves, this

layer contains the information that is going to be refined by a core domain expert to be integrated in the Upper Common Ontology. The different modules are then connected by matching context-term pairs. In the lexons shown in Fig. 6.3, the facts around Holiday Package would belong to the Domain Application Ontology (including the fact that a `Holiday Package` is a `Product`) and the facts and the facts around commodities and products to the UCO.

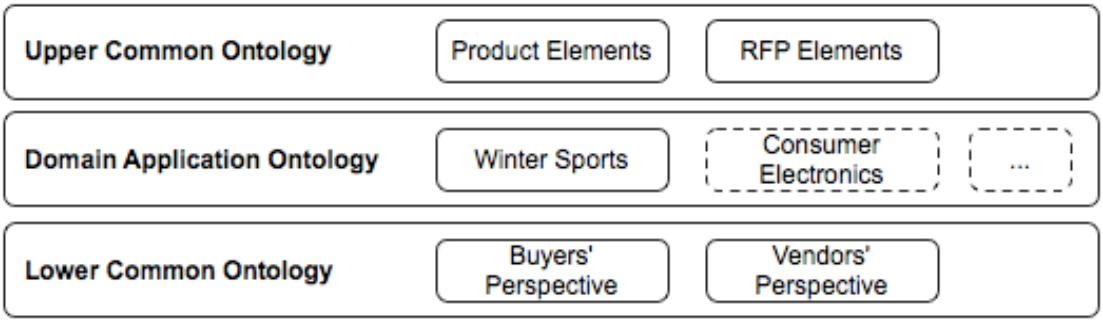

Fig. 6.4. The modular structure of ontologies modelled with DOGMA within the COMDRIVE architecture

Applications commit to the ontology by annotating the application symbols (e.g., fields in a database or tags in an XML schema) with concepts and relations in the ontology. An application commitment thus represents an explicit interpretation of an ontology for an application or a family of applications. In DOGMA, those annotations are made with Ω-RIDL (Verheyden et al. 2004). It consists of a selection of lexons from the ontology, which are relevant for the application, the constraints to specify how that selection can be used (mandatory and uniqueness constraints, for example) and a set of mappings between the application symbols and the symbols used in the ontology. It also provides some scripting functionalities allowing database programmers to manipulate instances whilst accessing the data. Fig. 6.5 shows some examples of Ω-RIDL statements.

Constraining lexons

Holiday Package is identified by Name. Holiday Package has exactly 1 Name. Holiday Package has at most 1 Name.
Mapping application symbols
Map "/items/item" on Holiday Package. Map "/items/item/title" on Name of Holiday Package. Map "/items/item/description" on Description of Holiday Package.

Fig. 6.5: Example of how lexons within an application commitment can be constrained and mapped onto application symbols.

This method was applied to construct the ontology that drives the COMDRIVE RFP platform. The matching engine exploits the application mappings expressed in Ω-RIDL to access the data by generating queries in vendor applications for comparison against the intent. As the interface of the platform is also driven by the concepts and relations described in the ontology, the COMDRIVE RFP platform is completely underpinned by semantics.

6.4.2. Annotation of Vendor Data

An application commitment represents an explicit interpretation of an ontology for an application or a family of applications. It consists of four things (Verheyden et al., 2004): (i) a selection of lexons from the ontology which are relevant for the application, (ii) constraints to specify how that selection can be used (mandatory and uniqueness constraints, for example), (iii) some scripting functionalities allowing database engineers/programmers to manipulate instances during the transformation process and (iv) a set of mappings between the application-specific symbols (e.g., XPath expressions) and the concepts used in the ontology. Fig. 6.5 shows how an application commitment of a vendor application constrains the use of lexons and the mapping to its application symbols. The transformation is performed by Collibra Business Semantic Enabler (included in BSS).

The effort needed to annotate the data of one vendor generally took one day when using BSS. The BSS commitment editor generates all occurring XPaths

which the users need to annotate with lexons from the ontology by means of drag and drop. Constraints are created either via a graphical editor or a controlled natural language as shown in Fig. 6.5.

6.4.3. AGB module

The automated group buying module enables communities to organise a group buying action for a variety of products. The software allows the community leader to handle most time intensive tasks himself, adding scalability for the partner company and a chance for the community leader to provide added value to his community. The group buying application is designed to be quickly customizable. A community group buying action with the logo and brand colours of the organizing partner can be set up in minutes. The application contains a FAQ section, product specific information pages which can be tuned to the community if needed and a prominent placement of community specific content on the homepage, which can be used as a community blog. The AGB Module holds various functionalities for community leaders and members. Leaders have a range of administration functionalities at their disposal. Community leaders can do first line support for their members. This enables the community leader to engage their members and reduces the overall time spent by the partner company on individual group buying actions, which increases scalability.

6.4.4. Semantic Matching Engine

The Personal RFP web application makes use of a semantic matching engine to select and present suitable vendor offerings based on customer intent (RFP) and an optional community profile.

The matching engine is an advanced search engine for analysing structured, semi-structured and free text data. Contrary to classic searching and querying technology, matching functionality will take into account the semantic context of concepts to match upon and it also returns *close* matches if no *exact* matches can be found. The engine scores and ranks the matches based on the degree in

which they match, taking into account configuration parameters such as weights, thresholds and optionality/requiredness of conditions.

The matching engine provides generic matching functionality and its interface is not specifically geared towards the notions of RFP or vendor offerings. Instead, from the match engine perspective, it simply matches match queries containing match conditions against a collection of match objects. A match property is a basic entity upon which can be matched. These match properties could be criteria such as price, age, distance, etc. A match object aggregates a number of match properties and assigns them specific values. Examples of match objects are: RFP, vendor offering, etc. A match condition represents the re- quested or "ideal" property. It is passed to the engine to compare with all known match properties that have the same id (and therefore same semantics) and to re- turn all match objects which match the query conditions as close as possible.

A list of all properties known to the engine is defined in the match engines ontology mapping (Ω- RIDL file), which maps the relevant concepts in the ontology to the match engines internal format. The matching engine commits thus to the ontology in the same way as a vendor applications. The mapping used by the engine is quite straightforward and simply maps each "matchable" concept to a match property of the corresponding type, using the path in the ontology as ID. The transformation service mentioned above takes care of transforming vendor offers into match objects.

6.4.5. Rapid Node Cloud Navigation

The main goal of the COMDRIVE RFP project is offering consumers an easier way to find the goods and services they are looking for by means of a personal Request for Proposal (RFP). From a user experience point of view, the biggest differentiator is the Rapid Node Cloud Navigation (RNCN) which is the visual component in the COMDRIVE platform that lets users configure their RFP in a quick and intuitive way. The RNCN makes the ontology visually navigable to the user. Doing this, the user creates an RFP. The offers matching the RFP are interactively shown. The user can refine these results by

either refining the importance of different aspects of his RFP or by modifying the RFP itself.

The main focus of the RNCN design is usability. A user must be able to quick and easy enter his or her wishes in the RNCN, configuring the RFP. The eventual design is the result of several design iterations, which have been tested using paper prototyping. This means it was possible to try out the user interface interaction with actual users, before implementation. Some of the initial assumptions did not withstand this process and had to be removed, in particular drag and drop and detailed representations of the relations between the different concepts in the RFP were more confusing than helpful to the users.

6.5. Case Study

Milq Media[1] is the publisher of the *wintersporters.nl* platform and agreed to take part as pilot partner in our project. Wintersporters.nl's content is characterized by its actuality and a large amount of community generated information. With an average reach of more than 600.000 visitors per month, it is the largest winter sports platform in The Netherlands. The pilot ran from Monday 4th October 2010 until Friday 29th October 2010. It was agreed with Milq Media to let the community test the interface to validate the assumptions and results of the project. Their forum provided feedback that enabled us to solve some of the initial bottlenecks in the pilot (e.g., suggest a starting point when users don't know where to start). 38% of the purchase intents were completed. The focus here is on the pilot evaluation aspects relating to the ontology. These aspects include: result accuracy, result completeness, and concept coverage. The accuracy of results improved significantly during the pilot as it was possible to tweak the parameters of the fuzzy matching engine according to the actual user queries to deliver better results.

[1] http://www.milq.nl/

Because of the heterogeneous nature of the vendor data streams, data that was present with one vendor, was sometimes not present with another. For example pictures were not present in all offers, which has implications for the uniformity of the results sheet.

The most important issue experienced was a serious discrepancy between what concepts and level of granularity the user thinks are important in defining an intent (the "ideal image") and what is offered by vendors. Multiple posts on the pilot forum thread (which had over 100 posts) related to the inability of users to express their intent fully. For example the size of the ski area, the height of the ski area, the presence of après-ski facilities, the calmness and/or cosiness of the environment, the presence of nice restaurants, the ability to buy travel insurance, ski bus distance, the grade of luxuriousness of the hotel or apartment, etc. This kind of data is not present in the vendor data streams, but constitutes *peripheral data* that is important in booking a ski holiday. Peripheral data is data that is used by the customer in the purchase decision process, but that is not part of the offering of the product or service provider. This kind of data directly relates to the function the user want to see performed by the service they book: to be relaxed, to have fun, to be satiated with good foods, to enjoy the scenery, to be safe, etc.

It can be seen that merely building ontologies on top of the data that is provided by vendors does not solve the problem of finding products that match user needs. When given the liberty of defining one's wish, users demonstrate the desire to involve peripheral data that pertains to the product application domain. Although some of these concepts were present in the ontology, there was no data to work with.

Committing to the ontology is not just a question of mapping existing data fields. The commitment will have to entail changes to the internal vendor data structure, for example added granularity or new peripheral concepts. As the business environment changes, vendors need to put on the hat of or work with their producers and innovate products and their respective representations so that they better correspond with the purchase intent of users.

When a user searched for a product he or she had an ideal image in mind. Through queries and navigating the node cloud the user approximated his or her ideal image by mapping the offers to what was in mind. Eventually the user made a choice and purchase if the offer mapped satisfactorily to his or her ideal image (notwithstanding eventual ideal image transformations influenced by and during the search process). What was completely lost in this process is the original intent, the ideal image or the imagined product the user had. We just know that he or she purchased something that approximated it. This misunderstanding shown in the triangle in Fig. 6.6 means that no optimisations can be made in terms of product offering, categorisation, presentation or engineering, other than through exterior (and posterior) processes like customer satisfaction analysis and other market research methods.

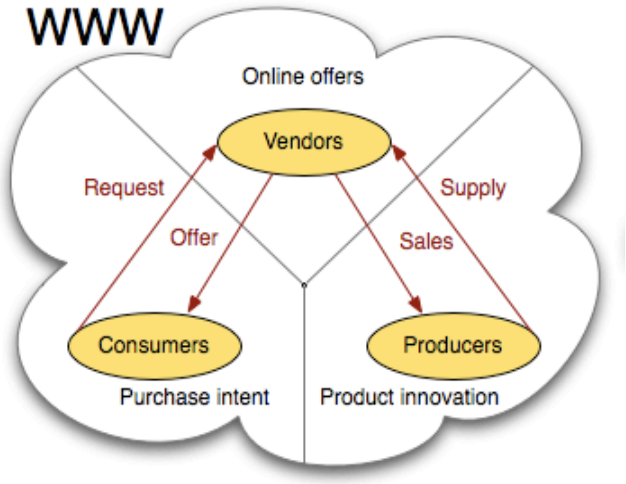

Fig. 6.6: Producers lack insight in evolving customer preferences and needs on the Web.

It can be argued that for product offers on the Web to improve in terms of matching user needs, the information expressed in purchase intents should correspond to structured data about the product application context. In other words, the entire domain in which the product is used needs to be modelled on the side of the vendor and producer.

In the winter sports pilot, there were several types of peripheral data that were entered by the users: structured data such as ski area size and height, but also concepts such as 'cosiness' and 'luxuriousness', which are user profile dependent.

Integrating peripheral data in one's data structure allows producers to innovate directly based on user desires as perceived through intent definitions and vendors to better tailor their offers to user needs. This is the crux of the problem in product search today: producers fail to realize that users performing queries are a vast (potential) source of direct information for innovation processes.

6.6. Intermediate discussion

The type of information that is most important in an innovation process is how the user perceives a product and what it *will do* for him or her. This information is essential in moving the product, but is also exactly the type of information market input in innovation processes should consist of. Producers think in terms of properties or features, whilst consumers think in terms of functions, or the "job they want to get done" by using the product or service (Christensen et al. 2007).

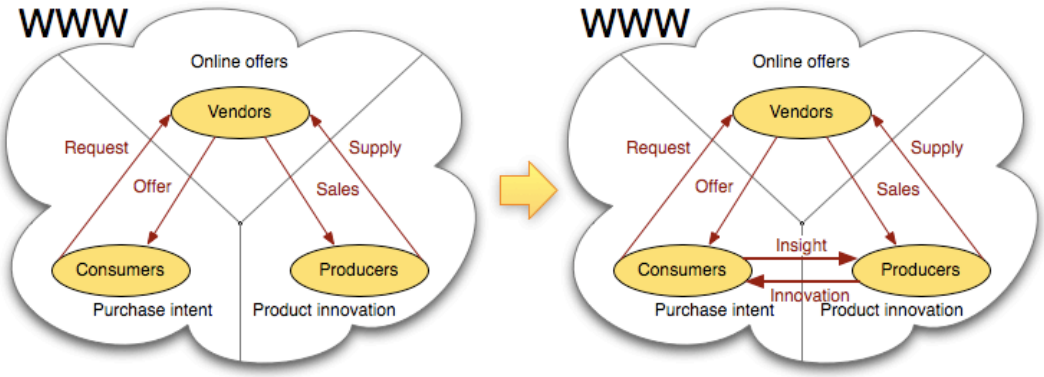

Fig. 6.7: Producers can use peripheral data to gain consumer insight and drive their product innovation, and (indirectly) supply better information to the customers through the vendors.

Whilst the properties of a product are per definition stable and known, the context in which it is used or even how it will be used are usually quite difficult to predict. The notion that Thomas Edison thought of the phonograph as a device that would be used to "record the wishes of old men on their death beds" (McDonald e al. 1987) is only one of many examples that the market frequently puts solutions to use for initially unexpected needs. If an organization wants to keep in touch with all the ways its products are used (and use that information to drive innovation), this information will have to come from the market, as shown in Fig. 6.7.

This approach could also offer contribution to bridging the ontology engineering lag. This conceptual dynamics bottleneck is essentially a lack of coverage of concepts by an ontology in a reality that is continually changing. When the concepts in a domain change, there is a "maintenance lag" in the ontology engineering process (Hepp 2006). If we look at the causes of conceptual dynamics in corporate environments, these will often be changing market conditions.

In the COMDRIVE RFP project, the initial outset was to improve product search on the Web by capturing the purchase intent of customers and match that to vendor offers using a request and product ontology and fuzzy matching engine. Although a success in terms of the ontology, we discovered an important gap between the intent descriptions of users and the available data in product descriptions. Users demonstrate the need to use *peripheral data* to describe their purchase intents. This can urge one to revisit the entire idea of product ontology and involve not only the customer and vendor side, but also and importantly the producer side of the equation, to establish a common understanding in the ménage à trois between these economic partners. Through capturing purchase intent including peripheral data (functions and application context), vendors are able to grasp evolving needs and preferences and innovate accordingly. The result is essentially a customer-driven innovation system that satisfies users with (increasingly) relevant results, and offers vendors a cost-effective way of gathering accurate insight into customer needs and preferences.

6.7. Online Travel Domain Innovation Process

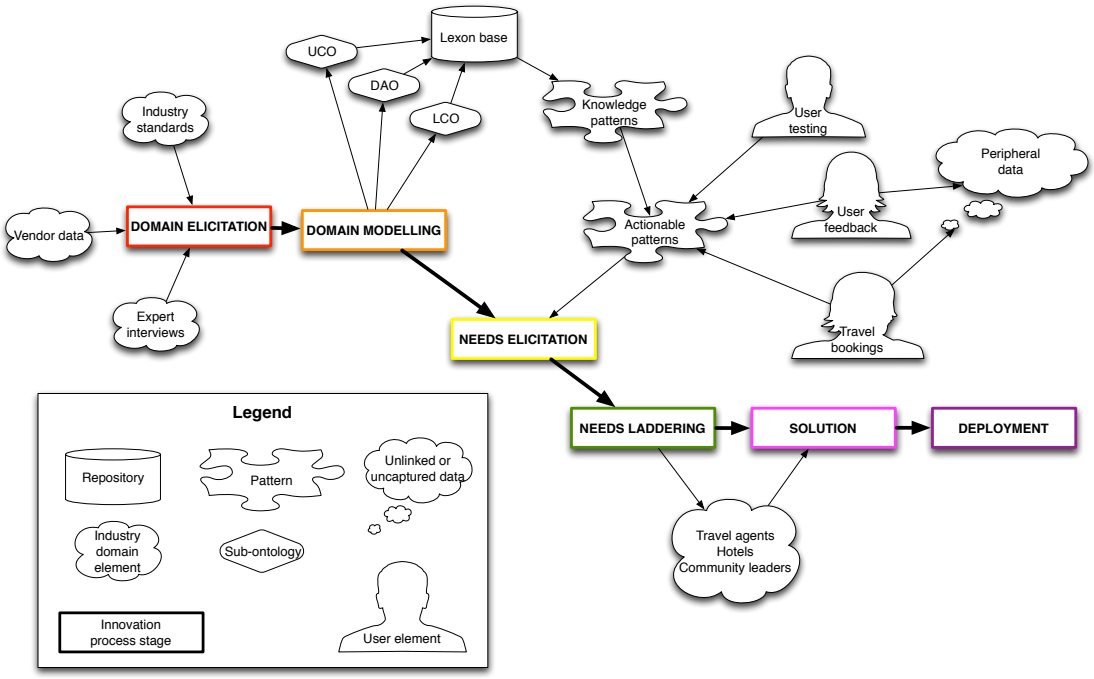

Fig. 6.8 Online Travel Domain Innovation Process

This domain is different from the previous two domains in the sense that in this project we developed a system for bottom-up innovation in that domain (amongst other functionalities such as transactions and group buying). This innovation process depicts the innovation process *enabled by* the information system developed in the project, and to an extent the development process of the system itself. This is also one of reasons why a separate design science process and innovation process are methodologically justified (notwithstanding other merits of the distinction).

The application of the innovation process model (see section 3.4.3.2) to the case study of the online travel domain results in a process model with six stages and varied knowledge interactions (Fig. 6.8). The atomisation stage was appended in this case because the communications from the users are passed along to the industry actors (travel agents, hotels, community leaders) who can use this to improve services. In this sense, the processes in place are

all about getting the right data to the right actor in the innovation process in the context of problem identification and ideation.

The inputs for the **Domain Elicitation** stage were the various industry standards, vendor data, and expert interviews (see section 6.4.1). The **Domain Modelling** stage used the DOGMA approach, but differed in that it worked with an equally suitable, but alternative hierarchical classification scheme according to the preference of the research partner. Important to note here is that the lexon base did not contain facts that fell outside of the scope of standards for travel information exchange. This translates to the knowledge patterns reflecting the top-down industry viewpoint of the domain. We see that the user interactions in this project fall apart into two parts: actionable patterns and peripheral data. Actionable patterns in this case are queries in the online travel process. Peripheral data is information that is part of a decision making process by a customer, but that is not captured or known for a reason. This brings to bear a very important notion at this stage: the platform.

In this project, the platform represents that which enables information and services to be delivered. Taking into account Gawer's (2000) definition, and considering peripheral data was demonstrably lost, one could propose a more elaborate working[1] definition: a platform is a relatively stable entity that enables *and constrains* the delivery of a variety of information and services by a provider to a customer. In the case of this project, the platform consists of the network, hardware, software, and standards. It is in the product classification standards used by industry that the platform falls short and is unable to process peripheral data. As discussed above, one could build workarounds that do capture the data, but the whole point of a standard is that every stakeholder can work with it in the same way.

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[1] The qualification of this current definition as a working definition is due to a further theoretical elaboration in the Synthesis chapter.

The **Needs Elicitation** stage hence only has as input those patterns that system was able to handle: selections of travel options as the sole expression of purchase intent and customer preference. Not surprisingly, the **Needs Laddering** stage is feeble: by having customers talk the language of vendors, the needs of customers are channelled and translated beforehand to only those options that can be processed by the matching engine. This is great from a transactional e-commerce standpoint, but less great when considering the importance of collective intelligence in the ideation process.

The limitations of the platforms relegated what should have been a dual purpose system to the primary function of delivering solutions in the form of possible travel packages to the users in the **Solution** stage, and the subsequent consumption of the package in the **Deployment** stage in a traditional process where customer feedback on the service is outside of the grasp of the information system. Even in the best-case work-around scenario, where feedback could be gathered from external sources, there is no clear way to couple individual feedback to the original intent because the peripheral data was never captured. It should be clear that a lot of potential is being left on the table by the travel industry.

"To keep every cog and wheel is the first precaution
of intelligent tinkering."

Aldo Leopold

A Sand County Almanac, and Sketches Here and There

7. Chapter 4D: Ambient Assisted Living

7.1. Chapter Preface

This Chapter is based on following publications:

- Meersman, D., Hadzic, F., Razo-Zapata, I., De Leenheer, P., & Hughes, J. (2013). Health Service Discovery and Composition in Ambient Assisted Living: the Australian Type 2 Diabetes Case Study. IEEE, *HICCS 46 Proceedings*, 1337-1346.
- Meersman, D., De Leenheer, P, & Hadzic, F. (2012). Patient and Business Rules Extraction and Formalisation Using SVN and SBVR for Automated Healthcare. AIS, *ACIS 2012 Proceedings*, 1-11.
- Meersman, D. & De Leenheer, P. (2012). Open Innovation in Health Service Value Networks: a Methodology for the Innovation of Ambient Assisted Living Platforms and Services. *BIS (Workshops) 2012, Springer Lecture Notes in Business Information Processing*, 25-36.

The roles of the co-authors were as follows:

- Myself: initiation, conceptualisation, overall research design, meta-level framework, service provider perspective extraction and formalisation, SBVR formalisation, overall coordination
- Fedja Hadzic: patient and practitioner perspective formalisation, rule base, and software development
- Pieter De Leenheer: SVN conceptualisation, SBVR formalisation
- Ivan Razo-Zapata: SVN execution
- Jeff Hughes: medical domain expert

I would also like to further acknowledge the invaluable contributions of Moyez Jiwa and Kreshnik Hoti as additional medical domain experts.

Appendices pertaining to this chapter are:

- Appendix IX: AAL Domain Rule Base

- Appendix X: AAL Domain Patient Profiles
- Appendix XI: AAL Domain Patient/FC Mappings
- Appendix XII: AAL Domain Service/FC Mappings
- Appendix XIII: AAL Personas
- Appendix XIV: Rudimentary AAL Domain Model

In the past 2 years, my collaborators and I were involved in a research capacity in parts of the innovation process of smart home platform being developed by one of Australia's largest telecommunications providers with about 1 million customers. The company is adding a smart home communication infrastructure (including capacity for AAL devices and services) on top of its existing network.

The smart home platform hardware consists of a back-end and network infrastructure, and a home gateway that controls a wireless sensor network, network communications and the delivery of a range of services including but not limited to: health, security and smart energy. The provision of services of these three domains over congruent endpoint infrastructure reveals that many services are overlapping and there is no need for disjoint approaches that result in a proliferation of heterogeneous systems and services that are potentially not economically viable or interesting on their own (e.g. solutions in the long tail of the spectrum). Ideally, disparate service providers would be able to (collaboratively) innovate in adjacent domains. Thus, all work we do within AAL has to take into account the context of multiple domains being serviced over the same infrastructure. The agnostic atomisation and recombination stages in the meta-level framework allow different service providers to (collaboratively) innovate in adjacent domains. This would blur unnecessary, conceptual and artificial boundaries between domains. This is further discussed in the Analysis and Synthesis chapters of the thesis.

However, before one can even speak of collaborative innovation (and especially with adjacent domain actors), one would need to get a good grasp of the actors, objects, and processes of the AAL domain. What I was especially interested in when developing the research design was not the smart home

itself, or the medical sensors. These building blocks are being developed by people undoubtedly more qualified than myself. The question I was looking to answer was: "What then?"

What if all building blocks of AAL were in place? How would these work as part of the *existing* complex service system that is healthcare, rather than as pie-in-the-sky future scenarios? What does the paradigm of AAL mean for the existing healthcare infrastructure and its actors, objects and processes? Answering these questions is what drove the research and its design described below.

7.2. Introduction

Ambient Assisted Living (AAL) has been identified as a viable option to mitigate the impact of costs associated with ageing populations in industrialized societies (AAL JP 2011). AAL is a relatively young domain that faces a number of technological challenges, i.a. heterogeneity, domain knowledge formalisation, and integration (Kleinberger et al. 2007). Heterogeneity in AAL refers to the nature of standalone, closed systems provided by different suppliers with diverging knowledge and technologies. Challenges associated with domain knowledge formalisation have to do with the difficulty of formalising heath domain knowledge for machine processing. Finally, integration challenges are related to the above heterogeneity issues and disparate data sources.

This research contributes to the health informatics domain by applying a service value network (SVN) approach to automatically match patient sensor data in a home care monitoring context to health services provided by a network of service providers. The process is based on machine-readable rules extracted from national medical guidelines, and health service networks that are inferred from medical benefits schedule item listings. In essence we cover the full spectrum from sensor reading to service delivery using already available data, although currently not all relevant data is used in calculating service offers in our framework.

This research further contributes to the area of SVN composition by replacing current assumptions that customers are actively involved in explicating their service requirements with a more tacit approach where requirements are derived from patterns in sensor readings (and corollary diagnosis) based on validated rules on the customer side as well as the supplier side.

The contributions are demonstrated with an SVN composition based on an initial set 493 patient profiles in the context of Type 2 Diabetes management. Rules for diabetes diagnosis and management were extracted and formalised from the Australian National Health and Medical Research Council (NHMRC) medical guidelines. For the service composition, the listed medical services of the Medicare Benefits Schedule (MBS) of the Australian government were used. All formalisations, rules, itemizations and mappings have been validated by medical domain experts.

7.3. Background

7.3.1. Ambient Assisted Living

The population of industrialised nations is undergoing significant demographic changes that have implications on the nature of health services in the future. In Europe, the population older than 65 is projected to be more than 30% by 2060 (Eurostat 2008). In Australia, we see similar projections with an increase of people over 65 to 23% by 2056 (ABS 2009)

The associated cost of the related increase in care needs is expected to place a significant burden on economies (Kleinberger et al. 2007). This effect is further exacerbated by the old age dependency ratio (i.e. the population older than 65 divided by the working age population supporting them), which is expected to rise from 25% to 53% by 2060 in Europe (Eurostat 2008), and from 20% to 38% by 2056 in Australia (ABS 2009). This means that for every old person there will be two or three people of working age that can support that person, compared to four or five people now. In Australia, the situation is further encumbered by the fact that a significant part of the population lives and will

continue to live in remote and rural areas with both lower and more expensive access to traditional healthcare services (AIHW 2012).

Ambient Assisted Living (AAL) technologies can help provide autonomy to elderly and disabled people, allow them to live at home individually for longer, and raise their quality of life, whilst at the same time relieving some of the economic burden on public health care systems. Systems focusing on supporting people with special needs in their home environment are called Home Care Systems (HCS). Technologies underpinning home care have various labels. 'Assisted Living' refers to devices and services that help people stay at home longer. 'Assistive Technologies' refer to devices that aid with daily living of patients. 'Telehealth' and 'Telecare' refer to remotely monitoring and supporting patients. 'Smart Home' refers to home automation and monitoring via sensor networks (Turner et al. 2009). The home care systems domain is coarsely categorised in Kleinberger et al. (2007) as follows:

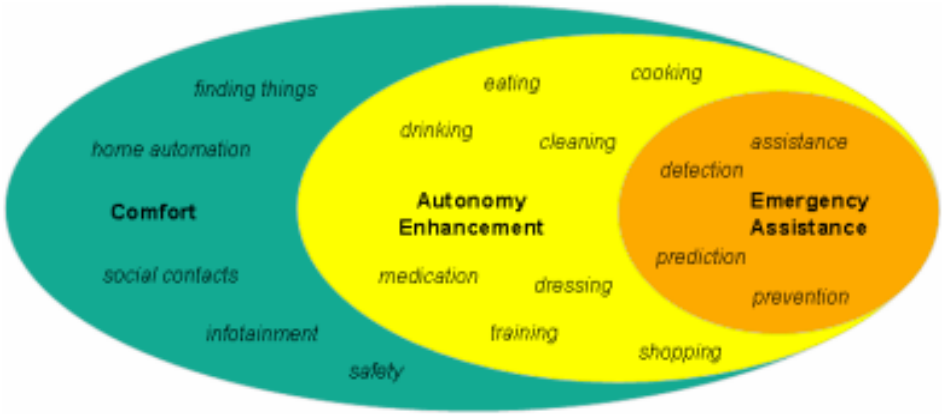

Fig. 7.1. The home care system domain. Reprinted from Kleinberger et al. (2007)

What are defined in Fig. 7.1 as comfort, autonomy enhancement and emergency assistance services, can be seen as a rudimentary categorisation of patient needs, serviced by service providers. In the HCS domain, there are 2 main actors: Service Recipients (patients) and Service Providers (including physicians, home care givers and relatives) (Dohr et al. 2010).

For now it is important to note that whilst the above categorisation is useful in itself as a description of the domain, it has no real function in the context of developing innovative home care services. Innovators in the domain are generally already well endowed with the intricacies of the domain, and a categorisation has the limitations that processes belong to a single category. For instance, the process `Medication` might satisfy the `EmergencyAssistance` need via a `ContinuousGlucoseMonitoringSystem` administering `Insulin` to the `Patient`, rather than satisfying `AutonomyEnhancement` as is proposed in the model.

Today's commercially available technologies in the AAL domain are products such as necklaces with emergency buttons, fall sensors in mobile phones with notification services, vital data monitoring plasters, wireless blood pressure and blood glucose sensors (Kleinberger et al. 2007, Dohr et al. 2010), and a myriad of other technologies that are increasingly being integrated in a smart object-based Internet Of Things with corresponding wireless standards such as ZigBee Pro (Wheeler 2007) and 6LoWPAN (Mulligan and Group 2007).

In our case of Type 2 Diabetes management at home, two types of sensors can be used to remotely monitor the health of patients: blood pressure sensors for measuring hypertension, and blood glucose sensors (which can be part of continuous blood glucose monitoring systems) for measuring hyperglycaemia. Lipids are measured as well for hyperlipidaemia in the context of diabetes, but can currently not be implemented via remote sensors.

As a relatively young domain, AAL is facing a number of technological challenges identified in Kleinberger et al. (2007):

1. *Adaptivity*: systems need to monitor their environment and adapt themselves constantly.
2. *Natural interactions*: systems need to provide interfaces for users with varying needs.
3. *Heterogeneity*: systems are closed, standalone, and provided by different suppliers with diverging knowledge and technologies.

4. *Domain knowledge formalization*: domain knowledge that is difficult to formalize needs to be transformed for processing.
5. *Elderly stakeholders*: the main stakeholders of AAL have generally low degrees of computer literacy and variable degrees of mental clarity, alertness and memory function, creating interface constraints.
6. *Low acceptance*: systems that are marketed as solely assisting with health problems have low acceptance rates because of the social stigma associated with them.
7. *Integration of available technologies*: AAL systems and services are characterized by heterogeneity and disparate data sources, which offers integration challenges.
8. *Immaturity*: although it is generally expected that AAL will be a huge market, there is only limited knowledge about what the products will look like, what their economic viability will be, who will provide them, how they will integrate, etc.

My collaborators and I concentrated on tackling the following innovation objectives:

7.3.1.1. Innovation Objective 1: Integrate Heterogeneous Systems (Challenge 3)

Following disparate and heterogeneous information and data sources were transformed into machine-readable assets that can be used in and across the context of automated healthcare:

a) On the medical practice side (or patient side), rules were extracted from the NHMRC guidelines (see section 7.3.2) and formalised;
b) On the business side (or provider side), services and service attributes were extracted from Medicare Benefits Schedule listings (see section 7.3.3) and formalised into machine-readable, automated rules;
c) Furthermore, business rules (or service provider rules) were formalised using SBVR, bringing to bear the 'rules of engagement' for the service providers when delivering services in the context of our AAL framework.

In a sense, this type of straightforward integration using readily available data levels the playing field for service providers. Because it can be assumed that each provider will claim to Medicare all performed services, a service network can be derived based on the claims providers make in conjunction with the service attributes and business rules.

7.3.1.2. Innovation Objective 2: Formalise All Relevant Domain Knowledge (Challenge 4)

The aforementioned formalisation of heterogeneous information and data sources, ranging from the initial biological parameters (patient) to ultimate service delivery (provider), offers a contribution to the formalisation of different aspect of the healthcare domain specifically in the context of AAL.

7.3.1.3. Innovation Objective 3: Increase Acceptance by Integrating AAL Devices into a Smart Home Infrastructure (Challenge 6)

The congruent endpoint infrastructure and overarching meta-model allow for an integrative approach in terms of platform and services being delivered. This offers an opportunity for AAL to be 'blended into' other smart home services and platform components (such as entertainment, energy, security, etc.), and provides incentives for users to acquire access to the platform without the social stigma associated with healthcare equipment.

7.3.1.4. Innovation Objective 4: Utilise an Integrative Approach to Existing Technologies (Challenge 7)

By using a service value network approach to integrate the 'medical practice' side of healthcare with the 'business' side of it, an integration of two healthcare realms and related technologies takes place. The integration of the healthcare aspect with other smart home components further contributes to solution of these challenges.

7.3.2. National Health and Medical Research Council

The National Health and Medical Research Council (NHMRC) in Australia is a government body promoting the development and maintenance of public and individual health standards. It serves the functions of research funding and development of advice and draws upon the resources of all components of the national health system (including governments, medical practitioners, nurses and allied health professionals, researchers, teaching and research institutions, public and private program managers, service administrators, community health organisations, social health researchers and consumers) (NHMRC 2012). The NHMRC guidelines are developed by a team of health and medical field specialists, with the purpose of providing a general guide to appropriate practice. They are based on the best evidence at the time of development and provide a set of principles and recommendations to assist in decision-making. These are expected to be followed by the general practitioner/clinician, subject to their judgement and patient's preference in each individual case.

7.3.3. Medicare Benefits Schedule

The Medicare Program provides access to medical and hospital services for Australian residents. Medicare benefits or 'rebates' are expressed as a percentage of the total cost of a medical service, ranging from 75% to 100%. Benefits are claimed by service providers and patients and are reimbursed by the Australian Government. (Department of Health and Ageing 2011). The Medicare Benefits Schedule (MBS) is a comprehensive listing of all professional medical services reimbursed through the Medicare Program. Each health service has a unique ID number, a name, a description and the fee/benefit of that service in Australian dollars. The MBS can be consulted in document form, via a web interface, and in a downloadable xml format. None of the business rules contained in the service listings are formalised (which is quite surprising considering the budgets involved). Services are related to each other by explanations containing hyperlinks. The descriptions of services also contain business rules, i.e. constraints on the use of the services from both

the patient and provider perspective (e.g. patient eligibility, service history, provider eligibility, cost constraints, etc.).

7.3.4. Semantics of Business Vocabulary and Business Rules

The Semantics of Business Vocabulary and Business Rules (SBVR) (Object Management Group 2008) is a standard developed by the Object Management Group (OMG) and is intended to serve as a basis for describing a complex entity such as a business in near-natural language. The fact that SBVR uses near-natural language allows business domain experts, rather than ontology and/or knowledge engineers to supply and define the business rules, business facts and business vocabularies. SBVR serves as a central framework for shared meaning between business actors, and allows these actors to describe all aspects of a business using shared concepts and formal logic, so that specifications can be understood by humans and processed by computers. Because SBVR is explicitly fact-oriented as well as rule-based, it is particularly useful for defining shared business concepts and 'rules of engagement' in business ecosystems or service networks with many, different, and often disparate participants.

7.3.5. Healthcare Platform and Service Innovation

There are two dimensions to the pace and nature of innovation on a HCS platform. One dimension is the evolution of the platform itself. As the platform grows and transforms, new capabilities are added to support new types of services. The other dimension is the innovation of services. By identifying, composing and developing new services, emerging customer needs are to be met with current platform capabilities. The platform innovation life cycle is typically slower because it involves hardware engineering, high investment costs and the need for a relatively stable service environment, whereas service innovation has a more dynamic nature and can thus respond to emerging customer needs faster (Eisenmann et al. 2007). However, all services are dependent on the platform over which they are delivered. Consider, e.g., the release of the iPhone 4 platform, which through

its new 3-axis gyroscope functionality allowed the iPhone developer network to build new 3-axis gyroscope-utilising services that had heretofore not been possible. Or closer to home in the HCS domain, e.g. the introduction of fall detection sensors has enabled service providers to deliver emergency assistance to patients. Therefore innovation in a service-based economy will have a dual character of platform and service innovation, with the platform determining the provided services, and the services (or lack thereof) influencing the shaping of the platform.

A platform provider needs to take into account service dynamics and the evolving technological landscape, and anticipate accordingly. Related work on health care service customisation and personalisation (De Blok et al. 2010, Eslami et al. 2010)) is valuable and useful, but does not generally include platform constraints and evolution when devising new services. For this reason, whilst new services do arise from personalisation and customisation, it cannot be fully considered service innovation.

7.3.6. Service Value Networks

The range of services in the HCS domain is large, which can lead to a proliferation where each provider supplies part of the solution, but suppliers do not co-innovate systematically. In this research, Service Value Networks (SVN) are used as an ecosystem for collective intelligence, co-creation and open innovation. A service value network is a flexible and dynamic web of enterprises and final customers who reciprocally establish relationships with each other for delivering an added-value service to a final customer (see Razo-Zapata et al. 2012; Hamilton 2004; Allee 2002; and Lovelock and Wirtz 2010).

The foundation for SVN that is adopted in this research is the well-established e3value framework (Gordijn and Akkermans 2003, Akkermans et al. 2004). It provides ontologies to analyse and model perspectives of customers and providers on service needs. Inspired by service marketing and management theory, the conceptualisation of services focuses on value aspects, rather than

merely computer-technical aspects as found in most service-oriented computing paradigms (e.g. WSDL, SOAP).

7.4. Approach

In this section the approach in terms of SVN composition is described. First, a general overview of the methodology is provided as well as a description of the modifications to the existing e3value framework for the healthcare domain and case study. An elaboration of the methodology used for converting sensor data into rule-based and validated functional consequences that can be used in SVN composition follows. Finally, the process used to map healthcare services and service providers to these functional consequences, again with the purpose of SVN composition is explained.

7.4.1. Overview

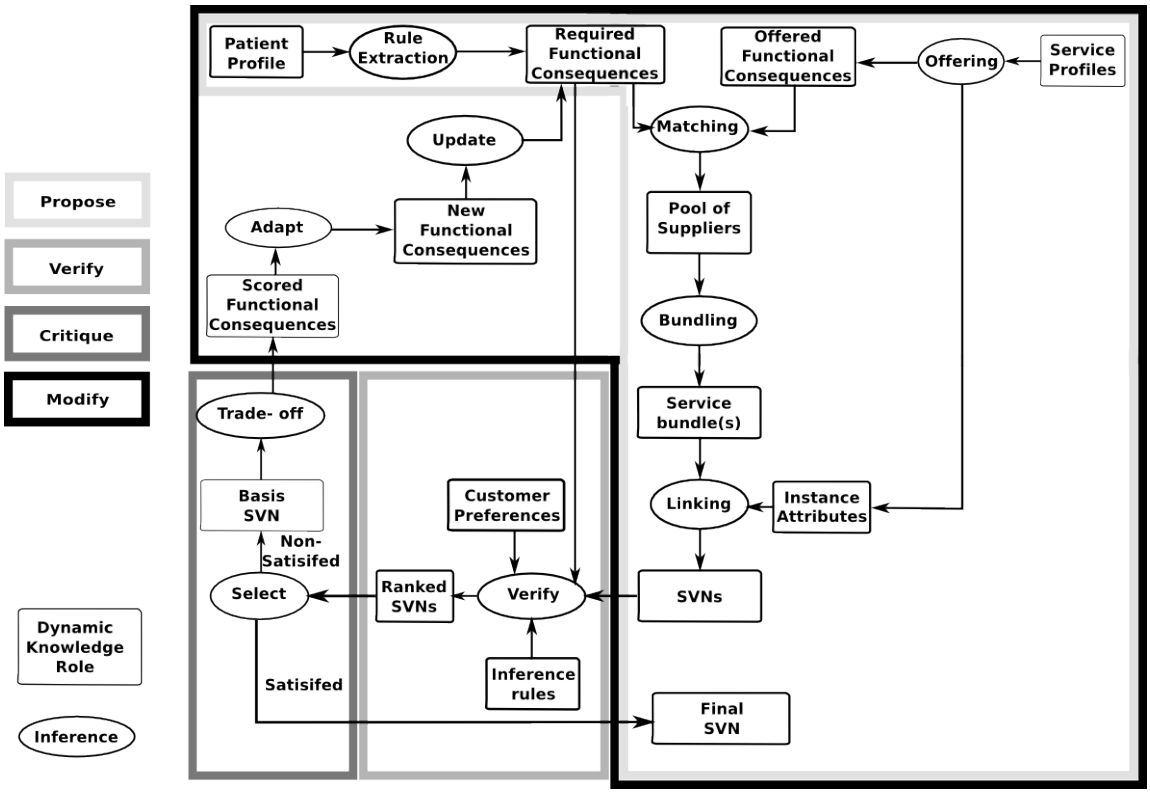

Fig. 7.2 SVN Method

The purpose of a Service Value Network is to find an optimal service composition (supplier perspective) for a given customer need (customer perspective). In e3value, this is done via a method described in Gordijn and Akkermans (2003), and Akkermans et al. (2004). The method consists of four subtasks as depicted in Fig. 7.2: Propose, Verify, Critique, and Modify (Tapscott 2006). Discussing the entire method is not the essence of this chapter, which is mainly focused on the Propose aspect. We will however give a brief overview of the other aspects as well.

(1) The **Propose** subtask is concerned with proposing an appropriate solution for a need. It involves a number of subprocesses. (a) *Laddering* is a marketing practice where marketers explore how customers link specific product properties to higher-level values. In SVNs, the process is used to transform customer needs into what is termed 'functional consequences' (FCs). FCs are actionable items that can be satisfied by suppliers. Traditionally, FCs in SVNs are derived from explicit customer needs. However, in many contexts, and especially those where end users have no clear idea, or insufficient knowledge, it is prohibitively difficult or unadvisable to have users explicate their needs (Meersman and Debruyne 2011, Meersman and De Leenheer 2012). Therefore, in this research the laddering process is replaced with a more tacit approach involving an extracted rule base that acts on sensor readings and recommends FCs according to the rule base. Although the end user is still the recipient of the service, the translation of their needs to FCs is done outside of their grasp, i.e. in an ambient manner. (b) *Offering* is a similar process to laddering, but the process takes place on the supplier side: suppliers translate their offers (assets and competencies) to FCs as well in order to create a 'common currency' for matching. In the current approach, this laddering is substituted with rigid mappings between services and FCs that have been validated by health domain experts. The reasoning behind this is that in a context of health services, a validation of the mappings between services and FCs is called for because of accountability and accuracy considerations, i.e. we need to make sure that the right value proposition and service are delivered according to agreed-upon medical practice

recommendations**.** (c) *Matching* concerns the matching of customer with suppliers in terms of FCs, additionally constrained by medical practice considerations and customer preference on the customer side, and business rules on the supplier side. In our case study, the matching process is appended in favour of a direct mapping based on Business Rules. The matching process results in a pool of service providers. (d) *Bundling* is the process where meaningful combinations of services and service providers are made to satisfy the customer need. The output of this process is a set of proposed service bundles that describe B2C relationships in terms of value exchanges. Finally, in the (e) *Linking* stage we solve any B2B dependencies that might exist between various service providers.

The following subtasks are not at the core of this paper, but will be discussed briefly with the aim of being complete.

(2) The **Verify** subtask refers to the process of verification if SVN designs satisfy functional requirements. Once the SVNs have been composed, the verification subtask determines (a) *whether* the SVN offers the required FCs and (b) *how* it fits the customer requirements.

(3) The **Critique** subtask identifies the source of failure in case of unsuccessful design and allows for the designs to be improved before deployment.

(4) Finally, the **Modify** subtask takes input from monitoring the SVN performance (customer preference, patient health status, performance monitoring, etc.) and allows for continuous improvements after initial deployment. We will now discuss our approach in extracting and formalising patient rules and services for use in the SVN composition process.

In the following section the approach in transforming the necessary data from customer and service provider sides to FCs is explained.

7.4.2. Patient Rule Extraction and Mapping

For the rule extraction, the focus was on the utilization of NHMRC guidelines related to treatment of patients diagnosed with Type 2 Diabetes. The guidelines provide detailed pharmacological advice on how to manage the

patient's hypertension, hyperlipidaemia and hyperglycaemia in the light of their existing biological parameters and clinical data. While the guidelines are very extensive in detailing the evidence for stated recommendations, including previous literature, research findings, case studies, etc., the focus was on the summary of recommendations within the guidelines. This is where the majority of recommendations for a typical patient profile can be found.

The NHMRC guidelines and recommendations related to hypertension (blood pressure control), hyperlipidaemia (lipid control) and hyperglycaemia (blood glucose control) were formalised in a format that could be implemented within the proposed framework. This formalization was in form of IF-THEN rules where the precedent of a rule indicates the set of preconditions that must hold, while the consequent indicates the treatment recommendation. These rules were verified and validated by domain experts. In consultation with the domain experts the rules were further enriched to reflect a particular stage of the treatment and when more specific information was available it was added to the more general rules extracted (e.g. specific medicine used, and which medicine should/should not be used in combination with other medicine/treatment). This resulted in a total of 131 rules out of which 90 were related to blood pressure control, 21 to blood glucose control and 20 for lipid control. Note that if the characteristics of a patient satisfy the pre-conditions of multiple rules, then multiple recommendations for treatment would be provided within the guidelines.

Note that henceforth the general term *attribute* is used to refer to a set of measurements (e.g. blood pressure, glucose level etc.) or patient characteristics. In the formulization that follows, for simplicity purposes we assume that the set of conditions/measurement values of attributes from NHMRC guidelines and observed from patients are represented by either a true or false value for a particular attribute.

Let the set $A = \{a_1, a_2, \ldots, a_{|A|}\}$ denote the attributes, AC the set of true/false conditions on a_i ($i = 1, \ldots, |A|$), and acp be the true/false value of attribute a_i for a patient p.

The set of treatment recommendations is denoted as $T = \{t_1, t_2, \ldots, t_{|T|}\}$ and the rule set is denoted as $R = \{r_1, r_2, \ldots, r_{|R|}\}$.

Each rule r_n ($n = (1, \ldots, |R|)$ is an implication of the form of $x \rightarrow y$ where $x \subseteq AC$ and $y \in T$.

The dataset containing patient observations/profiles is denoted as $O = \{O_1, O_2, \ldots, O_{|O|}\}$, where $O_p = \{ac_1p, ac_2p, \ldots, ac_{|A|}p\}$ denotes the set of observations of a particular patient p ($p = (1, \ldots, |O|)$).

Given O_p and R, the system will form a set of treatment recommendations Tp for a patient p as follows: $\forall t_i \in T$, if $\exists r_n = x \rightarrow y$ where $x \subseteq O_p$ and $y = t_i$ then $T_p = T_p \cup t_i$.

Note that recommendations are not unique for each rule, as different patient profile/observations may provoke the same treatment recommendation. Each treatment recommendation $t_i \in T$ was assigned a unique FC identifier (fc).

7.4.3. Service Attributes Extraction

In order to bootstrap the services, a broad selection of diabetes related services was extracted from the Medicare Benefits Schedule (MBS) database. This list was narrowed down by domain experts to include any and all services relating to Diabetes Type 2. This process amounted to a list of 32 services. The set of services will be denoted as $S = \{s_1, s_2, \ldots, s_{32}\}$ and each service has nine characteristics associated with it, denoted as s_ic_j ($i = (1,\ldots, 32)$; $j = (1, \ldots, 9)$).

The characteristics of each service in the context of SVNs, were extracted from the MBS listings and include:

(1) ServiceID: a unique identifier provided by Medicare. The ID number contains information about the 'family' of services a particular service belongs to. The first and second digits typically identify category and subcategory, and the last digit uniquely identifies the service. For example $s_1c_1 = 701$, $s_5c_1 = 2517$, $s_6c_1 = 2518$, $s_7c_1 = 2521$, $s_8c_1 = 2522$ and $s_{26}c_1 = 6651$, all belong to the same

'family' (i.e. Consultations performed by General Practitioners in Vocational Register (REG-GP) and/or Fellow of the Royal Australian College (FRACGP)). They differ in terms of length (i.e. time needed to execute the service) and/or place (i.e. place of execution, usually defined as in or outside a facility).

(2) Description: a short description for human interpretation, e.g. s_1c_2= "Brief Health Assessment", s_5c_2 = 'Consultation at consulting rooms' or $s_{26}c_2$ = 'Quantitation of glycosylated haemoglobin'.

(3) Duration: refers to the time needed to execute a service. Duration is expressed in a minute interval, e.g. s_5c_3= 0-20; s_7c_3 = 20-40; $s_9c_3 > 40$.

(4) Fee: refers to the total amount in Australian dollars that will be charged for the service, e.g. s_5c_4= \$35.6; $s_{26}c_4$= \$16.9.

(5) Benefit%: refers to the percentage of the fee that can be claimed for reimbursement, e.g. s_5c_5=100%; $s_{26}c_5$=75%.

(6) Benefit: reflects the actual amount that can be claimed for reimbursement, e.g. s_5c_6= \$35.6; $s_{26}c_6$=\$12.7.

7.4.4. Business Rules Extraction

In the MBS schedule listings, business rules regarding the Medicare items are described in plain text and as a result are not machine-readable. The process started off with extracting the rules and formalising them using straightforward if-then logic. This resulted in three business rule types that double as service attributes (doubling as service attributes allows for an unambiguous mapping of rules to services in our framework):

(7) CustomerRule: pertains to constraints for service delivery related to the status of the customer, e.g. s_1c_7="*IF* diabetes established *THEN* use s_5", s_8c_7 = "*IF* number of patients > 7 *THEN* $s_8c_4 = s_7c_4$* (number of patients * 1.9))".

(8) ProviderRule: pertains to constraints for services of which the delivery can only be performed by service providers with a certain status, e.g. s_5c_8 = "*IF* provider is REG-GP or FRACGP *THEN* valid *ELSE* use s_{11}".

(9) ServiceRule: refers to rules regarding the relation of a service to other services, e.g. service items that are iterations of each other; that are identical services with a different length, service dependencies, etc. For example, $s_{28}c_9$ = "Valid if patient has been delivered s_{27}" (in this case s_{27} is an assessment to be allowed to group service s_{28}).

7.4.5. Examples of Business Rule Formalisation using SBVR

The type of language used in the business rules above does not allow for easy readability by business providers. In order for service providers to easily interpret and express applicable business rules, they are formalised in a standards-compliant near-natural language SBVR format, which consists of business rules and supporting fact types. Examples are given below. The legend for the notation is as follows: underline is a concept; double underline is an instance; bold is **a logical operator or constraint**; and cursive is *a relation*.

7.4.5.1. Business Rule A5

It is permitted that a Medical Practitioner *renders* a Special Diabetes Attendance **if and only if the** Medical Practitioner *is listed in* Vocational Register of General Practitioners **or the** Medical Practitioner *holds* Fellowship of the Royal Australian College of General Practitioners

Supporting fact types for Rule A5:

Medical Practitioner *renders* Usual Attendance
Diabetes Attendance *specialises* Attendance
Special Diabetes Attendance *specialises* Diabetes Attendance
Medical Practitioner is *listed in* Register
Medical Practitioner *holds* Fellowship
Vocational Register of General Practitioners *is a* Register
Fellowship of the Royal Australian College of General Practitioners *is a* Fellowship

7.4.5.2. 3.5.2 Business Rule A44

If **a** Patient *has been diagnosed with* Diabetes Mellitus **and** *has completed diabetes care cycle* **then it is not permitted that the** Patient *is given* **a** Normal Attendance

Or the equivalent of the above negation:

If a Patient *has been diagnosed with* Diabetes Mellitus **and** *has completed diabetes care cycle* **then it is obligated that the** Patient *is given* **a** Diabetes Attendance

With supporting fact types:

Patient *has been diagnosed with* Diabetes Mellitus
Diabetes Mellitus *is a* Disease
Patient *has completed diabetes care cycle*
Patient *is given* Attendance

We devise a category of attendances that is exclusive from the usual attendances treated in business rule A5.

Special Attendance *specialises* Attendance
Exclusion between Usual Attendance **and** Special Attendance**:**
No Usual Attendance *is* **a** Special Attendance

7.4.6. Business Rules Mapping

Once all services were itemised, they were mapped to the FCs under guidance of a domain expert for validation. Mappings were non-exclusive, i.e. an FC can be satisfied with multiple services and a single service can satisfy multiple FCs. Hence, each FC was mapped to one or more services that it requires to produce the set of mappings $M = \{m_1, m_2, \ldots, m_{|M|}\}$, where each $m \in M$ is a 2-

tuple denoted as (fc_i,ms), where fc_i (i = (1,…, $|T|$) is a FC identifier and $ms \subseteq S$. Identical services of varying duration were assigned exclusive FCs within their family. For example, fc_2 ("Measure blood pressure") can be satisfied by the services s_5 (s_5c_3 = 0-20); s_7 (s_7c_3 = 20-40); and s_9 (s_9c_3 = >40). A blood pressure measurement only takes short time, and if that is all that is needed it is performed by s_5. However, if a patient requires one or more additional FCs at the same time, fc_2 would be amalgamated into the service with longer duration (e.g. s_9).

7.5. Case Study

7.5.1. Experimental setup

Customer perspective: 493 different patient profiles (i.e. $|O| = 493$) were run through the rule base with 111 rules (i.e. $|R| = 111$). Note that a single profile can trigger multiple rules resulting in multiple treatment recommendations or FCs. From the 493 profiles, 1090 rules were triggered while 64 profiles did not trigger any rules (no treatment was required). Each FC was mapped to one or more services, i.e. the mapping M ($|M| = 27$) was produced between 27 FCs (fc_1, …, fc_{27}) (Table 7.1) and the 32 services (S={s_1, …, s_{32}}) (Table 7.2). Although all profiles were different, the requested FCs were often very similar (as can be expected in a context of standardized medical treatment). For this reason, a sample of 5 very different profiles was selected for the SVN composition for demonstration purposes.

Service provider perspective: 10 different service providers (denoted as SP_1, …, SP_{10}) were used who between them had 45 single services (i.e. unique service-provider combinations). Each *SP* can provide multiple services as can be seen in Table 7.3 (where we show all services each *SP* provides). The total pool of service providers could satisfy all possible FCs.

Service value networks: The 5 profiles generated up to 20 alternative SVNs each. Although it is possible to generate more, the number was restricted for practical purposes. Out of our sample of 493 patient profiles, a representative

profile given by patient p=29 was selected. The following section elaborates on the process using this patient profile as an example.

Table 7.1: Functional Consequences

FC	Description
FC0	no action
FC1	Measure blood pressure
FC2	Lifestyle modifications
FC3	Initial therapy: (One of the following) angiotensin converting enzyme inhibitors, angiotensin receptor blockers, calcium channel blockers, β-blockers and diuretics
FC4	Consider combinations of antihypertensive agents
FC5	Initial therapy: consider combinations of angiotensin converting enzyme inhibitors and angiotensin receptor blockers.
FC6	Initial therapy: diuretics.
FC7	Consider combinations of antihypertensive agents and angiotensin receptor blockers
FC8	Initial therapy: consider combinations of angiotensin converting enzyme inhibitors and/or β-blockers.
FC9	Initial therapy: consider combinations of angiotensin converting enzyme inhibitors and/or diuretic and/or β-blockers.
FC10	Initial therapy: β-blockers.
FC11	Initial therapy: calcium channel blockers or thiazide diuretic
FC12	Initial therapy: α-blockers.
FC13	Consider combinations of antihypertensive agents, avoid β-blockers.
FC14	Pharmacological options selected on the basis of individual clinical circumstances, side effects and contraindications (a) metformin
FC15	Pharmacological options selected on the basis of individual clinical circumstances, side effects and contraindications (b) sulphonylurea
FC16	Pharmacological options selected on the basis of individual clinical circumstances, side effects and contraindications (c) add-on therapies: acarbose, DPP-4 inhibitors, exenatide
FC17	Pharmacological options selected on the basis of individual clinical circumstances, side effects and contraindications (d) insulin: basal or premixed
FC18	No response to treatment after 3-6 months: intensify treatment
FC19	No response to treatment: assess the patient for other condition (Latent Autoimmune Diabetes of Adults [LADA], malignancy)
FC20	Combination of statin and a bile acid binding resin or low dose nicotinic acid

FC21	Specific dietary advice for weight reduction
FC22	Improve blood glucose control
FC23	No change after 3 months: lipid modifying medications
FC24	No change after 3 months: statin therapy
FC25	Combination of statin and fibrate
FC26	No change after 3 months: intensify statin therapy or consider fibrates
FC27	No change after 3 months: fibrates

Table 7.2: Services

Service	ServiceID	Description
1	701	Brief Health Assessment
2	703	Standard Health Assessment
3	705	Long Health Assessment
4	707	Prolonged Health Assessment
5	2517	Consultation at consulting rooms
6	2518	Consultation at a place other than consulting rooms
7	2521	Consultation at consulting rooms
8	2522	Consultation at a place other than consulting rooms
9	2525	Consultation at consulting rooms
10	2526	Consultation at a place other than consulting rooms
11	2620	Standard/surgery consultation
12	2622	Long/surgery consultation
13	2624	Prolonged/surgery consultation
14	2631	Standard/out-of-surgery consultation
15	2633	Long/out-of-surgery consultation
16	2635	Prolonged/out-of-surgery consultation
17	10951	Diabetes education service
18	10953	Exercise physiology
19	10954	Dietetics service
20	66500	Quantitation in serum, plasma, urine or other body fluid
21	66503	2 x 66500
22	66506	3 x 66500
23	66509	4 x 66500
24	66512	5 x 66500
25	66536	Quantitation of HDL cholesterol
26	66551	Quantitation of glycosylated haemoglobin
27	81100	Diabetes education service - assessment for group services
28	81105	Diabetes education service - group service
29	81110	Exercise physiology - assessment for group services

30	81115	Exercise physiology - group service
31	81120	Dietetics service - assessment for group services
32	81125	Dietetics service - group service

Table 7.3: Service Providers and Services per Provider

Service Provider	Services
SP1	s1, s2, 3, s4, s5, s6, s7, s8, s9, s10
SP2	s1, s2, 3, s4, s11, s12, s13, s14, s15, s16
SP3	s17, s27, s28
SP4	s17
SP5	s18, s29, s30
SP6	s20, s21, s22, s23, s24, s25, s26
SP7	s21
SP8	s11, s12, s13, s14, s15, s16
SP9	s19, s31, s32
SP10	s19

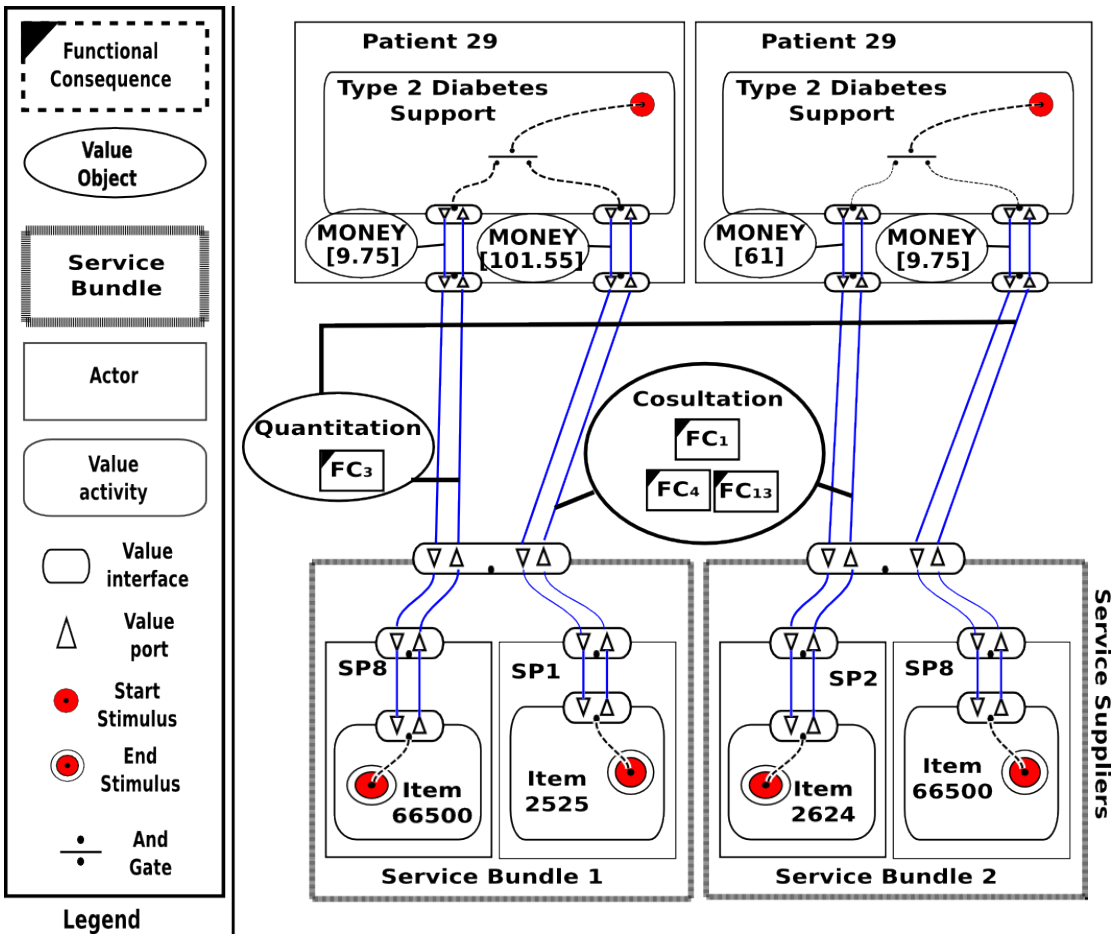

Fig. 7.3 SVN Composition Patient 29

7.5.2. Patient Number 29

Patient Number 29 has established Type 2 diabetes and is already part of a cycle of care involving his condition. He has had prior advice to make lifestyle modifications, and has a heart condition. His blood pressure sensor indicates that his blood pressure has risen above a predefined threshold, which has triggered a number of rules, resulting in a set of required FCs.

7.5.2.1. Patient Rules and Resulting Functional Consequences for Patient 29

Running the sensor readings of Patient 29 through the rule base, three rules are activated as below:

Matched to Patient Rule 8	*Matched to Patient Rule 29*	*Matched to Patient Rule 44*

IF One of the following applied? Angiotensin converting enzyme inhibitors, angiotensin receptor blockers| calcium channel blockers, beta-blockers and diuretics=no *AND* BP < 125/75 mmHg=no *AND*	*IF* BP < 125/75 mmHg=no	*IF* BP < 125/75 mmHg=no *AND*
Proteinuria > 1 g/day=yes *AND*	Heart Failure=yes *AND*	Proteinuria > 1 g/day=yes *AND*
Combinations of antihypertensive agents=no *AND* DiscussedLifeModificationFactors=yes *THEN* High blood pressure (it should be < 125/75 mmHg): Initial therapy: (One of the following) angiotensin converting enzyme inhibitors| angiotensin receptor blockers, calcium channel blockers, beta-blockers and diuretics	Proteinuria > 1 g/day=yes *AND* Combinations of antihypertensive agents=no *AND* DiscussedLifeModificationFactors=yes *AND* Combinations of angiotensin converting enzyme inhibitors and/or diuretic and/or beta-blockers=yes *THEN* high blood pressure (it should be < 125/75 mmHg): Combinations of antihypertensive agents	Combinations of antihypertensive agents=no *AND* DiscussedLifeModificationFactors=yes *AND* Intermittent Claudication=yes *THEN* high blood pressure (it should be < 125/75 mmHg): Consider combinations of antihypertensive agents, avoid beta-blockers.
(maps to fc_1 *and* fc_3)	**(maps to fc_4)**	**(maps to fc_{13})**

The rules have triggered a treatment recommendation $T_{29} = \{fc_1, fc_3, fc_4, fc_{13}\}$ for patient $p = 29$. This serves as the input for the SVN composition process.

7.5.2.2. Services and Triggered Business Rules:

The set of recommendations $T_{29} = \{fc_1, fc_3, fc_4, fc_{13}\}$ are satisfied by services s_2 (s_2c_1=703), s_3 (s_3c_1=705), s_4 (s_4c_1=707), s_5 (s_5c_1=2517), s_7 (s_7c_1=2521), s_9 (s_9c_1=2525), s_{11} ($s_{11}c_1$=2620), s_{12} ($s_{12}c_1$=2622), s_{13} ($s_{13}c_1$=2624), s_{20} ($s_{20}c_1$=66500).

These services initially trigger a number of business rules that are represented as follows:

Business Rule A5 (triggered by 2517, 2521, and 2525)**: It is permitted that a** Medical Practitioner *renders* 2517 **if and only if the** Medical Practitioner *is listed in* Vocational Register of General Practitioners **or the** Medical Practitioner *holds* Fellowship of the Royal Australian College of General Practitioners

Supporting fact types:

2517 *is a* Special Diabetes Attendance

2620 *is a* Diabetes Attendance

Business Rule A44 (triggered by 701-707, 2517-2526, and 2620-2635): *If a* Patient *has been diagnosed with* Diabetes Mellitus **and** *has completed diabetes care cycle* **then it is obligated that the** Patient *is given* **a** Diabetes Attendance

Instances for Diabetes Attendance are 2517, 2518, 2521, 2522, 2525, 2526, and 2620, 2622, 2624, 2631, 2633, 2635. If we look at the case of Patient 29, we can see that our patient has already been diagnosed with Diabetes. This excludes services 701 (Brief Health Assessment), 703 (Standard Health Assessment), 705 (Long Health Assessment), and 707 (Prolonged Health Assessment) from the possible SVNs.

7.5.2.3. SVN Composition

After applying the business rules, the applicable mappings from the predefined set M are = $(fc_1, \{s_5, s_{11}\}) \subseteq m_1$, $(fc_3, \{s_7, s_{12}, s_{20}\}) \subseteq m_3$, $m_4 = (fc_4, \{s_9, s_{13}\}) \subseteq m_4$, $(fc_{13}, \{s_9, s_{13}\}) \subseteq m_{13}$. s_5, s_7 and s_9 are all consultations by REG-GP or FRACGP, and are amalgamated to s_9. s_{11}, s_{12} and s_{13} are consultations performed by other medical practitioners, and are amalgamated to s_{13}. s_{20} is a quantitation service.

The end result of the amalgamation is that fc_1, fc_3, fc_4, fc_{13} are all amalgamated into s_9 and s_{13}, and fc_{13} to s_{20}, resulting in three services overall. In the service provider pool, s_9 is offered by SP_1, s_{13} by SP_2 and s_{20} is only provided by SP_8.

This results in two possible service bundles, as depicted in Fig. 7.3.

- *Service bundle 1* is offered by a combination of SP_1 and SP_8 and has a total price of $111.3.
- *Service bundle 2* is offered by a combination of SP_2 and SP_8 and has a total price of $70.75.

The difference between both bundles is that *Service bundle 1* has a higher quality of service as REG-GP and FRAC-GP are general practitioners who have additional qualifications. Depending on the preference and budget of the patient, *Service bundle 1* or *Service bundle 2* can be chosen.

To avoid over fitting and lower fitting, providing many unnecessary FCs and/or missing important FCs, the framework allows verifying the fitness of the alternative SVNs against the required FCs, which help doctors (and patients) to easily select an SVN.

Although the proposed framework can compose alternative SVNs, it cannot apply the so-called *ServiceRules*, i.e. the application of such rules is still a human-based task. Once an SVN is selected by the medical doctor, s/he has to amalgamate the services in case it is needed. Nonetheless, the given SVN provides the starting point for a doctor to give the final recommendation in terms of services.

7.6. Intermediate discussion

Diabetes Type 2 management focuses on a number of biological parameters related to hypertension (blood pressure control), hyperlipidaemia (lipid control) and hyperglycaemia (blood glucose control). Currently only blood pressure and blood glucose data are used in the AAL framework. Lipid control can currently not be performed in the context of remote healthcare using wireless sensors. For this reason the rules (and corollary treatment recommendations and functional consequences) pertaining solely to lipid control have not been executed in the calculations of FCs for patients in the current framework. However, the rules are present and can be used by the framework when desired, because lipid control is an essential element of diabetes management. This points to gaps indicating future directions.

The relevance of information in patient profiles is currently dictated by its use in the context of the framework, i.e. information that is not used is not relevant. In the case of lipids, we would need to add another cycle in the SVN composition to increase the validity of the framework. This cycle would

suggest (until technology advances: non-sensor-based) lipids measurement in certain situations before suggesting other services, thus offering the full gamut of measurements in the context of diabetes. The lipid measurements would need to be recorded in a way that can be understood by the rule execution program.

This opens up the discussion of the importance of patient profiles. The current focus is on diabetes management, but various kinds of information are relevant to other healthcare service domains. For example in palliative care, an acuteness dimension would be added to the framework: people need to be helped quickly in emergency situations (for example after falling on the ground). Patient location thus becomes an important – perhaps in some cases overruling – factor.

Another important aspect of patient profiles is budget: currently different cost options are offered without having a good idea of what the patient can afford. In Australia, the future model of home care will be one where patients are capped on a yearly basis (Gillard and Butler 2012). Cost becomes an important factor in such a model, and patient budgets become an area of optimisation of SVN composition. The aggregated individual SVN optimisations lead to optimisations on a national health policy level.

On the provider side, the business rules currently only contain those rules pertaining to the application of the Medicare services as defined in the listings. This results in an incomplete representation of the real-world business context. For example opening hours, the number of patients who can be treated simultaneously, preferred network partners, etc. would add to the completeness and accuracy of the SVN composition.

The framework could also be extended to include services performed by friends and relatives, for example in the case of palliative care, and to be able to handle ServiceRules in an automated manner, rather than the current manual approach.

The current approach solves some of the technical challenges of the ambient assisted living domain and contributes to the field of SVN composition.

By applying a service value network approach using existing medical data, the playing field is essentially opened up for service providers and offer solutions to problems pertaining to AAL Challenge 3: 'Heterogeneity'.

By extracting and formalizing rules and characteristics from both the NHMRC guidelines and MBS listings, solutions are offered to the problems posed by AAL Challenge 4: 'Formalization'.

By integrating the 'medical practice' side of healthcare with the 'business' side of it through the application of a service value network approach, solutions are offered to AAL Challenge 7: 'Integration'.

Furthermore, the field of service value network composition has been extended by replacing current assumptions that customers are actively involved in explicating their service requirements with a more tacit approach where requirements are derived from patterns in sensor readings (and corollary diagnosis) based on validated rules on the customer side as well as the supplier side.

With the degree of automation, formalization and integration currently provided by the framework, one could argue that it is well on its way towards a form of 'sensor-driven, automated healthcare'.

7.7. AAL Domain Innovation Process

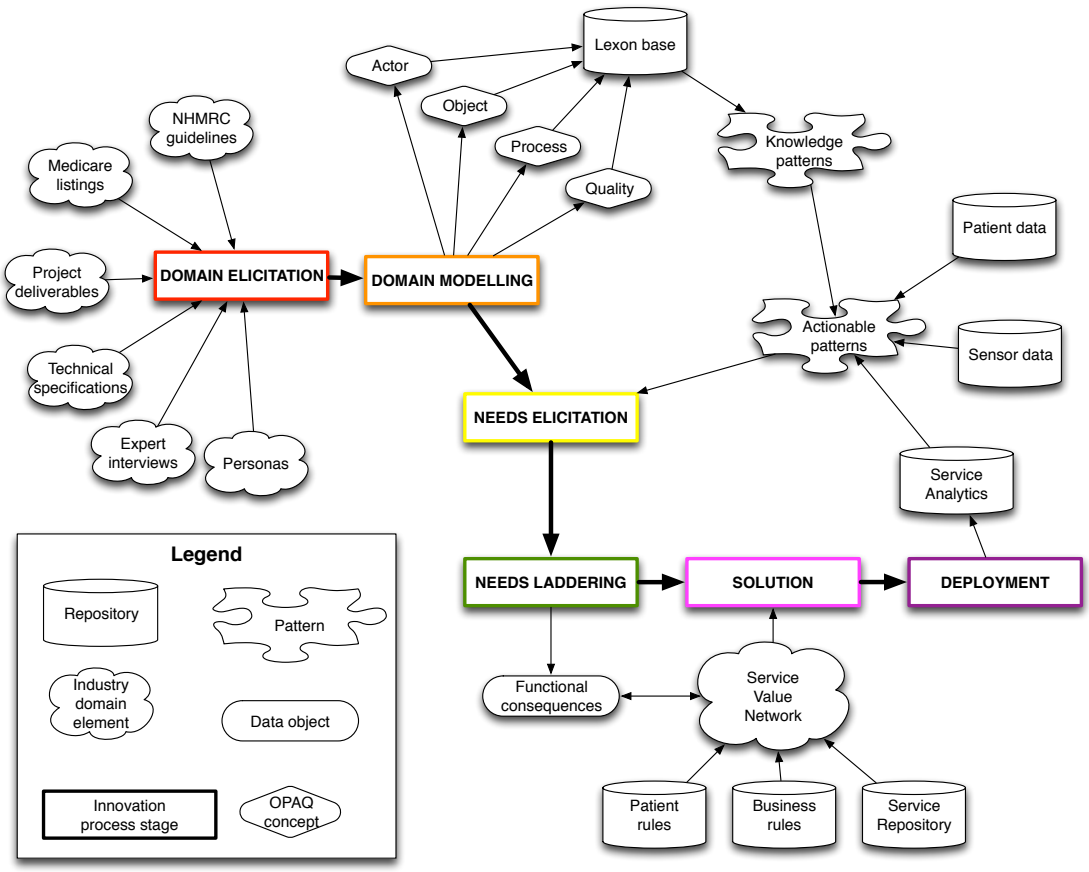

Figure 7.4 AAL Domain Innovation Process

The AAL Domain required a lot of groundwork to build the blueprint for a platform capable of service selection, composition, and delivery, as well as service/platform innovation. The final result was a set of integrated artefacts that allowed for an information flow across the stages of the innovation process (with a dual purpose analogous to the online travel domain). Whilst the performed research was mainly on the service side, the inability to execute services due to lacking platform components points to a duality of both service and platform innovation aspects.

The application of the innovation process model (see section 3.4.3.2) to the case study of the ambient assisted living domain results in a process model with six stages and – at certain points – two-layered knowledge interactions. The atomisation stage was appended *in the representation* of this innovation

process due to the service focus of the case study. However, in case of platform innovation cycles, such an atomisation stage would take place and could be represented.

The **Domain Elicitation** stage was an arduous task in this domain, not only because of the need of creating absolutely correct and domain expert-validated domain models through multiple iterations, but also due to the sheer size of the multi-disciplinary AAL domain, especially considering we only tackled one health aspect, in one service system, with relatively simple and easily measurable biological parameters. The inputs for this stage were personas and project deliverables (which were used to construct a high-level overview of the domain), medical practice guidelines, service listings, technical device specifications, AAL personas (see Appendix XIII), and multiple domain expert interviews. This resulted in one rudimentary OPAQ domain model (see Appendix XIV) that was mainly used to structure the knowledge and activities developed and performed by the research team.

The **Domain Modelling** stage in this case concerned more than just the high-level OPAQ domain model represented in Fig. 7.4. Other models and formal representations developed were the SBVR service listings and providers (cfr. Fig 7.4 "Service Repository" and "Business Rules"), the NHMRC rule base (cfr. Fig 7.4 "Patient Rules"), and the various mappings. The reasoning behind the current representation is that the OPAQ domain model *can* contain all facts about the domain that are now part of another domain-related model. The concepts and their relations have not been migrated to the main domain model because it was pragmatically unnecessary for the scope of the current research, although it is part of future work as it is recognised that interesting research questions on the nature of services, platforms, and their interrelationship might arise from the exercise.

In the context of service delivery, the nature of the actionable patterns for the **Needs Elicitation** stage is very clear: it is a combination of parameters including biological parameters above a pre-defined threshold and the patient treatment history (patient profile). It needs to be noted here that service analytics based on executed (or non-executed) services could in future work

also form a basis for service optimisation (e.g. selecting a better constellation of service providers to reduce cost/time), and importantly, platform innovation (e.g. developing technology that allows for remote wireless lipids measurement).

The **Needs Laddering** stage was 'hard-coded' into the system with regard to service selection and delivery using straightforward, expert-validated mappings because of the importance of meticulously delivering the right service in this domain. The mapped Functional Consequences then serve as input for the SVN together with the business and patient rules, and the service repository, resulting in (the value proposition of) a **Solution** that can be **Deployed** in the real world. The argument could be made here that due to the dynamic nature of services and service providers (and e3value's unique capability of handling this semi-automatically), each service is a new service and thus 'an innovation', but that would seem somewhat of a stretched definition. What makes the constellation of artefacts innovation-capable is the (theoretical) ability to handle input from the service performance and use that to create structurally different service compositions. As discussed earlier in this chapter, more and richer data would have to be available about the patient and the service providers for this to be actualised.

A further observation to be made here is also that the service-heavy nature of the case study is also reflected in the domain actors who are all medical practitioners and service providers. This points to a shortcoming of the current setup as far as platform innovation goes. The SVN actors are probably some of the best people to come up with new service solutions, but not so much the right people to innovate on the platform level, which e.g. includes wireless network communications technology. Finally, we see quite clearly in this case as well that the platform is that what constrains and enables service and information delivery.

"You look at where you're going and where you are and it never makes sense, but then you look back at where you've been and a pattern seems to emerge. And if you project forward from that pattern, then sometimes you can come up with something."

Robert M. Pirsig

Zen and the Art of Motorcycle Maintenance

8. Chapter 5: Synthesis

8.1. Principles and Practice

8.1.1. Overview

In this section an overview is presented of the main lessons learnt form the domain chapters, leading to a synthesis that (a) conceptually clarifies the role of products, services, and platforms (section 8.1.2), and (b) principles that apply across domains (section 8.1.3).

The Real Estate CRM domain was dissimilar to the other domains in that the bifurcation process concerned an application of the TRIZ Segmentation principle on the level of the entire domain, rather than concepts within a domain. Nevertheless, the utility of the segmentation/merging principles was established on this level as well.

Another contribution of the Real Estate CRM Domain was the versatility of a domain model in reasoning about a domain (and its objects, actors, processes) and in driving a discovery process (the intended application of the domain model in data mining which partly drove the design logic).

A key principle learnt from the Scuba Diving Equipment Domain project was that it is imperative to include functions (and by extension the entire domain) into any product-centric shared knowledge representation in a collaborative innovation context. Functions are what drive the existence of properties and components. Property clusters (combinations of properties and their relations to components) are the platform for delivery of the function to the user in the context of the domain. By expressing domain concepts in terms of their properties and function, a very straightforward way of discovering new innovation candidates: innovation is finding new properties for existing functions, or vice versa.

Another principle form the scuba domain is that of the balance between perspicuity and granularity. For example the granularity of properties such as

'material' is virtually endless. Often innovations in materials that result in value for the end-user go beyond what is meaningful to describe on a semantic level. Finding the balance is ultimately a pragmatic matter that is the answer to the question: "Does the current level of expressivity allow us to come up with valuable innovations?" The key word in that question is 'us'. Depending on the shared competences of the innovation process participants, the need for expressivity will vary (for example a materials scientist would require a high degree of expressivity, whereas a usability expert typically would not).

In the Online Travel domain, the most important issue experienced was a serious discrepancy between (a) the concepts the user finds important, and (b) the concepts vendors are including in their offerings. When given the liberty, users express their intent in concepts that are simply mostly not present in how vendors offer their services. The users expressed their need in terms of *peripheral data* – i.e. data that is used in the purchase decision of the customer, but is not explicitly part of the offer of the service provider – for example the size of the ski area, the presence of après-ski facilities, the calmness or cosiness of the environment, the presence of nice restaurants in the area, the distance to the ski bus, etc. This kind of peripheral data directly relates to the function the user wants to see performed when s/he makes a booking: to be safe, to have fun, to be satiated with good foods, to enjoy the scenery, etc.

Granted, peripheral data can mostly be found online, or even be part of the description of the offer on the webpage of the accommodation provider, but it is not present in the data that vendors provide to be matched against. So in the end, some knowledge about which factors exactly contribute to a purchase decision (the user's 'ideal image') is lost because it cannot be part of the query. Therefore, this is a major gap in the information assets in the innovation process of the providers. It becomes difficult to innovate and position oneself perfectly without having all the necessary data to support decision-making.

One of the key aspects learned from the Ambient Assisted Living Domain project was that SVNs can serve as a valuable tool in the context of

collaborative innovation in business networks. By the clear explication of customer needs in terms of functional consequences that can or cannot be satisfied by the SVN, the needs that are not satisfied form an immediate opportunity for service innovation. Combined with a monitoring functionality, providers can also learn how many times a need was unsatisfied in a given period of time, and decide from there whether it is a commercially interesting avenue to pursue.

Furthermore, it was established that services (both in the software and commercial sense) are platform-dependent: if the platform is not capable of delivering a service, customer needs will remain unmet. In other words, platform innovation opportunities can be derived from a lack of services or from poor needs satisfaction by existing services, as detected by SVN monitoring. An apparent example of this principle in our case is the inability to measure lipids remotely, which seems to be an inhibiting factor for automated healthcare in the context of Diabetes Type 2 Management. This forms a market problem that AAL companies could pursue to solve.

Finally, the utility of building the innovation knowledge capacity as part of a platform with other adjacent (commercial or non-commercial) functionality was established in the Online Travel and AAL domains. Moreover, such a capacity can lead to not only an improvement of the service or information provision between actors in a domain, but also of the platform itself, in essence pointing to future directions for platform evolution.

8.1.2. The role of products, platforms, and services

Taking a step back and looking at the patterns in the seemingly disparate domains, there are a number of thoughts and principles that seem to apply in particular to the three final domains.

When applying the principle that all products are exclusively vehicles for the delivery of services (as discussed in section 2.6.1) to the scuba diving domain, this brings to bear an interesting result. In this perspective, the services are the functions performed by the second stage regulator. There are two types of

services: (a) services that support each other, to ultimately lead to (b) services that create value for the user. If a laddering technique (as discussed in section 3.4.3.2) is employed, we could envisage the following: a diver (actor) wants to live (need) → in order to live, s/he must breathe (process) → s/he needs a self-contained underwater breathing apparatus (S.C.U.B.A.) (object). The various components of the (first and) second stage regulator together perform services that lead to the main service of providing a 'breathing mix' (usually air, but can be nitrox or tri-mix), hence, enabling the process 'breathing'. The hardware, being the collection of properties and their relations of the regulator, can be considered the platform for service delivery and constraint. Only the services that the platform is capable of delivering can be delivered.

When applying the same perspective of platforms and services to the travel domain, it can be seen that the absence of parts of the platform, being the peripheral data that was not provided by the vendors, inhibits service innovation and value creation (as discussed in section 6.7). Interestingly, users seem to look at accommodation in the winter sports industry as a platform on top of which services are delivered, but which they can also use to self-create services of their own to satisfy their individual needs (e.g. 'enjoying the scenery'). Although in many instances of the latter case no value exchange takes place, including this self-creation of services ('experiences') by users in the scoping of one's service space as a service provider, obviously creates the opportunity for future value exchanges (e.g. 'come and enjoy the scenery on our guided tour!').

When the platform/service perspective is applied to the AAL domain, a clear manifestation of the same pattern emerges. The platform is formed by the sensor network, the communication infrastructure, the rule base extracted from the medical guidelines (which constrain the applicable services), and the business rules of the providers (which constrain the delivery of services). The services in this case are the ambient assisted living services. In this instance the absence of lipid control sensors in the platform (as discussed in section 10.6) inhibit the delivery of services in the context of AAL. An interesting note to make here regarding the platform-service relation, is that in the case of a

platform that delivers services from different domains over a congruent endpoint infrastructure, such as in the AAL case, service providers can not only possibly broaden the scope of service delivery, but also enjoy the benefits of what is essentially a native boundary-spanning environment. Platform providers also can enjoy the same benefits and create more capable and dynamic platforms as a result.

From a Service-Dominant Logic perspective, it seems there is a case to be made to bring the platform more to the forefront in service science thinking than is currently the case, and do away with the concept of a 'product' altogether. The perspective of functions as services delivered and constrained by platforms, supported by examples, could contribute to a further unification of S-DL and the still very much alive Goods-Dominant Logic in the intricate context of innovation management and engineering. A lot of this has to do with nomenclature and semantics, but as Vargo and Lusch (2008b) discussed, it is part of the process of progress for the field. Indeed, bridging the chasm could ultimately unify the competences of two schools of thought to create better, faster and smarter ways to innovate.

8.1.3. Summary of Key Principles

Innovation by Design: Make your innovation or peer production process part of your information system when building or improving it. This dual character will allow for an improved information management in the context of innovation in knowledge-intensive environments. All data and interactions can be input for innovation. Main domain chapters demonstrating the principle: Chapters 4A, 4B, 4C, 4D.

Old-Man-on-the-Pole[1] **Principle**: Do not rely solely on existing standards, rather build a domain model that allows for peripheral data to be captured by all domain actors, in essence closing leaks and integrating the data and information flow within a domain between al actors, including customers.

[1] See introductory quote Chapter 4C: Online Travel Domain

Ensure to keep a pragmatic balance between granularity and perspicuity in the domain model. Main domain chapters demonstrating the principle: Chapters 4C, 4D.

Functions Drive Properties: People buy products because they want them to "do a job" for them. Functions are the reason properties exist, so they need to be modelled for use in ideation. Finding new functions for existing properties, or vice versa, constitutes innovation. Main domain chapters demonstrating the principle: Chapters 4B, 4D.

Functions are Services: Functions are services, either between Objects, or between Objects and Actors. This means that the ideation process for services and platforms can be performed in a similar fashion, and that services and platform co-evolve (albeit at different speeds). Main domain chapters demonstrating the principle: Chapters 4B, 4C, 4D.

Formalise the Platform: A platform is defined as a relatively stable entity of components and services that *enables and constrains* the delivery of a dynamic variety of information and services by a provider to a customer. For example: if a person wants to "fly through the sky like a bird" a service provider can offer a solution to an approximation of that need ('laddering') based on the available platform, e.g. a plane or helicopter – i.e. the service is enabled and constrained by the platform. The platform needs to be formalised (brought to bear in structured fashion) in a service innovation context because it can help in understanding the inherent limitations of new services, or why things are the way they are at a given point in time. Main domain chapter demonstrating the principle: Chapter 4D.

8.2. Domain-Driven Innovation Framework

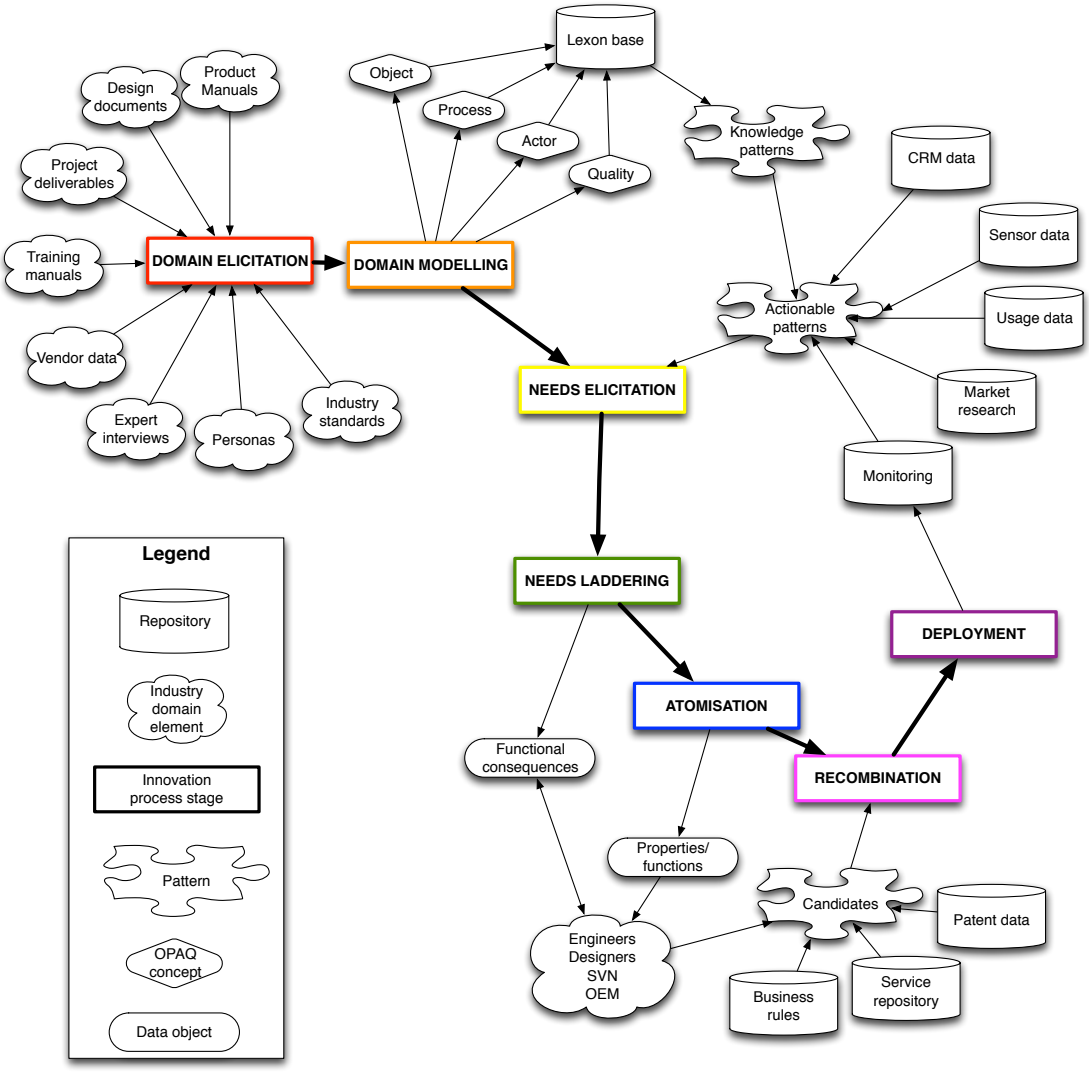

Fig. 8.1 Domain-Driven Innovation Framework

8.2.1. Overview

Domain-Driven Innovation (DDI) is defined as knowledge-based collaborative innovation by actors in a domain on the basis of a shared domain model for reasoning, knowledge discovery, communication, and information sharing.

The proposed DDI framework (Fig. 8.1) is defined as a framework because it is modular in terms of applied *processes*, participating domain *actors*, and

knowledge and data *objects* used. Considering the framework is aimed at comprehensiveness, this modularity translates to the ability to append process stages and knowledge/data objects, as evidenced by the different variations throughout the domains.

The DDI framework intends to contribute to the practice of innovation in knowledge-intensive environments as an artefact that offers improvements in terms of knowledge elicitation, knowledge modelling, knowledge discovery, knowledge management, human and machine reasoning, market needs articulation, ideation, and innovation monitoring.

The DDI framework consists of seven stages with varied knowledge interactions, explained below.

8.2.1.1. Domain Elicitation

Various domain documents, data, and interviews are aggregated and an initial rudimentary domain model is elicited for further refinement. All information pertaining to a domain can be of relevance for this stage.

Input:

- Domain expert interviews
- Design documents,
- Product manuals
- Project deliverables
- Industry standards
- Personas
- Vendor data
- Training manuals

Output:

- Initial rudimentary domain model

8.2.1.2. Domain Modelling

The entire domain is modelled in a fact-oriented, representation-agnostic, and standards-independent fashion. To this end, we employ engineering method DOGMA, with OPAQ as a classification method.

Input:

- Initial rudimentary domain model

Output:

- Industry domain model classified according to its Objects, Processes, Actors, and Quality
- Lexon base containing all facts about a domain in the form of lexons
- Knowledge patterns resulting from the lexon base

8.2.1.3. Needs Elicitation

Using the domain model, actionable patterns are selected or discovered, and needs are articulated. This can be a human process (research) or automated process (data mining) based on the domain model itself or on domain data. Input sources for the actionable patterns can be CRM data, sensor data, usage data (e.g. website analytics), and/or market research (e.g. customer interviews).

Input:

- Actionable patterns

Output:

- Articulated needs

8.2.1.4. Needs Laddering

The articulated needs are laddered further into the language and competence domain of vendors or service providers. In the case of services, functional consequences (actionable items that can be satisfied by suppliers) serve as the basis for a service design process. In the case of platforms, output is delivered

to the atomisation stage in the shape of a scope for atomisation (e.g. a specific component).

Input:

- Articulated needs

Output:

- Functional consequences
- Atomisation scope

8.2.1.5. Atomisation

Within the defined scope, all concepts are atomised into their most basic 'semantic atoms': properties and functions. These are added to the domain model and where required, related to other concepts (e.g. a process). Domain actors initiate a process to develop new services (SVN) or platform components (based on property/function variations). This results in candidate patterns. Input for the selection/composition of candidate patterns is patent data, service repositories, and/or business rules.

Input:

- Atomisation scope

Output:

- Properties and functions
- Candidate patterns

8.2.1.6. Recombination

Selected candidate patterns are combined into new, autonomous solutions, or recombined with pre-existing solution constellations. The new or improved solutions are realised.

Input:

- Candidate patterns

Output:

- Realised solutions

8.2.1.7. Deployment

Realised solutions are deployed either in the market directly or in a living lab setting, after which the performance of the new solutions is monitored according to some model of domain actors' objectives. The monitoring output allows for a cyclic, iterative improvement of the new solutions based starting from the Needs Elicitation stage.

Input:

- Realised solutions

Output:

- Performance monitoring data

8.2.2. Validation overview

The stages of the DDI framework have been validated in the covered industry domains as follows.

Table 8.1 Validation overview: innovation stages

Innovation Process Stage	Real Estate CRM	Scuba Diving Equipment	Online Travel	AAL
Domain Elicitation	✓	✓	✓	✓
Domain Modelling	✓	✓	✓	✓
Needs Elicitation		✓	✓	✓

Needs Laddering		✓	✓	✓
Atomisation / Bifurcation	✓	✓		
Recombination / Solution			✓	✓
Deployment			✓	✓

Although practical limitations have led to not one domain having deployed all DDI process stages, all process stages have been validated in the combined domains. Important to note here is that the two final stages have been validated only in the context of service, and not platform innovation due to time constraints and methodological choices clarified in Chapter 3: Methodology. The absence of a full-flow domain points to an interesting opportunity for future work, further discussed in the following and final chapter.

As for the characteristics of the business environments where evolving and partial versions of the DDI framework were implemented, Table 8.2 indicates a full coverage of B2C (business to consumer), B2B (business to business), Goods-Dominant (mainly product/platform related), and Service-Dominant (mainly service-related) innovation environments.

Whilst the DDI framework has not been validated in every imaginable domain or context, the coverage in terms of intrinsic process stages and extrinsic business environment characteristics, as well as the modularity of the framework do suggest a broad applicability of the DDI framework and its underlying principles.

Table 8.2 Validation overview: business environment characteristics

Characteristics	Real Estate CRM	Scuba Diving Equipment	Online Travel	AAL
B2C		✓	✓	✓
B2B	✓		✓	✓
Goods-Dominant		✓		
Service-Dominant	✓		✓	✓

"Peer production is about more than sitting down and having a nice conversation... It's about harnessing a new mode of production to take innovation and wealth creation to new levels."

Eric Schmidt

Executive Chairman, Google

9. Chapter 6: Conclusion and Future Work

9.1. Answers to the overall research questions

This thesis has presented research leading up to the development of a Domain-Driven Innovation Framework and related principles. In the process of the research and design of the artefacts, following questions regarding the problem space have been answered:

- Exploring the utility of domain models and ontologies in integrating heterogeneous data, knowledge, systems and actors in distributed innovation processes:
    - Out of the research it has become apparent that domain models, ontologies, and the OPAQ modelling approach were indeed useful artefacts in integrating knowledge in the innovation process in the Real Estate CRM domain (Chapter 4a), the Scuba Diving Equipment domain (Chapter 4b), the Online Travel domain (Chapter 4c), and the AAL domain (Chapter 4d).
- Exploring the disparity between product, service, and platform innovation and if a generic, knowledge-based innovation framework can be designed that can handle this disparity:
    - Out of the research it has become apparent that an integrative approach to disparate product, service, and platform innovation is possible and useful, although a proof of such a fully integrated process is part of future work.
- Exploring in what ways business information systems can be designed as innovation systems from the ground up:
    - Out of the research it has become apparent that there are many ways in which such business information systems can be built, but that they should share the underlying principles as outlined in Chapter 5: Synthesis.

- Providing empirical support for the general principles that emerge from patterns between industry domains:
    - Based on the presented case studies, I believe the framework and underlying principles have been sufficiently supported by empirical evidence. Furthermore, the variety in the domains suggests a broad applicability.

9.2. Chapters Overview and Future Work

Chapter 1 introduced the changing business landscape that forms the backdrop for the innovation research presented in this thesis. Major evolutions contained within technological developments include an increased openness, interconnectedness, granularisation, servitisation, and cyber-physicality.

Chapter 2 presented a targeted overview of the State-of-the-Art including an overview of the main innovation process models in use today. Based on these models, the initial innovation process model was constructed. The main open innovation and co-creation techniques were reviewed for general guidance on the integration of customer knowledge in the innovation process. An overview was given of the notion of knowledge creation and sharing in a collaborative enterprise environment, including ontology and an overview of the main enterprise ontologies in use today: The Enterprise Ontology, Enterprise Ontology, REA, TOVE, and ARIS. Some of the main product ontologies were also discussed: eClassOWL, PRONTO, SWOP, and GoodRelations. The observation was made that none of these ontologies cater for the formalisation of functions, something that was addressed in this thesis. Finally, an overview of Service-Dominant Logic and Service Science was provided in relation to product, service, and platform innovation.

Chapter 3 presented the T-shaped nature of this work and made the case for a deep and broad approach, and the methodological ramifications of such an approach. Design Science Research – the core methodology for designing the artefacts in this thesis – and Action Research – the methodology that guided

the trans-domain work – were discussed and the limitations of the respective methodologies were brought to bear in the context of the envisaged research design. The novel Hybrid Research Methodology and its 3 levels were introduced: Design Science Research, Action Research, and Meta-Knowledge. An initial and stripped-down version of the innovation process model, which was later applied in each domain, was explicated.

Chapter 4A described the real estate CRM domain research project where a bifurcation process was applied to a domain model resulting in a generic CRM domain model and a real estate domain model. The advantages of the bifurcated domain model were twofold: (1) the customisation and migration of CRM systems in a cloud-based environment, and (2) the application of the domain models for business intelligence. The main shortcoming of this domain is that it got stuck in the design stage due to lack of funding: this is evidenced in the 5-stage innovation process model where the recombination and deployment stages have not been executed (see section 4.7). Apart from this, the main future work with the artefacts from this domain would be application of the domain models in a domain-driven data mining process, rather than employing them post-factum in the interpretation of the patterns, which is a pretty straightforward process. It would also be nice to see the domain models pick up traction and be used in some capacity by other researchers or companies at some point.

Chapter 4B described the development and application of a formal domain model that can be used in the context of scuba diving equipment innovation. The domain model was developed through domain expert interviews. The idea of including functions in the formalisation of products/services and their domains was elaborated and implemented in the domain model. The resulting artefact has a dual purpose: reasoning in a product innovation context and the semantic annotation of web resources. The domain model was applied in a web-based ideation process where it was used to reason about the intricacies of the 2nd stage regulator and look for possible improvements. Looking at the innovation process that was enabled by the approach, we see that 6 of the generic 7 stages of the innovation process

model were covered, and a decent amount of knowledge interactions occurred. In this sense, and although the project was situated almost exclusively in a goods-dominant setting at the time, the scuba diving domain was the domain where a lot of the ideas for this thesis came to fruition, albeit in an early stage. It is also the only domain that had a clear validation of the atomisation/recombination principle. The main value of the resulting artefacts lies in the fact that the approach can offer contributions towards broadening the scope of collaborative innovation, i.e. involving a broader base of actors on an intricate engineering level. The scuba domain would also be a perfect candidate for an integrated product/platform/service application of the DDI framework, considering how well-defined it is, how many qualified and accredited domain experts it counts, and the fact that it is both service-heavy and equipment-heavy. In other words, the entire 'service trail' from materials engineering and innovation, to domain-specific engineering and ultimately, the scuba diving shop and touristic dive boats, would be able to be modelled more easily than other domains that count many more intersections with other adjacent domains. This is something that would make a very interesting case study in bridging the traditional goods-dominant and the emerging service-dominant approaches in the context of innovation. Such a project would also allow one to explore the previously indicated future work on the domain level itself: exploring the needed level of granularity, elaborating the 'material' property, and the addition of failure processes. In addition, it would be interesting to further study the application of DDI in organisational contexts, and the practical considerations for 'real-world' deployments.

Chapter 4C described what was the biggest project in terms of person months committed and software developed. In the online travel domain, the initial outset was to improve product search by 'flipping the supply chain' through capturing the purchase intent of customers and matching that in real time to vendor offers using an intermediary ontology. The system also doubled as a bottom-up innovation system, since by capturing the intent not as a selection but as the intent itself, would allow to see mismatches and improve service

offerings accordingly. The cool thing about the system was that customers were essentially participating in a peer production system without explicitly knowing: their interactions were driven by a need to go on vacation, but served the additional purpose of delivering input to the innovation process. The big 'but' here is that the generated peripheral data could not be matched by the platform and thus the information chain was broken, resulting in a decreased capacity (by lack of customer insight) for innovation by the service providers (hotels etc.). The importance of the platform (including standards) in service innovation was brought to bear here. This notion would be interesting to explore further in the context of a future 'service-heavy' innovation project.

Chapter 4D was situated in the ambient assisted living domain in the context of a smart home platform being developed by one of Australia's largest telecommunications providers. A great amount of extraction, formalisation, and integration was needed to build an information system that would operate with the existing complex healthcare service system in Australia. It should be noted that only one relatively-easy-to-model health aspect, Type 2 Diabetes, was addressed in our research. This gives an idea of how complex the health service system is and how much work a broader implementation would require. In the performed research, an SVN approach was applied to identify, select, and compose services for patients based on biological parameters measurable by sensors. Although the research placed an emphasis on services, the inclusion of an overarching domain model and the apparent platform-dependence of the services added platform aspects to approach. Future work in this domain would include the complete formalisation of platform and services in the context of detecting patterns for platform/service innovation.

Chapter 5 provided an integration of key meta-level insights from the domains, and explored further the role of products, platforms, and services in relation to prevalent paradigms. Key principles were further listed as "Innovation by Design", "Old Man on the Pole", "Functions Drive Properties", "Functions are Services", and "Formalise the Platform". The

listed principles constitute evidence-supported best practice in the context of DDI. The current state of the Domain-Driven Innovation Framework was presented, including the proposed process stages and knowledge interactions.

9.3. Contributions to the State of the Art

Looking at the state of the art, I believe a sound contribution was made in more formally integrating knowledge in various forms into a collaborative innovation process. An overview of the validation of the various process stages was provided and this illustrates clearly that there was not one domain that covered each process stage. The lack of a project that effectively integrated product/service/platform innovation aspects into a single process leaves room for improvement mainly between the needs laddering and atomisation stage.

In summary, and amongst others, this thesis has presented contributions to following domains: *Design Science Research* by the development of a hybrid methodological framework capable of transcending industry domains; *Innovation Management* via the development of a framework that allows for a more granular representation of knowledge in the innovation process and its role in the creation of new products and services, as well as the social aspects by modelling the actors and their processes; *Service Science* by offering additional insights into the role of the platform in service innovation, as well as a common basis for service innovation via a shared language; *Service Value Networks* by replacing current assumptions that customers are actively involved in explicating their service requirements with a more tacit approach where requirements are derived from patterns in ambient data; *Healthcare Informatics* by applying a SVN approach for automated matching of patient requirements to medical practice recommendation based on patient sensor data in the context of home care monitoring as part of a more complex service system; *E-Commerce* by implementing and exploring the notion of web-based, bottom-up innovation/ideation using the existing transaction infrastructure augmented with a semantic meta-model and fuzzy matching service; *New Product Development* by introducing a method for eliciting, modelling, and

sharing domain knowledge for use in the NPD process; *Business Intelligence* by introducing a bifurcation approach; and *Domain Modelling* by further validating the OPAQ hierarchy in additional industry domains, as well as introducing domain- and industry-specific modelling principles.

The transforming business landscape that provided the backdrop for this research was underpinned by a number of intertwined technological evolutions towards more openness, interconnectedness, granularisation, servitisation, and cyber-physicality. The DDI framework sits comfortably between these trends in a variety of ways. *Openness* and *interconnectedness*, exemplified by open innovation, open data, open hardware, etc., are catered for by the semantic, knowledge-based nature of the platform, allowing for information and knowledge exchange across the (web-based) collaborative innovation cycle. Knowledge-based innovation does not only mean on the level of knowledge, but also purposefully disregarding a plethora of non-knowledge related aspects in the framework. For instance the framework does not in any way relate to financial resources/capacity or specify that its actors need to be business enterprises. They can just as well be teams looking to build something in their free time, NGOs looking to improve their services, or a single individual looking to interact with industry domains. This *granularisation* of economic activity, where geographically distributed individuals interact and create value over the Internet, can be supported by the DDI framework by allowing shared and structured innovation-specific reasoning. *Servitisation* and *cyber-physicality* are in a sense two sides of the same coin: they both signify a convergence of physical and non-physical realms. One of the biggest contributions this research has made in that respect was in proposing directions for a formal unifying framework of products, platforms, and services in the context of innovation – perhaps in some way contributing to the way innovation will be performed in future societies where the distinction between digital and physical realms may further lose its relevance.

"Oh, well, there we are. Here's the theme music. Goodnight."

Monty Python

Monty Python's The Meaning of Life

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11. Appendices

Appendix I: Hybrid Research Methodology

Appendix II: CRM Domain Model (also online)

Appendix III: Real Estate Domain Model (also online)

Appendix IV: Scuba Diving Equipment Domain Model (also online)

Appendix V: Scuba Domain Expert Interview Transcript

Appendix VI: Scuba Domain Expert Interview Screenshots

Appendix VII: Online Travel Domain Model (also online)

Appendix VIII: Online Travel Domain Software Descriptions

Appendix IX: AAL Domain Rule Base (only online)

Appendix X: AAL Domain Patient Profiles and their Recommendations (only online)

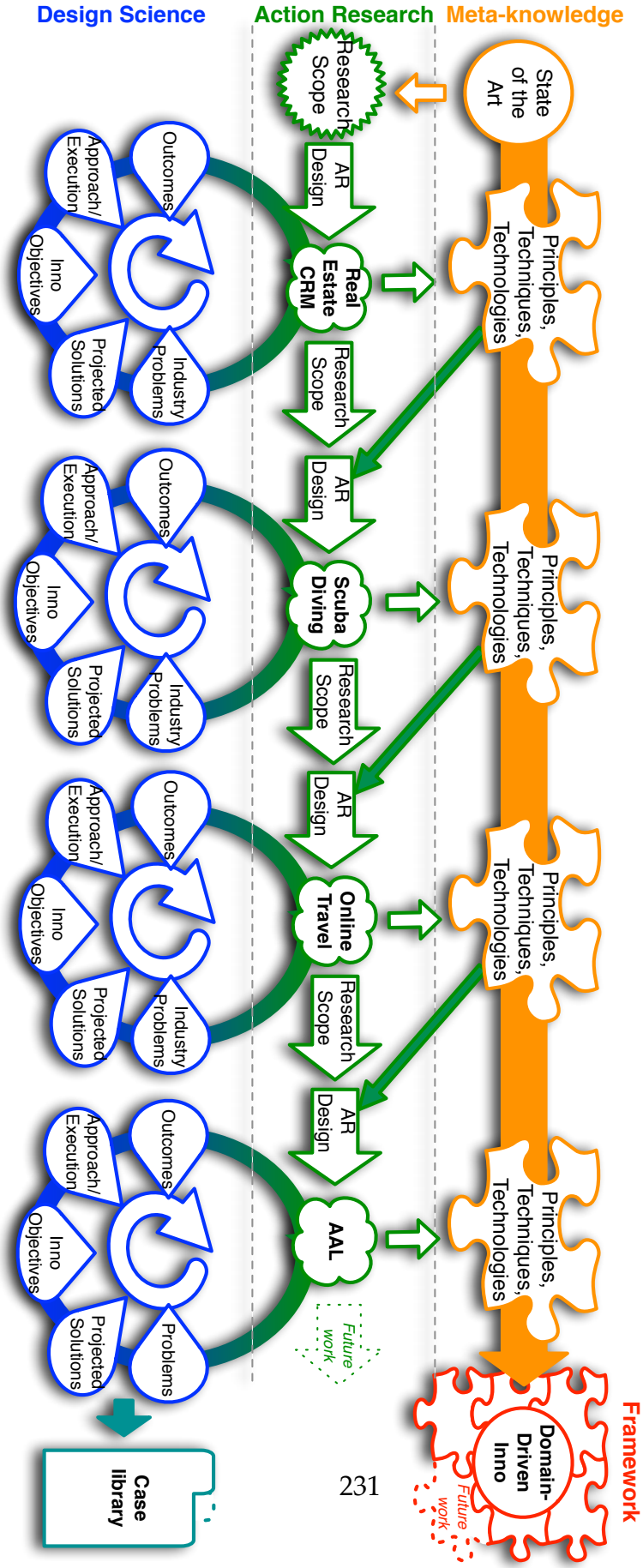
Appendix XI: AAL Domain Patient/FC Mappings (only online)

Appendix XII: AAL Domain Service/FC Mappings (only online)

Appendix XIII: AAL Personas (only online)

Appendix XIV: Rudimentary AAL Domain Model (also online)

11.1. Appendix I: Hybrid Research Methodology



11.2. Appendix II: CRM Domain Model

Also digitally available at
https://www.researchgate.net/publication/236047118_CRMDomainModel

Account	is a	subsumes	T
Account	has	ispartof	AccountNumber
AccountNumber	is a	subsumes	T
ActivityStatus	is a	subsumes	T
ActivityStatus	isa	subsumes	Status
Actor	is a	subsumes	T
Actor	subsumes	isa	User
Actor	subsumes	isa	CustomerOrPotentialCustomer
Actor	subsumes	isa	Vendor
AffiliateCompany	is a	subsumes	T
BillingAddress	is a	subsumes	T
Carrier	is a	subsumes	T
City	is a	subsumes	T
CommissionRate	is a	subsumes	T
CompanyName	is a	subsumes	T
Contact	is a	subsumes	T
Contact	has	ispartof	ContactNumber
ContactNumber	is a	subsumes	T
CostPrice	isa	subsumes	Price
CostPrice	is a	subsumes	T
Country	is a	subsumes	T
CRMSystem	has	ispartof	Object
CRMSystem	has	ispartof	Actor
CRMSystem	is a	subsumes	T
CRMSystem	has	ispartof	Quality
CRMSystem	has	ispartof	Process
Currency	is a	subsumes	T
CustomerOrPotentialCustomer	assignedto	manages	User
CustomerOrPotentialCustomer	has	ispartof	CustomerOrPotentialCustomerDescription
CustomerOrPotentialCustomer	subsumes	isa	Potential
CustomerOrPotentialCustomer	has	ispartof	IdentityInformation
CustomerOrPotentialCustomer	has	ispartof	TimeOfModification
CustomerOrPotentialCustomer	subsumes	isa	Lead
CustomerOrPotentialCustomer	subsumes	isa	Contact

CustomerOrPotentialCustomer	subsumes	isa	Account
CustomerOrPotentialCustomer	is a	subsumes	T
CustomerOrPotentialCustomer	has	ispartof	TimeOfCreation
CustomerOrPotentialCustomerDescription	is a	subsumes	T
Date	is a	subsumes	T
Date	ispartof	has	TimeAndDate
Document	has	ispartof	DocumentTitle
Document	has	ispartof	FileOrAttachment
Document	isa	subsumes	Object
Document	has	ispartof	UploadDateAndTime
Document	ispartof	has	DocumentCategory
Document	is a	subsumes	T
Document	has	ispartof	DocumentNumber
Document	has	ispartof	ModificationDateAndTime
Document	assignedto	manages	User
DocumentCategory	is a	subsumes	T
DocumentNumber	is a	subsumes	T
DocumentTitle	is a	subsumes	T
DueDate	isa	subsumes	Date
DueDate	is a	subsumes	T
EmailAddress	is a	subsumes	T
EndDate	is a	subsumes	T
EndDate	isa	subsumes	Date
ExchangeRate	is a	subsumes	T
ExpectedCloseDate	is a	subsumes	T
ExpectedCloseDate	isa	subsumes	Date
ExpectedRevenue	isa	subsumes	Number
ExpectedRevenue	is a	subsumes	T
FaxNumber	is a	subsumes	T
FileOrAttachment	is a	subsumes	T
FirstName	is a	subsumes	T
HomePhoneNumber	is a	subsumes	T
IdentityInformation	subsumes	isa	PhysicalAddress
IdentityInformation	subsumes	isa	WebsiteAddress
IdentityInformation	subsumes	isa	PhoneNumber
IdentityInformation	subsumes	isa	FirstName
IdentityInformation	subsumes	isa	CompanyName
IdentityInformation	subsumes	isa	LastName
IdentityInformation	is a	subsumes	T
IdentityInformation	subsumes	isa	EmailAddress

IdentityInformation	subsumes	isa	PersonalTitle
IdentityInformation	subsumes	isa	FaxNumber
IdentityInformation	subsumes	isa	AffiliateCompany
Invoice	has	ispartof	InvoiceNumber
Invoice	is a	subsumes	T
Invoice	isa	subsumes	SalesArtifact
Invoice	has	ispartof	Status
Invoice	has	ispartof	DueDate
Invoice	has	ispartof	InvoiceSubject
InvoiceNumber	is a	subsumes	T
InvoiceNumber	isa	subsumes	Number
InvoiceSubject	is a	subsumes	T
LastName	is a	subsumes	T
Lead	is a	subsumes	T
Lead	has	ispartof	LeadNumber
LeadNumber	is a	subsumes	T
ListPrice	isa	subsumes	Price
ListPrice	is a	subsumes	T
MailingAddress	is a	subsumes	T
Manufacturer	has	ispartof	IdentityInformation
Manufacturer	isa	subsumes	Actor
Manufacturer	is a	subsumes	T
MarketingArtifact	is a	subsumes	T
MarketingArtifact	subsumes	isa	MarketingCampaign
MarketingCampaign	assignedto	manages	User
MarketingCampaign	has	ispartof	Sponsor
MarketingCampaign	has	ispartof	ExpectedCloseDate
MarketingCampaign	has	ispartof	MarketingCampaignNumber
MarketingCampaign	has	ispartof	NumberOfMarketingItemsSent
MarketingCampaign	has	ispartof	TimeOfModification
MarketingCampaign	is a	subsumes	T
MarketingCampaign	has	ispartof	MarketingCampaignName
MarketingCampaign	ispartof	has	MarketingCampaignCategory
MarketingCampaign	has	ispartof	TimeOfCreation
MarketingCampaign	has	ispartof	ExpectedRevenue
MarketingCampaign	has	ispartof	Status
MarketingCampaignCategory	is a	subsumes	T
MarketingCampaignName	is a	subsumes	T
MarketingCampaignNumber	is a	subsumes	T
MarketingProcess	has	ispartof	MarketingArtifact

MarketingProcess	is a	subsumes	T
MobilePhoneNumber	is a	subsumes	T
ModificationDateAndTime	is a	subsumes	T
Number	is a	subsumes	T
NumberOfMarketingItemsSent	isa	subsumes	Number
NumberOfMarketingItemsSent	is a	subsumes	T
Object	subsumes	isa	MarketingArtifact
Object	is a	subsumes	T
OfficePhoneNumber	is a	subsumes	T
OtherPhoneNumber	is a	subsumes	T
PersonalTitle	is a	subsumes	T
PhoneNumber	subsumes	isa	OtherPhoneNumber
PhoneNumber	is a	subsumes	T
PhoneNumber	subsumes	isa	OfficePhoneNumber
PhoneNumber	subsumes	isa	HomePhoneNumber
PhoneNumber	subsumes	isa	MobilePhoneNumber
PhysicalAddress	subsumes	isa	MailingAddress
PhysicalAddress	is a	subsumes	T
PhysicalAddress	has	ispartof	City
PhysicalAddress	has	ispartof	Street
PhysicalAddress	has	ispartof	PostOfficeBoxNumber
PhysicalAddress	has	ispartof	StreetNumber
PhysicalAddress	subsumes	isa	BillingAddress
PhysicalAddress	has	ispartof	Country
PhysicalAddress	has	ispartof	PostalCode
PhysicalAddress	subsumes	isa	ShippingAddress
PhysicalAddress	has	ispartof	State
PostalCode	is a	subsumes	T
PostOfficeBoxNumber	is a	subsumes	T
Potential	has	ispartof	PotentialNumber
Potential	is a	subsumes	T
PotentialNumber	is a	subsumes	T
Price	subsumes	isa	SalesPrice
Price	subsumes	isa	UnitPrice
Price	isa	subsumes	Number
Price	is a	subsumes	T
Price	has	ispartof	Currency
PriceBook	has	ispartof	ListPrice
PriceBook	relatedto	relatedto	Product
PriceBook	has	ispartof	UnitPrice

PriceBook	has	ispartof	TimeOfModification
PriceBook	has	ispartof	ExchangeRate
PriceBook	has	ispartof	PriceBookName
PriceBook	is a	subsumes	T
PriceBook	has	ispartof	PriceBookNumber
PriceBook	isa	subsumes	SalesArtifact
PriceBook	has	ispartof	Currency
PriceBook	has	ispartof	CostPrice
PriceBook	has	ispartof	TimeOfCreation
PriceBookName	is a	subsumes	T
PriceBookNumber	is a	subsumes	T
Process	subsumes	isa	SalesProcess
Process	is a	subsumes	T
Process	subsumes	isa	MarketingProcess
Process	subsumes	isa	SupportProcess
Product	has	ispartof	CommissionRate
Product	has	ispartof	ProductNumber
Product	is a	subsumes	SalesArtifact
Product	has	ispartof	ProductName
Product	madeby	makes	Manufacturer
Product	has	ispartof	ProductImage
Product	has	ispartof	Price
Product	soldby	sells	Vendor
Product	has	ispartof	ActivityStatus
Product	ispartof	has	ProductStock
ProductImage	is a	subsumes	T
ProductName	is a	subsumes	T
ProductNumber	is a	subsumes	T
ProductNumber	isa	subsumes	Number
ProductQuantity	is	subsumes	Number
ProductQuantity	is a	subsumes	T
ProductQuantityInDemand	is a	subsumes	T
ProductQuantityInDemand	is	subsumes	ProductQuantity
ProductQuantityInStock	is	subsumes	ProductQuantity
ProductQuantityInStock	is a	subsumes	T
ProductStock	is	subsumes	SalesArtifact
ProductStock	assignedto	manages	User
ProductStock	has	ispartof	ReorderLevel
ProductStock	has	ispartof	ProductQuantity
ProductStock	is a	subsumes	T

Progress	is a	subsumes	T
PurchaseOrder	has	ispartof	PurchaseOrderSubject
PurchaseOrder	has	ispartof	TrackingCode
PurchaseOrder	isa	subsumes	PurchasingArtifact
PurchaseOrder	assignedto	manages	User
PurchaseOrder	has	ispartof	PurchaseOrderNumber
PurchaseOrder	has	ispartof	Carrier
PurchaseOrder	is a	subsumes	T
PurchaseOrder	sentto	receives	Vendor
PurchaseOrder	has	ispartof	Status
PurchaseOrderNumber	isa	subsumes	Number
PurchaseOrderNumber	is a	subsumes	T
PurchaseOrderSubject	is a	subsumes	T
PurchasingArtifact	ispartof	has	PurchasingProcess
PurchasingArtifact	is a	subsumes	T
PurchasingProcess	is a	subsumes	T
PurchasingProcess	isa	subsumes	Process
Quality	subsumes	isa	Number
Quality	subsumes	isa	Progress
Quality	is a	subsumes	T
Quote	sentto	receives	Potential
Quote	has	ispartof	TimeOfCreation
Quote	isa	subsumes	SalesArtifact
Quote	has	ispartof	ValidityDate
Quote	has	ispartof	QuoteSubject
Quote	has	ispartof	Carrier
Quote	assignedto	manages	User
Quote	has	ispartof	TimeOfModification
Quote	is a	subsumes	T
QuoteSubject	is a	subsumes	T
ReorderLevel	is a	subsumes	T
SalesArtifact	isa	subsumes	Object
SalesArtifact	ispartof	has	SalesProcess
SalesArtifact	is a	subsumes	T
SalesOrder	has	ispartof	SalesOrderNumber
SalesOrder	isa	subsumes	SalesArtifact
SalesOrder	has	ispartof	SalesOrderSubject
SalesOrder	sentto	receives	Account
SalesOrder	is a	subsumes	T
SalesOrder	has	ispartof	DueDate

SalesOrder	has	ispartof	Status
SalesOrderNumber	isa	subsumes	Number
SalesOrderNumber	is a	subsumes	T
SalesOrderSubject	is a	subsumes	T
SalesPrice	is a	subsumes	T
SalesProcess	is a	subsumes	T
ServiceContract	isa	subsumes	SupportArtifact
ServiceContract	is a	subsumes	T
ServiceContract	has	ispartof	ServiceContractNumber
ServiceContract	has	ispartof	StartDate
ServiceContract	has	ispartof	DueDate
ServiceContract	has	ispartof	Progress
ServiceContract	has	ispartof	Status
ServiceContract	has	ispartof	EndDate
ServiceContract	relatedto	relatedto	Account
ServiceContract	has	ispartof	ServiceContractSubject
ServiceContract	assignedto	manages	User
ServiceContractNumber	is a	subsumes	T
ServiceContractSubject	is a	subsumes	T
ShippingAddress	is a	subsumes	T
Sponsor	is a	subsumes	T
StartDate	isa	subsumes	Date
StartDate	is a	subsumes	T
State	is a	subsumes	T
Status	is a	subsumes	T
Status	isa	subsumes	Quality
Street	is a	subsumes	T
StreetNumber	is a	subsumes	T
SupportArtifact	isa	subsumes	Object
SupportArtifact	ispartof	has	SupportProcess
SupportArtifact	is a	subsumes	T
SupportProcess	is a	subsumes	T
SupportTicket	isa	subsumes	SupportArtifact
SupportTicket	is a	subsumes	T
SupportTicket	has	ispartof	Status
SupportTicket	has	ispartof	SupportTicketNumber
SupportTicket	assignedto	manages	User
SupportTicket	has	ispartof	SupportTicketTitle
SupportTicket	relatedto	relatedto	Account
SupportTicketNumber	is a	subsumes	T

SupportTicketTitle	is a	subsumes	T
Time	is a	subsumes	T
Time	ispartof	has	TimeAndDate
TimeAndDate	isa	subsumes	Quality
TimeAndDate	is a	subsumes	T
TimeOfCreation	is a	subsumes	T
TimeOfCreation	isa	subsumes	Time
TimeOfModification	is a	subsumes	T
TimeOfModification	isa	subsumes	Time
TrackingCode	is a	subsumes	T
UnitPrice	is a	subsumes	T
UploadDateAndTime	is a	subsumes	T
User	is a	subsumes	T
ValidityDate	is a	subsumes	T
ValidityDate	isa	subsumes	Date
Vendor	has	ispartof	IdentityInformation
Vendor	is a	subsumes	T
WebsiteAddress	is a	subsumes	T

11.3. Appendix III: Real Estate Domain Model

Also digitally available at
https://www.researchgate.net/publication/236047119_RealEstateDomainModel

ACLedge	is a	subsumes	T
ACLedgeNumber	ispartof	has	ACLedge
ACLedgeNumber	isa	subsumes	Number
ACLedgeNumber	is a	subsumes	T
Actor	is a	subsumes	T
Actor	subsumes	isa	Contractor
Actor	subsumes	isa	Lead
Actor	subsumes	isa	RealEstateAgent
Actor	subsumes	isa	PropertyManager
Actor	subsumes	isa	PropertyValuer
Actor	subsumes	isa	Customer
Actor	subsumes	isa	CustomerServiceRepresentative
Apartment	is a	subsumes	T
Attic	is a	subsumes	T
AudioVisualRoom	is a	subsumes	T
Balcony	subsumes	isa	RearBalcony
Balcony	subsumes	isa	FrontBalcony
Balcony	is a	subsumes	T
Basement	is a	subsumes	T
Bathroom	has	ispartof	BathroomNumber
Bathroom	is a	subsumes	T
Bathroom	subsumes	isa	MasterBathroom
BathroomNumber	is a	subsumes	T
Bedroom	has	ispartof	BedroomNumber
Bedroom	is a	subsumes	T
Bedroom	subsumes	isa	MasterBedroom
BedroomNumber	is a	subsumes	T
BreakfastRoom	is a	subsumes	T
Bungalow	is a	subsumes	T
Buyer	is a	subsumes	T
CarPark	is a	subsumes	T
CarPark	subsumes	isa	RearCarPark
CarPorch	is a	subsumes	T
CommercialProperty	is a	subsumes	T

CommunityHall	is a	subsumes	T
Condominium	subsumes	isa	HighRiseCondominium
Condominium	is a	subsumes	T
Condominium	subsumes	isa	LowRiseCondominium
Contractor	is a	subsumes	T
Corridor	is a	subsumes	T
CourtYard	is a	subsumes	T
Customer	subsumes	isa	Buyer
Customer	subsumes	isa	Tenant
Customer	is a	subsumes	T
CustomerServiceRepresentative	is a	subsumes	T
Deck	is a	subsumes	T
Defect	subsumes	isa	StaircaseDefect
Defect	has	ispartof	DefectsLocation
Defect	subsumes	isa	DoorDefect
Defect	subsumes	isa	WallDefect
Defect	has	ispartof	DefectsArea
Defect	subsumes	isa	FloorDefect
Defect	subsumes	isa	RoofOrCeilingDefect
Defect	is a	subsumes	T
DefectsArea	is a	subsumes	T
DefectsCategory	is a	subsumes	T
DefectsLocation	isa	subsumes	Location
DefectsLocation	is a	subsumes	T
DefectsLocationCode	is a	subsumes	T
DefectsManagement	is a	subsumes	T
Department	is a	subsumes	T
DepartmentName	is a	subsumes	T
DevelopmentProject	is a	subsumes	T
DiningRoom	has	ispartof	DiningRoomTerrace
DiningRoom	is a	subsumes	T
DiningRoomTerrace	is a	subsumes	T
DiningRoomTerrace	isa	subsumes	Terrace
Division	ispartof	has	Department
Division	is a	subsumes	T
DoorDefect	is a	subsumes	T
Driveway	is a	subsumes	T
DryKitchen	is a	subsumes	T
DryKitchen	has	ispartof	DryKitchenTerrace
DryKitchenTerrace	isa	subsumes	Terrace

DryKitchenTerrace	is a	subsumes	T
DryYard	isa	subsumes	Yard
DryYard	is a	subsumes	T
ElectricalAndTelephoneRiser	is a	subsumes	T
Entrance	is a	subsumes	T
Entrance	has	ispartof	EntranceLobby
Entrance	has	ispartof	EntranceFoyer
Entrance	has	ispartof	EntranceTreshold
Entrance	subsumes	isa	MainEntrance
EntranceFoyer	isa	subsumes	Foyer
EntranceFoyer	is a	subsumes	T
EntranceLobby	isa	subsumes	Lobby
EntranceLobby	is a	subsumes	T
EntranceTreshold	isa	subsumes	Staircase
EntranceTreshold	is a	subsumes	T
FamilyBalcony	isa	subsumes	Balcony
FamilyBalcony	is a	subsumes	T
FamilyFoyer	isa	subsumes	Foyer
FamilyFoyer	is a	subsumes	T
FamilyHallOrArea	is a	subsumes	T
FamilyLivingRoom	isa	subsumes	LivingRoom
FamilyLivingRoom	is a	subsumes	T
FlatRoof	is a	subsumes	T
FloorDefect	is a	subsumes	T
FloorOrStorey	is a	subsumes	T
FloorOrStorey	has	ispartof	FloorOrStoreyNumber
FloorOrStoreyNumber	is a	subsumes	T
Foyer	is a	subsumes	T
FrontBalcony	is a	subsumes	T
Gallery	is a	subsumes	T
Garage	is a	subsumes	T
GardenStore	isa	subsumes	Store
GardenStore	is a	subsumes	T
GuestBathroom	is a	subsumes	T
GuestBathroom	isa	subsumes	Bathroom
GuestRoom	is a	subsumes	T
Hallway	is a	subsumes	T
Hallway	has	ispartof	HallwayNumber
HallwayNumber	is a	subsumes	T
HandWashBasin	is a	subsumes	T

HighRiseCondominium	is a	subsumes	T
Kitchen	is a	subsumes	T
Kitchen	subsumes	isa	DryKitchen
Kitchen	subsumes	isa	WetKitchen
LandedProperty	is a	subsumes	T
Lawn	is a	subsumes	T
Lead	is a	subsumes	T
LivingRoom	has	ispartof	LivingRoomTerrace
LivingRoom	has	ispartof	LivingRoomNumber
LivingRoom	is a	subsumes	T
LivingRoomNumber	is a	subsumes	T
LivingRoomTerrace	is a	subsumes	T
LivingRoomTerrace	isa	subsumes	Terrace
Lobby	is a	subsumes	T
Location	is a	subsumes	T
LowRiseCondominium	is a	subsumes	T
Mailbox	is a	subsumes	T
MainEntrance	is a	subsumes	T
MasterBalcony	isa	subsumes	Balcony
MasterBalcony	is a	subsumes	T
MasterBathroom	is a	subsumes	T
MasterBedroom	is a	subsumes	T
MasterWardrobe	isa	subsumes	Wardrobe
MasterWardrobe	is a	subsumes	T
MeterCompartment	is a	subsumes	T
Nook	is a	subsumes	T
Nook	has	ispartof	NookTerrace
NookTerrace	isa	subsumes	Terrace
NookTerrace	is a	subsumes	T
Number	is a	subsumes	T
Number	subsumes	isa	Number
Number	subsumes	isa	HallwayNumber
Number	subsumes	isa	LivingRoomNumber
Number	subsumes	isa	FloorOrStoreyNumber
Number	subsumes	isa	BedroomNumber
Number	subsumes	isa	StoreNumber
Number	subsumes	isa	BathroomNumber
Object	is a	subsumes	T
Object	subsumes	isa	Property
Object	subsumes	isa	PropertyDevelopmentCompany

Patio	is a	subsumes	T
Playground	is a	subsumes	T
PorteCochere	is a	subsumes	T
PowderRoom	is a	subsumes	T
PrayerRoom	is a	subsumes	T
Process	subsumes	isa	DefectsManagement
Process	is a	subsumes	T
Process	subsumes	isa	PropertyDevelopment
Product	is a	subsumes	T
ProjectGroup	has	ispartof	PropertyDevelopmentProject
ProjectGroup	is a	subsumes	T
ProjectNumber	is a	subsumes	T
Property	subsumes	isa	SemiDetachedProperty
Property	subsumes	isa	ServiceIndustryProperty
Property	subsumes	isa	TraditionalVillageProperty
Property	isownedby	owns	Customer
Property	subsumes	isa	Bungalow
Property	isrentedby	rents	Customer
Property	subsumes	isa	ShopHouse
Property	has	ispartof	PropertySection
Property	has	ispartof	Defect
Property	has	ispartof	PropertyLocation
Property	is a	subsumes	T
Property	subsumes	isa	TownHouse
Property	subsumes	isa	Apartment
Property	isdevelopedby	develops	PropertyDevelopmentCompany
Property	subsumes	isa	ShopOffice
Property	subsumes	isa	Condominium
Property	subsumes	isa	LandedProperty
Property	subsumes	isa	CommercialProperty
PropertyDevelopment	is a	subsumes	T
PropertyDevelopment	has	ispartof	PropertyDevelopmentProject
PropertyDevelopmentCompany	manages	ismanagedby	PropertyDevelopmentProject
PropertyDevelopmentCompany	has	ispartof	Department
PropertyDevelopmentCompany	is a	subsumes	T
PropertyDevelopmentProject	is a	subsumes	T
PropertyDevelopmentProject	has	ispartof	ProjectNumber
PropertyLocation	is a	subsumes	T
PropertyLocation	isa	subsumes	Location
PropertyManager	is a	subsumes	T

PropertySection	subsumes	isa	Lobby
PropertySection	subsumes	isa	Toilet
PropertySection	subsumes	isa	CommunityHall
PropertySection	subsumes	isa	HandWashBasin
PropertySection	subsumes	isa	ReadingRoom
PropertySection	subsumes	isa	AudioVisualRoom
PropertySection	subsumes	isa	Yard
PropertySection	subsumes	isa	Mailbox
PropertySection	subsumes	isa	Nook
PropertySection	subsumes	isa	WaterTankAccess
PropertySection	subsumes	isa	RefuseCompartment
PropertySection	subsumes	isa	Lawn
PropertySection	subsumes	isa	Corridor
PropertySection	subsumes	isa	Verandah
PropertySection	subsumes	isa	Patio
PropertySection	subsumes	isa	Driveway
PropertySection	subsumes	isa	Garage
PropertySection	subsumes	isa	Hallway
PropertySection	subsumes	isa	MeterCompartment
PropertySection	subsumes	isa	Entrance
PropertySection	subsumes	isa	Bedroom
PropertySection	subsumes	isa	LivingRoom
PropertySection	subsumes	isa	PorteCochere
PropertySection	subsumes	isa	StudyRoom
PropertySection	subsumes	isa	Roof
PropertySection	subsumes	isa	FamilyHallOrArea
PropertySection	subsumes	isa	UtilityArea
PropertySection	subsumes	isa	ElectricalAndTelephoneRiser
PropertySection	subsumes	isa	Balcony
PropertySection	subsumes	isa	PrayerRoom
PropertySection	subsumes	isa	Wardrobe
PropertySection	subsumes	isa	CarPark
PropertySection	subsumes	isa	CarPorch
PropertySection	subsumes	isa	Foyer
PropertySection	subsumes	isa	Staircase
PropertySection	subsumes	isa	StaircaseEntrance
PropertySection	subsumes	isa	RearUtility
PropertySection	subsumes	isa	BreakfastRoom
PropertySection	subsumes	isa	Playground
PropertySection	is a	subsumes	T

PropertySection	subsumes	isa	DiningRoom
PropertySection	subsumes	isa	WaterFilterCompartment
PropertySection	subsumes	isa	Kitchen
PropertySection	subsumes	isa	Basement
PropertySection	subsumes	isa	Gallery
PropertySection	subsumes	isa	Bathroom
PropertySection	subsumes	isa	Terrace
PropertySection	subsumes	isa	Attic
PropertySection	subsumes	isa	ACLedge
PropertySection	subsumes	isa	Deck
PropertySection	subsumes	isa	GuestRoom
PropertySection	subsumes	isa	Store
PropertySection	subsumes	isa	PowderRoom
PropertySection	subsumes	isa	FloorOrStorey
PropertyType	is a	subsumes	T
PropertyValuer	is a	subsumes	T
Quality	subsumes	isa	Location
Quality	subsumes	isa	Defect
Quality	is a	subsumes	T
Quality	subsumes	isa	Number
ReadingRoom	is a	subsumes	T
RealEstateAgent	is a	subsumes	T
RealEstateDomain	has	ispartof	Actor
RealEstateDomain	has	ispartof	Quality
RealEstateDomain	has	ispartof	Process
RealEstateDomain	is a	subsumes	T
RealEstateDomain	has	ispartof	Object
RearBalcony	is a	subsumes	T
RearCarPark	is a	subsumes	T
RearUtility	is a	subsumes	T
RefuseCompartment	is a	subsumes	T
Roof	subsumes	isa	FlatRoof
Roof	is a	subsumes	T
RoofOrCeilingDefect	is a	subsumes	T
SemiDetachedProperty	is a	subsumes	T
ServiceIndustryProperty	is a	subsumes	T
ShopHouse	is a	subsumes	T
ShopOffice	is a	subsumes	T
SideYard	is a	subsumes	T
Staircase	is a	subsumes	T

StaircaseDefect	is a	subsumes	T
StaircaseEntrance	is a	subsumes	T
Store	has	ispartof	StoreNumber
Store	is a	subsumes	T
StoreNumber	is a	subsumes	T
Storey	is a	subsumes	T
StudyRoom	is a	subsumes	T
T	ispartof	has	ACLedge
Tenant	is a	subsumes	T
Terrace	subsumes	isa	WetKitchenTerrace
Terrace	is a	subsumes	T
Toilet	has	ispartof	ToiletNumber
Toilet	is a	subsumes	T
ToiletNumber	isa	subsumes	Number
ToiletNumber	is a	subsumes	T
TownHouse	is a	subsumes	T
TraditionalVillageProperty	is a	subsumes	T
Unit	ispartof	has	Department
Unit	is a	subsumes	T
UtilityArea	is a	subsumes	T
Verandah	is a	subsumes	T
WallDefect	is a	subsumes	T
Wardrobe	is a	subsumes	T
WaterFilterCompartment	is a	subsumes	T
WaterTankAccess	is a	subsumes	T
WetKitchen	is a	subsumes	T
WetKitchen	has	ispartof	WetKitchenTerrace
WetKitchenTerrace	is a	subsumes	T
Yard	subsumes	isa	SideYard
Yard	is a	subsumes	T
Yard	subsumes	isa	CourtYard

11.5. Appendix IV: Scuba Diving Equipment Domain Model

Also digitally available at
https://www.researchgate.net/publication/236047722_ScubaDomainModel

Actor	is a	subsumes	T
Actor	isa	subsumes	T
Air	is a	subsumes	BreathingMix
Air	isa	subsumes	BreathingMix
AmbientGasPressure	is a	subsumes	Quality
Aperture	is a	subsumes	Quality
Ascent	is a	subsumes	DiveProcess
AudioVisualGear	is a	subsumes	RecordingGear
AudioVisualGear	isa	subsumes	RecordingGear
BackPlate	is a	subsumes	SupportingGear
BalancingCylinder	hasshapefeature	isshapefeatureof	Closed
BalancingCylinder	hasfunction	isfunctionof	RegulateGasPressure
BalancingCylinder	hasshape	isshapeof	Cylinder
BalancingCylinder	hasmaterial	ismaterialof	HardPlastic
BalancingCylinder	is a	subsumes	ScubaGearComponent
BalancingCylinder	hasshapefeature	isshapefeatureof	Groove
BalancingCylinder	uses	usedby	DynamicOring
BalancingCylinder	haspart	ispartof	Spring
BalancingCylinder	hasmaterial	ismaterialof	Metal
Bend	is a	subsumes	ComponentFunction
Bent	is a	subsumes	ShapeFeature
Boots	isa	subsumes	ExposureProtectionGear
Boots	is a	subsumes	ExposureProtectionGear
Breathing	uses	usedby	BreathingGear
Breathing	is a	subsumes	DiveProcess
BreathingGear	is a	subsumes	ScubaGear
BreathingGear	isa	subsumes	ScubaGear
BreathingMix	is a	subsumes	Gas
BreathingMix	has	ispartof	MinimumOperatingDepth
BreathingMix	usedby	uses	Breathing
BreathingMix	has	ispartof	MaximumOperatingDepth
BreathingMix	isa	subsumes	Gas

Buoyancy	is a	subsumes	Quality
BuoyancyControl	is a	subsumes	DiveProcess
BuoyancyControlDevice	isa	subsumes	ScubaGear
BuoyancyControlDevice	is a	subsumes	ScubaGear
Camera	is a	subsumes	AudioVisualGear
Camera	isa	subsumes	AudioVisualGear
CameraStrobe	is a	subsumes	AudioVisualGear
CameraStrobe	isa	subsumes	AudioVisualGear
CarbonDioxide	is a	subsumes	Gas
CarbonDioxide	isa	subsumes	Gas
CarbonMonoxide	is a	subsumes	Gas
CarbonMonoxide	isa	subsumes	Gas
Cave	is a	subsumes	DiveLocation
Closed	is a	subsumes	ShapeFeature
ClosedCircuitBreathingGear	is a	subsumes	BreathingGear
ClosedCircuitBreathingGear	isa	subsumes	BreathingGear
Coating	is a	subsumes	Material
Comfort	is a	subsumes	ComponentFunction
CommercialDiver	is a	subsumes	Diver
CommercialDiver	isa	subsumes	Diver
ComponentFunction	is a	subsumes	Quality
ComponentProperty	is a	subsumes	Quality
Compression	is a	subsumes	ComponentFunction
ConductHeat	is a	subsumes	ComponentFunction
CoverRing	hasmaterial	ismaterialof	Metal
CoverRing	hasshape	isshapeof	Round
CoverRing	hasshapefeature	isshapefeatureof	ScrewHole
CoverRing	hasmaterial	ismaterialof	HardPlastic
CoverRing	hasfunction	isfunctionof	HoldDiaphragm
CoverRing	hasshapefeature	isshapefeatureof	Ring
CoverRing	hasshapefeature	isshapefeatureof	ExternalThread
CoverRing	is a	subsumes	ScubaGearComponent
CoverRing	hasfunction	isfunctionof	HoldDiaphragmCover
CoverRing	hasfunction	isfunctionof	SealDiaphragm
Cup	is a	subsumes	Shape
Cutout	is a	subsumes	ShapeFeature
Cylinder	is a	subsumes	Shape
CylinderValve	is a	subsumes	ScubaGearComponent
Deflector	hasfunction	isfunctionof	GuideGasFlow
Deflector	is a	subsumes	ScubaGearComponent

Deflector	hasmaterial	ismaterial	HardPlastic
Deflector	hasshape	isshapeof	Trapezium
Deflector	hasshapefeature	isshapefeatureof	Bent
Descent	is a	subsumes	DiveProcess
Diameter	is a	subsumes	Quality
Diaphragm	haspart	ispartof	WearPad
Diaphragm	hasfunction	isfunctionof	Bend
Diaphragm	hasshape	isshapeof	Cup
Diaphragm	hasfunction	isfunctionof	SealRegulatorHousing
Diaphragm	is a	subsumes	ScubaGearComponent
Diaphragm	hasmaterial	ismaterialof	Silicone
DiaphragmCover	hasshape	isshapeof	Round
DiaphragmCover	hasfunction	isfunctionof	ProtectDiaphragm
DiaphragmCover	hasshapefeature	isshapefeatureof	Ring
DiaphragmCover	hasmaterial	ismaterialof	HardPlastic
DiaphragmCover	is a	subsumes	ScubaGearComponent
DiaphragmCover	sameas	sameas	Washer
DigitalSLRCamera	isa	subsumes	PhotoCamera
DigitalSLRCamera	is a	subsumes	PhotoCamera
DINValve	is a	subsumes	CylinderValve
Disc	is a	subsumes	ShapeFeature
DiveComputer	isa	subsumes	PlanningGear
DiveComputer	is a	subsumes	PlanningGear
DiveCondition	is a	subsumes	Quality
DiveDuration	is a	subsumes	Quality
DiveLocation	is a	subsumes	Quality
DiveLocation	has	ispartof	GPSCoordinates
DiveMaster	is a	subsumes	Actor
DiveMaster	isa	subsumes	Actor
DiveProcess	is a	subsumes	Process
DiveProcess	has	ispartof	DiveDuration
DiveProcess	has	ispartof	DiveCondition
DiveProcess	has	ispartof	DiveLocation
DivePropulsionVehicle	is a	subsumes	SwimmingGear
Diver	performs	performedby	Breathing
Diver	is a	subsumes	Actor
Diver	operates	operatedby	ExhaustValve
Diver	isa	subsumes	Actor
Diver	performs	performedby	BuoyancyControl
Diver	performs	performedby	TrimControl

Diver	operates	operatedby	Diaphragm
Diver	performs	performedby	Descent
Diver	performs	performedby	Ascent
DivertGas	is a	subsumes	ComponentFunction
DiveTable	isa	subsumes	PlanningGear
DiveTable	is a	subsumes	PlanningGear
Doctor	isa	subsumes	HospitalEmployee
Doctor	is a	subsumes	HospitalEmployee
DrySuit	isa	subsumes	Suit
DrySuit	is a	subsumes	Suit
DynamicOring	usedby	uses	VenturiControlLever
DynamicOring	is a	subsumes	Oring
Elasticity	is a	subsumes	ComponentFunction
ExhaustCover	is a	subsumes	ScubaGearComponent
ExhaustTee	hasfunction	isfunctionof	RegulateWaterFlow
ExhaustTee	hasmaterial	ismaterialof	HardPlastic
ExhaustTee	is a	subsumes	ScubaGearComponent
ExhaustTee	sameas	sameas	ExhaustCover
ExhaustTee	hasfunction	isfunctionof	DivertGas
ExhaustTee	hasfunction	isfunctionof	HoldExhaustValve
ExhaustTee	hasfunction	isfunctionof	ProtectExhaustValve
ExhaustValve	hasshapefeature	isshapefeatureof	Disc
ExhaustValve	hasfunction	isfunctionof	Seal
ExhaustValve	hasfunction	isfunctionof	ResistGasPressure
ExhaustValve	is a	subsumes	ScubaGearComponent
ExhaustValve	hasshape	isshapeof	Round
ExhaustValve	hasmaterial	ismaterialof	Silicone
ExhaustValve	hasfunction	isfunctionof	Bend
ExposureProtectionGear	is a	subsumes	ScubaGear
ExposureProtectionGear	isa	subsumes	ScubaGear
ExternalThread	is a	subsumes	ShapeFeature
FilmCamera	is a	subsumes	PhotoCamera
FilmCamera	isa	subsumes	PhotoCamera
Fins	is a	subsumes	SwimmingGear
FirstStageRegulator	is a	subsumes	Regulator
Flexible	is a	subsumes	Quality
FreshWater	is a	subsumes	Water
FreshWater	has	ispartof	River
FreshWater	has	ispartof	Lake
Gas	is a	subsumes	Object

Gas	isa	subsumes	Object
Gloves	isa	subsumes	ExposureProtectionGear
Gloves	is a	subsumes	ExposureProtectionGear
GPSCoordinates	is a	subsumes	Quality
Groove	is a	subsumes	ShapeFeature
GuideGasFlow	is a	subsumes	ComponentFunction
Handle	is a	subsumes	ShapeFeature
HardPlastic	is a	subsumes	Material
Harness	is a	subsumes	SupportingGear
HeatSink	hasshape	isshapeof	Round
HeatSink	hasfunction	isfunctionof	ConductHeat
HeatSink	hasfunction	isfunctionof	PreventFreezing
HeatSink	hasmaterial	ismaterialof	Metal
HeatSink	is a	subsumes	ScubaGearComponent
HeatSink	hasshapefeature	isshapefeatureof	Ring
Helium	is a	subsumes	Gas
Helium	isa	subsumes	Gas
Helium	ispartof	has	Trimix
Hexagon	is a	subsumes	Shape
HoldCoverRing	is a	subsumes	ComponentFunction
HoldDiaphragm	is a	subsumes	ComponentFunction
HoldDiaphragmCover	is a	subsumes	ComponentFunction
HoldExhaustTee	is a	subsumes	ComponentFunction
HoldExhaustValve	is a	subsumes	ComponentFunction
HoldHeatSink	is a	subsumes	ComponentFunction
HoldMouthPiece	is a	subsumes	ComponentFunction
HoldValveTube	is a	subsumes	ComponentFunction
Hole	is a	subsumes	ShapeFeature
Hole	hasfunction	isfunctionof	RegulateWaterFlow
Hood	isa	subsumes	ExposureProtectionGear
Hood	is a	subsumes	ExposureProtectionGear
Hose	has	ispartof	Length
Hose	has	ispartof	Diameter
Hose	is a	subsumes	ScubaGearComponent
Hose	has	ispartof	MaximumPressure
Hose	hasfunction	isfunctionof	Flexible
Hose	hasfunction	isfunctionof	Waterproof
HoseAssembly	is a	subsumes	ScubaGearComponent
HoseAssembly	haspart	ispartof	RegulatorHose
HospitalEmployee	is a	subsumes	Actor

HospitalEmployee	isa	subsumes	Actor
Housing	hasfunction	isfunctionof	HoldExhaustTee
Housing	hasfunction	isfunctionof	HoldValveTube
Housing	hasfunction	isfunctionof	HoldCoverRing
Housing	hasfunction	isfunctionof	ProtectInternalParts
Housing	hasmaterial	ismaterialof	HardPlastic
Housing	hasshapefeature	isshapefeatureof	InternalThread
Housing	hasfunction	isfunctionof	HoldMouthPiece
Housing	is a	subsumes	ScubaGearComponent
HyperbaricSpecialist	isa	subsumes	Doctor
HyperbaricSpecialist	is a	subsumes	Doctor
InflatorHose	is a	subsumes	Hose
InletCoupling	is a	subsumes	ScubaGearComponent
Instructor	is a	subsumes	Actor
Instructor	isa	subsumes	Actor
IntermediateGasPressure	is a	subsumes	Quality
InternalThread	is a	subsumes	ShapeFeature
JetFins	is a	subsumes	Fins
JValve	is a	subsumes	CylinderValve
KnifeEdge	is a	subsumes	ShapeFeature
KnifeEdge	hasfunction	isfunctionof	SealSeatingSeal
Knob	is a	subsumes	ShapeFeature
Lake	is a	subsumes	DiveLocation
LaminarAirFlow	is a	subsumes	Quality
Length	is a	subsumes	Quality
Lever	hasmaterial	ismaterialof	Metal
Lever	is a	subsumes	ScubaGearComponent
Lever	hasfunction	isfunctionof	MovePiston
LeverAttachmentPoint	is a	subsumes	ShapeFeature
Light	is a	subsumes	ViewingGear
LimitMovementSpringAdjustKnob	is a	subsumes	ComponentFunction
LowPressureSeat	is a	subsumes	ScubaGearComponent
Mask	is a	subsumes	ViewingGear
Material	is a	subsumes	ComponentProperty
MaximumOperatingDepth	is a	subsumes	Quality
MaximumPressure	is a	subsumes	Quality
Metal	is a	subsumes	Material
MinimumOperatingDepth	is a	subsumes	Quality
MoldablePlastic	is a	subsumes	Material
MoldablePlastic	hasfunction	isfunctionof	ReduceJawFatigue

MouthPiece	hasmaterial	ismaterialof	Silitex
MouthPiece	is a	subsumes	ScubaGearComponent
MouthPiece	operatedby	operates	Diver
MouthPiece	hasmaterial	ismaterialof	MoldablePlastic
MouthPiece	has	ispartof	Aperture
MouthPiece	hasfunction	isfunctionof	GuideGasFlow
MouthPiece	hasmaterial	ismaterialof	Silicone
MouthPiece	hasfunction	isfunctionof	Comfort
MovePiston	is a	subsumes	ComponentFunction
Nitrogen	isa	subsumes	Gas
Nitrogen	ispartof	has	Trimix
Nitrogen	is a	subsumes	Gas
Nitrox	is a	subsumes	BreathingMix
Nitrox	isa	subsumes	BreathingMix
Nitrox32	is a	subsumes	Nitrox
Nitrox32	isa	subsumes	Nitrox
Nitrox36	is a	subsumes	Nitrox
Nitrox36	isa	subsumes	Nitrox
Nurse	isa	subsumes	HospitalEmployee
Nurse	is a	subsumes	HospitalEmployee
Nut	hasfunction	isfunctionof	HoldHeatSink
Nut	hasshape	isshapeof	Hexagon
Nut	is a	subsumes	ScubaGearComponent
Nut	hasshapefeature	isshapefeatureof	Ring
Nut	hasfunction	isfunctionof	HoldValveTube
Nut	hasmaterial	ismaterialof	Metal
NutCover	is a	subsumes	ScubaGearComponent
Object	isa	subsumes	T
Object	is a	subsumes	T
Ocean	is a	subsumes	DiveLocation
OpenCircuitBreathingGear	has	ispartof	FirstStageRegulator
OpenCircuitBreathingGear	isa	subsumes	BreathingGear
OpenCircuitBreathingGear	has	ispartof	SecondStageRegulator
OpenCircuitBreathingGear	is a	subsumes	BreathingGear
Orifice	uses	usedby	StaticOring
Orifice	is a	subsumes	ScubaGearComponent
Orifice	hasshape	isshapeof	Cylinder
Orifice	hasmaterial	ismaterialof	Metal
Orifice	sameas	sameas	Seat
Orifice	hasshapefeature	isshapefeatureof	KnifeEdge

Orifice	hasfunction	isfunctionof	GuideGasFlow
Oring	hasmaterial	ismaterialof	Rubber
Oring	is a	subsumes	ScubaGearComponent
Oring	hasshape	isshapeof	Round
Oring	hasshapefeature	isshapefeatureof	Ring
Oring	hasfunction	isfunctionof	Seal
Oxygen	ispartof	has	Nitrox
Oxygen	isa	subsumes	Gas
Oxygen	ispartof	has	Trimix
Oxygen	is a	subsumes	Gas
Oxygen	ispartof	has	Air
PhotoCamera	isa	subsumes	Camera
PhotoCamera	is a	subsumes	Camera
Pin	is a	subsumes	ScubaGearComponent
Pin	hasshape	isshapeof	Cylinder
Pin	hasfunction	isfunction	LimitMovementSpringAdjustKnob
Pin	hasmaterial	ismaterialof	Metal
Piston	hasshapefeature	isshapefeatureof	LeverAttachmentPoint
Piston	hasfunction	isfunctionof	RegulateGasFlow
Piston	hasfunction	isfunctionof	GuideGasFlow
Piston	uses	usedby	DynamicOring
Piston	hasmaterial	ismaterialof	HardPlastic
Piston	hasshapefeature	isshapefeatureof	Groove
Piston	sameas	sameas	LowPressureSeat
Piston	is a	subsumes	ScubaGearComponent
Piston	hasshape	isshapeof	Cylinder
Piston	hasmaterial	ismaterialof	Metal
PlanningGear	is a	subsumes	ScubaGear
PlanningGear	isa	subsumes	ScubaGear
PointAndShootCamera	isa	subsumes	Camera
PointAndShootCamera	is a	subsumes	PhotoCamera
PressLever	is a	subsumes	ComponentFunction
PreventFreezing	is a	subsumes	ComponentFunction
Process	is a	subsumes	T
Process	isa	subsumes	T
ProtectDiaphragm	is a	subsumes	ComponentFunction
ProtectExhaustValve	is a	subsumes	ComponentFunction
ProtectInternalParts	is a	subsumes	ComponentFunction
PurgeButton	haspart	ispartof	Spring
PurgeButton	hasfunction	isfunctionof	PressLever

PurgeButton	hasshape	ishapeof	Round
PurgeButton	is a	subsumes	ScubaGearComponent
PurgeButton	hasmaterial	ismaterialof	HardPlastic
PurgeButton	operatedby	operates	Diver
PurgeButton	hasshapefeature	isshapefeatureof	Disc
PurgeDome	is a	subsumes	ScubaGearComponent
PurgeDome	hasshapefeature	isshapefeatureof	Hole
PurgeDome	hasfunction	isfunctionof	ProtectDiaphragm
PurgeDome	hasmaterial	ismaterialof	HardPlastic
PurgeDome	haspart	ispartof	PurgeButton
PurgeDome	hasmaterial	ismaterialof	SoftPlastic
PurgeDome	hasshape	isshapeof	Cup
Quality	is a	subsumes	T
Quality	isa	subsumes	T
Quarry	ispartof	has	FreshWater
Quarry	is a	subsumes	DiveLocation
Ratchet	is a	subsumes	ShapeFeature
RecordingGear	is a	subsumes	ScubaGear
RecordingGear	isa	subsumes	ScubaGear
RecreationalDiver	is a	subsumes	Diver
RecreationalDiver	isa	subsumes	Diver
ReduceJawFatigue	is a	subsumes	ComponentFunction
RegulateGasFlow	is a	subsumes	ComponentFunction
RegulateGasPressure	is a	subsumes	ComponentFunction
RegulateSpringTension	is a	subsumes	ComponentFunction
RegulateWaterFlow	is a	subsumes	ComponentFunction
Regulator	is a	subsumes	ScubaGearComponent
RegulatorHose	is a	subsumes	Hose
ResistGasPressure	is a	subsumes	ComponentFunction
Ribbed	is a	subsumes	ShapeFeature
Ring	is a	subsumes	ShapeFeature
River	is a	subsumes	DiveLocation
Round	is a	subsumes	Shape
Rubber	is a	subsumes	Material
SaltWater	has	ispartof	Ocean
SaltWater	is a	subsumes	Water
ScrewHole	is a	subsumes	ShapeFeature
ScubaCylinder	is a	subsumes	ScubaGearComponent
ScubaGear	isa	subsumes	Object
ScubaGear	is a	subsumes	Object

ScubaGearComponent	is a	subsumes	ScubaGear
Seal	is a	subsumes	ComponentFunction
SealDiaphragm	is a	subsumes	ComponentFunction
SealMouthPiece	is a	subsumes	ComponentFunction
SealRegulatorHousing	is a	subsumes	ComponentFunction
SealSeatingSeal	is a	subsumes	ComponentFunction
Seat	is a	subsumes	ScubaGearComponent
SeatingSeal	is a	subsumes	ScubaGearComponent
SeatingSeal	hasshapefeature	isshapefeatureof	Disc
SeatingSeal	hasshape	isshapeof	Cylinder
SeatingSeal	hasmaterial	ismaterialof	Rubber
SeatingSeal	hasfunction	isfunctionof	GuideGasFlow
SeatingSeal	hasfunction	isfunctionof	Seal
SecondStageRegulator	haspart	ispartof	Pin
SecondStageRegulator	haspart	ispartof	ValveTube
SecondStageRegulator	haspart	ispartof	PurgeDome
SecondStageRegulator	haspart	ispartof	CoverRing
SecondStageRegulator	haspart	ispartof	DiaphragmCover
SecondStageRegulator	haspart	ispartof	Spring
SecondStageRegulator	haspart	ispartof	Nut
SecondStageRegulator	haspart	ispartof	SeatingSeal
SecondStageRegulator	haspart	ispartof	Housing
SecondStageRegulator	is a	subsumes	Regulator
SecondStageRegulator	haspart	ispartof	Diaphragm
SecondStageRegulator	haspart	ispartof	Lever
SecondStageRegulator	haspart	ispartof	Piston
SecondStageRegulator	haspart	ispartof	SpringAdjustKnob
SecondStageRegulator	haspart	ispartof	MouthPiece
SecondStageRegulator	haspart	ispartof	HeatSink
SecondStageRegulator	haspart	ispartof	Orifice
SecondStageRegulator	haspart	ispartof	Deflector
SecondStageRegulator	haspart	ispartof	VenturiControlLever
SecondStageRegulator	haspart	ispartof	BalancingCylinder
SecondStageRegulator	haspart	ispartof	TieWrap
SecondStageRegulator	haspart	ispartof	ExhaustTee
SecondStageRegulator	haspart	ispartof	ExhaustValve
SemiClosedCircuitBreathingGear	is a	subsumes	BreathingGear
SemiClosedCircuitBreathingGear	isa	subsumes	BreathingGear
SemiDrySuit	isa	subsumes	Suit
SemiDrySuit	is a	subsumes	Suit

ServiceTechnician	isa	subsumes	Actor
ServiceTechnician	is a	subsumes	Actor
Shape	is a	subsumes	ComponentProperty
ShapeFeature	is a	subsumes	ComponentProperty
Silicone	is a	subsumes	Material
Silitex	is a	subsumes	Material
Slate	isa	subsumes	WritingGear
Slate	is a	subsumes	WritingGear
Slot	is a	subsumes	ShapeFeature
Snorkel	isa	subsumes	BreathingGear
Snorkel	is a	subsumes	BreathingGear
SoftPlastic	is a	subsumes	Material
SPGHose	is a	subsumes	Hose
Spiral	is a	subsumes	Shape
SplitFins	is a	subsumes	Fins
Spring	hasmaterial	ismaterialof	Metal
Spring	hasfunction	isfunctionof	Compression
Spring	has	ispartof	SpringTension
Spring	is a	subsumes	ScubaGearComponent
Spring	hasshape	isshapeof	Spiral
Spring	hasfunction	isfunctionof	Elasticity
Spring	hasmaterial	ismaterialof	Coating
SpringAdjustKnob	hasshape	isshapeof	Cylinder
SpringAdjustKnob	hasfunction	isfunctionof	RegulateSpringTension
SpringAdjustKnob	uses	usedby	DynamicOring
SpringAdjustKnob	hasmaterial	ismaterialof	Metal
SpringAdjustKnob	is a	subsumes	ScubaGearComponent
SpringAdjustKnob	operatedby	operates	Diver
SpringAdjustKnob	hasshapefeature	isshapefeatureof	ExternalThread
SpringAdjustKnob	hasshapefeature	isshapefeatureof	Knob
SpringTension	is a	subsumes	Quality
StaticOring	usedby	uses	ValveTube
StaticOring	is a	subsumes	Oring
Strip	is a	subsumes	Shape
Suit	is a	subsumes	ExposureProtectionGear
Suit	isa	subsumes	ExposureProtectionGear
SupportingGear	is a	subsumes	ScubaGear
Surge	is a	subsumes	DiveCondition
Swell	is a	subsumes	DiveCondition
Swimming	performedby	performs	Diver

Swimming	is a	subsumes	DiveProcess
SwimmingGear	is a	subsumes	ScubaGear
Switch	is a	subsumes	ShapeFeature
TechnicalDiver	is a	subsumes	Diver
TechnicalDiver	isa	subsumes	Diver
Temperature	is a	subsumes	DiveCondition
TestPressure	is a	subsumes	Quality
TieWrap	is a	subsumes	ScubaGearComponent
TieWrap	hasshape	isshapeof	Strip
TieWrap	hasfunction	isfunctionof	SealMouthPiece
TieWrap	hasshapefeature	isshapefeatureof	Slot
TieWrap	hasmaterial	ismaterialof	SoftPlastic
TieWrap	hasshapefeature	isshapefeatureof	Ribbed
TrainingProcess	is a	subsumes	Process
Transport	is a	subsumes	Process
Trapezium	is a	subsumes	Shape
Treatment	is a	subsumes	Process
Trim	is a	subsumes	Quality
TrimControl	is a	subsumes	DiveProcess
Trimix	is a	subsumes	BreathingMix
TurbulentAirFlow	is a	subsumes	Quality
TurtleFins	is a	subsumes	Fins
UnderwaterHousing	is a	subsumes	AudioVisualGear
UnderwaterHousing	isa	subsumes	AudioVisualGear
ValveTube	hasshapefeature	isshapefeatureof	Hole
ValveTube	hasfunction	isfunctionof	GuideGasFlow
ValveTube	hasmaterial	ismaterialof	Metal
ValveTube	haspart	ispartof	InletCoupling
ValveTube	hasshape	isshapeof	Cylinder
ValveTube	hasshapefeature	isshapefeatureof	ExternalThread
ValveTube	hasshapefeature	isshapefeatureof	InternalThread
ValveTube	is a	subsumes	ScubaGearComponent
VenturiControlLever	hasshapefeature	isshapefeatureof	Ratchet
VenturiControlLever	hasshape	isshapeof	Cylinder
VenturiControlLever	hasshapefeature	isshapefeatureof	Handle
VenturiControlLever	hasmaterial	ismaterialof	HardPlastic
VenturiControlLever	is a	subsumes	ScubaGearComponent
VenturiControlLever	hasshapefeature	isshapefeatureof	Switch
VenturiControlLever	operatedby	operates	Diver
VenturiControlLever	hasshapefeature	isshapefeatureof	Cutout

VenturiControlLever	hasfunction	isfunctionof	RegulateGasFlow
VideoCamera	isa	subsumes	Camera
VideoCamera	is a	subsumes	Camera
ViewingGear	is a	subsumes	ScubaGear
Visibility	is a	subsumes	DiveCondition
Washer	is a	subsumes	ScubaGearComponent
Water	has	ispartof	Visibility
Water	has	ispartof	Temperature
Water	is a	subsumes	DiveCondition
Waterproof	is a	subsumes	Quality
WearPad	is a	subsumes	ScubaGearComponent
WearPad	hasmaterial	ismaterialof	HardPlastic
WearPad	hasmaterial	ismaterialof	Metal
WearPad	hasfunction	isfunctionof	WearResistance
WearResistance	is a	subsumes	ComponentFunction
Wetnotes	is a	subsumes	WritingGear
Wetnotes	isa	subsumes	WritingGear
Wetsuit	isa	subsumes	Suit
WetSuit	is a	subsumes	Suit
Wetsuit	is a	subsumes	T
Wind	is a	subsumes	DiveCondition
Wing	isa	subsumes	BuoyancyControlDevice
Wing	is a	subsumes	BuoyancyControlDevice
WorkingPressure	is a	subsumes	Quality
WristSlate	isa	subsumes	Slate
WristSlate	is a	subsumes	Slate
WritingGear	isa	subsumes	RecordingGear
WritingGear	is a	subsumes	RecordingGear
YokeValve	is a	subsumes	CylinderValve

11.6. Appendix V: Scuba Domain Expert Interview Transcript

Transcript interview domain expert

Date: 22nd June 2010

Interviewer: Davor Meersman

Domain Expert: technical diving instructor / service technician / dive shop owner

Subject: Second Stage Regulator

D: This here is the cover ring. So is that shape always round or are there other shapes?

C: Yes. Normally. I can't think of an example where it isn't.

D: Is it always screwed?

C: Other styles have locking. Fitting with a locking ring, usually it's screwed.

D: What about models with nuts and bolts or so.

C: Not really.

D: I have an A700 where this doesn't come off

C: Ah yes, the A700, it has an Allen key. Oh yeah, there is another example, older styles, or maybe some modern too. You'd have something like this that would fit on, this is the diaphragm cover, and this would fit directly on, and then there would be a piece of metal locking ring that you would screw together, that you would lock into position on the housing. The function of the cover ring is to hold the diaphragm cover in place, sealing against the diaphragm.

D: Are the purge dome and the diaphragm cover the same?

C: Yes. Sometimes the cover ring and diaphragm cover are the same, one piece, and sometimes two pieces. Do you want the functions of these as well?

D: Yeah. So the purge dome has a button.

C: Correct, this is a purge button, to allow you to manually actuate the lever arm. It also has holes in it to allow water through, to allow the ambient water pressure to act on the diaphragm, and at the same time protecting the diaphragm from excessive water, for example if you are diving in a current or you're swimming very quickly, you will get too much water and actuate the diaphragm, so you can restrict the amount of water that flows by reducing the holes.

D: This other reg has a soft purge dome

C: The function is the same, either it's spring loaded or either it's a softer material. There's a science behind the flow of water through that onto that. That's a critical design thing. And the HOG reg doesn't even allow water to flow directly onto the diaphragm. You will allow water to flow onto it, but not directly. OK, then you have the diaphragm, which is normally a silicone type material, with a hard part in the middle. The diaphragm needs to be very flexible, so that when the pressure on the inside and the outside of the housing changes, it allows it to move freely, without any significant resistance. But because it is acting on a hard part inside, the lever, it needs to have a wear resistance (the hard part in the middle), which is why you have this wear pad, which can be metal or a hard plastic. And that's somehow bonded into that diaphragm. The colour is unimportant from a function point of view. OK, let's move on. Inside here we have a lever arm. What happens is when you're breathing from the mouthpiece, you breathe in, you reduce the pressure of the inside of the second stage housing , which means that the ambient pressure is greater than the pressure on the inside, which pushes on the diaphragm, which in turn pushes on this lever, or lever arm. That lever arm then moves a low pressure seat on the inside which allows air to flow.

D: The size of the room of the other reg is smaller than the other. Does that have a function?

C: There's two things here. The size of the diaphragm is bigger, which would indicate, at first glance you would think that the breathing resistance of the

bigger regulator is less. When you inhale, you have to inhale less to push the diaphragm down because of the bigger surface area. And that's probably true in this case, because the other one has other features. It's also a function of how the regulator is set up, the springs, the spring tensions. Those can be varied by the service technician and also by the design of the spring, how strong the spring is, the amount of force needed to move the diaphragm is determined by many factors, the diaphragm, the spring, the balance, all those things. So it doesn't necessarily follow that the smaller regulator is harder to breathe, but at first glance you would expect it would be. The other second stage is an alternate second stage, and one of the features of it is that it is smaller, because it is not something you use, it's something you carry. Some divers prefer to have a smaller one, because it makes it less likely to knock into, less obtrusive, it's less drag. But with making it smaller you introduce other issues. It might be that it's harder to breathe, I'm not saying that's the case with this one, but that might be another function, which you need to overcompensate in other ways. Alright, so the mouthpiece is an often overlooked and very, very important part of the second stage. People commonly will take their standard mouthpieces off and put their own preferred one or cheaper one on. That is not recommended, because each regulator is matched to a mouthpiece and that mouthpiece design affects the flow of gas through the second stage. That outlet is matched to this second stage. See how it pinches a bit here. If you put an even smaller one, it will wear more at the edge and it will shrink more around the outlet, which will affect the aperture and you will get less flow. One of the things to detune a regulator is to put another mouthpiece on.

D: It's always silicone, these days, the mouthpiece?

C: No, you can get silitex, which is cheaper, and moldable mouth guard types. That one you heat up, bite and then it takes the shape of your mouth. That one is sold to reduce jaw fatigue, it is hard material but it sits in your mouth. However, I have taken them off regulators because they didn't perform well, if the mouthpiece outlet was too small for the regulator. The mouthpiece

forms a seal with the second stage housing. OK, this side is where the intermediate pressure air will come from, from the first stage.

D: Is that a standard pressure?

C: IT varies between manufacturers. Somewhere 9-10 bar above ambient. Commonly line pressure (= same). The intermediate pressure is delivered to the second stage. The second stage then further reduces it for delivery to the diver at ambient pressure. This here is the inlet coupling, so that is where your hose would go. It also allows you to swivel, but that's on the hose side. That's for comfort. This nut here serves to hold the whole tube and also to hold the heat sink. Now we will take the whole valve tube out.

D: Why is there no thread on the heat sink?

C: I don't know. But it's common like that. The purpose of a heat sink is to guide away the cold from the pressurised gas, to prevent freezing. To hold heat in. We have o-rings on both ends here, these are static o-rings. There is two types of o-rings in a regulator, static and dynamic. Static o-rings just seal and sit, whilst dynamic are subject to movement. They need to be replaced with every service of the regs. Same material. OK, so this is the valve tube with the lever on, we've discussed already. There are two adjusments on this reg, not common on all regs, the firs is this plastic lever, this will reveal and cover over the air outlet. In the minus position it covers the hole, in the plus position it opens the hole.

D: It's not sealing, does it make that big of a difference?

C: The function of this lever is a dive and pre-dive setting. In the minus position, it cannot freeflow. In the plus function it offers the optimum breathing performance.

D: Why is it not a switch then?

C: Cost could be a factor (cheaper mechanism), some regs have racthet with 5 steps and there are on-off regs too. I don't see the point of having it in the middle. On some regs it says pre-dive and dive, rather than minus and plus. Some people dive with pre-dive setting and don't even really notice. The plus

setting is optimal for laminar (linear) air flow into your mouthpiece, rather than turbulent.

D: Is that why the other materials on the inside are also smooth?

C: Possibly. OK, the second adjustment here which is common on lots of regs, is the spring adjust knob. There is a pin there prevents the diver from completely unwinding the knob. The spring adjust knob function is to vary the spring tension. There is an adjustable orifice, or seat. It is threaded, so you can move the position. there is a knife edge on it, that edge seals on low pressure seat, seating seal, and prevents gas flow. The seat is removable, and is a service part. It is not in every reg, there are servo or upstream regs, but it is in 99 percent of regs. The lever arm sits in the grooves of the piston, and when the lever is pushed in the piston moves and there is a gap created for the air to flow. The air flows in this one around and through the piston. There is a hole in the seat, basically you've always got air in the balancing cylinder, or balance chamber, a pocket of air. The o-rings seal the thing. There is intermediate pressure air. That's why this is a balanced second stage. When you breathe, this moves in, because of the intermediate pressure, it ensures that the breathing effort is the same regardless of depth. Unlike an unbalanced second stage.

D: Is it always in plastic?

C: No, can be in metal, but plastic is good because it doesn't corrode and is lightweight. The whole reg needs to be lightweight, but you do need metal in certain places.

D: What kind of metals are used?

C: Marine grade steel, chrome plated, but there's also titanium. The critical service parts are seat and balance o-rings. When the spring adjustment knob is fully open, you'd want it to free flow a bit.

D: So why do you want to adjust this?

C: Exertion requires less effort, strong currents require a bit more. Some companies like Mares and Poseidon don't have any adjustments, just optimal

performance, why would you want to change it? Atomic has a different philosophy.

D: So the air flow in an adjustable second stage has to be able to cope with a range of 'optimal' amounts of air?

C: That's more design. OK, the exhaust now. When the diver exhales, the pressure in the second stage increases, and that means that the pressure on the inside goes above ambient pressure, and you will get some resistance from the exhaust diaphragm and that will allow the inhalation diaphragm to return to its original position, closed. And then your exhalation effort is determined by the size of the exhaust diaphragm, this diaphragm allows the gas to pass out of the reg, but not the water in. The little thing on top of it is an assembly, that's how it's made, it's used to pull the diaphragm through but you do not really need it. Often you clip it off. The last thing is the exhaust cover or exhaust tee. Two functions: one is bubble diversion, the other is protection of the exhaust valve. You will see that bit that's quite close there one the outside. If you imagine it's not on there, and you swish this around, you're gonna lift and fold that thing. Very often we'll get customers who come in and say their regulator is leaking, but the exhaust diaphragm is just folded or there is something that prevents it from closing. This series of veins there on the side is designed to reduce the water flow across it, to reduce that thing getting disturbed. But also to break up exhalation bubbles. But you don't want to restrain it too much, because that will increase the exhalation effort.

D: Is there always one tie wrap?

C: Usually one, but in some cases two for redundancy. Sometimes, for example Scubapro, use a reusable clamp. OK, the other second stage regulator. This one is very simple. Diaphragm cover and an additional locking ring. You always need this kind of washer

D: So this ring holds the purge dome in place, and this holds the diaphragm in place?

C: Yes. It holds the diaphragm in place with a washer. The washer is there because when you have a soft diaphragm, you put the washer on it so you don't damage it when turning down the ring. Another reason for a separate ring and dome is so you can position the logo, also important. You don't want it upside down. Because you have a smaller diaphragm, i wouldn't breathe as easy, this one, because it doesn't have features to compensate for it. There is also an orifice there, it's a slot drive rather than hexagonal. There's the low pressure seat, spring, washer, lock nut, lever arm, it's unbalanced this one. But it works the same.

D: This spring seems to be coated.

C: Yes with some blue stuff, I don't know what exactly that is. (...)

D: Thanks for everything, awesome.

11.7. Appendix VI: Scuba Domain Interview Video Screenshots

11.8. Appendix VII: Online Travel Domain Model

This model was made completely by Christophe Debruyne and his STARlab collaborators for the COMDRIVE RFP project. They are not my work and are included for clarification purposes only.

Also digitally available at
https://www.researchgate.net/publication/236088496_OnlineTravelDomainModel

Accommodation	provides	provided by	Room and Board
Accommodation	has contact	is contact of	Person
Accommodation	provides	provided by	Facility
Accommodation	has	of	Homepage
Accommodation	has	of	Type
Accommodation	of	with	Ski Resort
Accommodation	is a	subsumes	Service
Accommodation	with	of	Remote Facility
Accommodation	reached at	reaches	Telephone
Accommodation	has	of	Address
Address	with	of	Country Name
Address	with	of	State
Address	with	of	Street
Address	with	of	Postal Code
Address	with	of	City
Address	is a	subsumes	T
Address	with	of	Post Office Box
Agent	is a	subsumes	Entity
Air Field	is a	subsumes	Air Landing Area
Air Force Station	is a	subsumes	Air Landing Area
Air Landing Area	is a	subsumes	Location
Air Port	is a	subsumes	Air Landing Area
Air Station	is a	subsumes	Air Landing Area
Altitude	of	with	Location
Altitude	is a	subsumes	Quantity
Amount	is a	subsumes	T
Apres Ski	is a	subsumes	Facility
Attribute	is a	subsumes	Descriptor
Bar	is a	subsumes	Facility
Bay	is a	subsumes	Sea Area

Beach	is a	subsumes	Theme
Bed and Breakfast	is a	subsumes	Room and Board
Black	is a	subsumes	Color
Blue	is a	subsumes	Color
Budget	with	of	Currency
Budget	is a	subsumes	T
Budget	with	of	Range
Bus	is a	subsumes	Transportation
Camping Site	has	of	Plot
Camping Site	has	of	Tent
Camping Site	has	of	Caravan
Camping Site	is a	subsumes	Accommodation
Canal	is a	subsumes	Sea Area
Cape	is a	subsumes	Sea Area
Car	is a	subsumes	Transportation
Car Free	is a	subsumes	Attribute
Caravan	is a	subsumes	T
Carrental	is a	subsumes	Service
Chalet	is a	subsumes	Accommodation
Channel	is a	subsumes	Sea Area
Child Animation	is a	subsumes	Facility
Child Seat	is a	subsumes	Facility
City	is a	subsumes	Geographical Area
City Trip	is a	subsumes	Theme
Clinic	is a	subsumes	Medical Facility
Code	is a	subsumes	T
Color	with	of	Name
Color	is a	subsumes	T
Commodity	has	of	Description
Commodity	manufactured by	manufactures	Organization
Commodity	with	of	Web Page
Commodity	uses	used by	Commodity
Commodity	with	of	Image
Commodity	supplied by	supplies	Organization
Commodity	is a	subsumes	Object
Commodity	has	of	Attribute
Commodity	identified by	identifies	Code
Commodity	has	of	Name
Commodity	has	of	Price
Context	is a	subsumes	Descriptor

Context	expressed by	expresses	Location
Context	expressed by	expresses	Time
Country	is a	subsumes	Geographic Area
Country	with	of	Country Code
Country Code	is a	subsumes	T
Country Name	is a	subsumes	T
Cross Country Skiing	with	of	Length
Cross Country Skiing	is a	subsumes	T
Cruise	is a	subsumes	Theme
Currency	is a	subsumes	T
Date	has	of	Day
Date	has	of	Year
Date	has	of	Month
Date	is a	subsumes	T
Date and Time	has	of	Date
Date and Time	has	of	Time
Date and Time	is a	subsumes	T
Day	is a	subsumes	T
Degree	is a	subsumes	T
Description	is a	subsumes	T
Descriptor	is a	subsumes	T
Dispensary	is a	subsumes	Medical Facility
Distance	is a	subsumes	T
Diving	is a	subsumes	Theme
Dock	is a	subsumes	Sea Area
Duration	is a	subsumes	T
Email	is a	subsumes	T
Entity	is a	subsumes	T
Entity	participates	involves	Predicate
Entry	involves	of	Commodity
Entry	for	of	Amount
Entry	is a	subsumes	T
Event	has	of	Location
Event	is a	subsumes	Predicate
Excursion	is a	subsumes	Service
Facility	is a	subsumes	T
Facility	has	of	Description
Facility	has	of	Name
Family Housing	is a	subsumes	Housing Civilian Facility

Fax	is a	subsumes	Telephone
First Name	is a	subsumes	T
Fitness Center	is a	subsumes	Recreation
Fitness In Complex	is a	subsumes	Facility
Flat	is a	subsumes	Accommodation
Flat Hotel	is a	subsumes	Hotel
Full Board	is a	subsumes	Room and Board
Gender	is a	subsumes	T
Geographic Area	with	of	Short Name
Geographic Area	is a	subsumes	T
Geographic Area	with	of	Long Name
Geographical Area	is a	subsumes	Location
Golf	is a	subsumes	Theme
Green	is a	subsumes	Color
Group Size	is a	subsumes	T
Group Travel	is a	subsumes	Theme
Guest House	is a	subsumes	Lodging House
Gulf	is a	subsumes	Sea Area
Half Board	is a	subsumes	Room and Board
Hard Requirement	is a	subsumes	Requirement
Hemisphere	is a	subsumes	T
Holiday Centre	is a	subsumes	Lodging House
Holiday Package	with origin	origin of	Country
Holiday Package	has	of	Period
Holiday Package	has	of	Transportation
Holiday Package	with origin	origin of	Location
Holiday Package	has	of	Insurance
Holiday Package	with theme	theme of	Theme
Holiday Package	has	of	Group Size
Holiday Package	has	of	Accommodation
Holiday Package	has	of	Duration
Holiday Package	includes	included in	Commodity
Holiday Package	with destination	destination of	Ski Area
Holiday Package	with departure on	of departing of	Date and Time
Holiday Package	with destination	destination of	Country
Holiday Package	with destination	destination of	Ski Resort
Holiday Package	is a	subsumes	Service
Home Telephone	is a	subsumes	Telephone
Homepage	is a	subsumes	T
Hospital	is a	subsumes	Medical Facility

Hostel	is a	subsumes	Lodging House
Hotel	is a	subsumes	Lodging House
Hour	is a	subsumes	T
Housing Civilian Facility	is a	subsumes	Location
Hut	is a	subsumes	Accommodation
Image	is a	subsumes	T
Infant Bed	is a	subsumes	Facility
Insurance	is a	subsumes	Service
International Airpot	is a	subsumes	Air Landing Area
Internet Connection	is a	subsumes	Facility
Island	is a	subsumes	Geographical Area
Joint Use Airport	is a	subsumes	Air Landing Area
Lake	is a	subsumes	Sea Area
Last Name	is a	subsumes	T
Latitude	with	of	Hemisphere
Latitude	is a	subsumes	T
Latitude	with	of	Minute
Latitude	with	of	Second
Latitude	with	of	Degree
Laundromat	is a	subsumes	Facility
Length	is a	subsumes	Quantity
Lift Service	is a	subsumes	Service
Lift Service	with bottom	bottom of	Altitude
Lift Service	starts in	start of	Month
Lift Service	with top	top of	Altitude
Lift Service	open at	opening of	Time
Lift Service	closes at	closing of	Time
Lift Service	ends in	end of	Month
Lift To Areas	is a	subsumes	Attribute
Location	with	of	Longitude
Location	with	of	Name
Location	is a	subsumes	Descriptor
Location	with	of	Latitude
Location	located in	contains	Geographic Area
Lodging House	is a	subsumes	Accommodation
Lodging House	has	of	Star Rating
Lodging House	has	of	Room
Long Name	is a	subsumes	T
Longitude	with	of	Degree
Longitude	with	of	Minute

Longitude	with	of	Hemisphere
Longitude	is a	subsumes	T
Longitude	with	of	Second
Luge	is a	subsumes	T
Luge	with	of	Length
Manner	is a	subsumes	Descriptor
Medical Facility	is a	subsumes	Location
Military Airport	is a	subsumes	Air Landing Area
Minute	is a	subsumes	T
Mobile Telephone	is a	subsumes	Telephone
Month	is a	subsumes	T
Name	is a	subsumes	T
Number of Days	is a	subsumes	T
Object	is a	subsumes	Entity
Ocean	is a	subsumes	Sea Area
Operating Area	is a	subsumes	Geographical Area
Organization	with	of	Email
Organization	is a	subsumes	Agent
Organization	with	of	Description
Organization	with	of	Homepage
Organization	with	of	Address
Organization	reached at	reaches	Telephone
Organization	with	of	Name
Parking	is a	subsumes	Facility
Passage	is a	subsumes	Sea Area
Perception	is a	subsumes	Predicate
Period	is a	subsumes	T
Period	ends on	end of	Date and Time
Period	starts on	start of	Date and Time
Person	has	is of	Gender
Person	is-a	subsumes	Agent
Person	has	is of	Email
Person	reached at	reaches	Telephone
Person	has	is of	Address
Person	has	is of	Homepage
Person	has	is of	Title
Person	with	of	First Name
Person	with	of	Last Name
Person	born on	of birth of	Date
Piste	is a	subsumes	T

Piste	with	of	Length
Piste	with	of	Color
Plane	is a	subsumes	Transportation
Playground	is a	subsumes	Recreation
Plot	is a	subsumes	T
Port	is a	subsumes	Sea Area
Post Office Box	is a	subsumes	T
Postal Code	is a	subsumes	T
Predicate	is a	subsumes	T
Price	with	of	Currency
Price	is a	subsumes	T
Price	with	of	Range
Price	with	of	Value
Product	is a	subsumes	Commodity
Quantity	is a	subsumes	Descriptor
Quantity	has	of	Unit
Quantity	has	of	Value
Range	with minimum	minimum of	Value
Range	with maximum	maximum of	Value
Range	is a	subsumes	T
Recovery and Holiday Home	is a	subsumes	Lodging House
Recreation	is a	subsumes	Housing Civilian Facility
Red	is a	subsumes	Color
Region	of	with	Country
Region	is a	subsumes	Geographic Area
Relation	is a	subsumes	Predicate
Remote Facility	is a	subsumes	T
Remote Facility	with	of	Location
Remote Facility	with	of	Distance
Requirement	of	with	Room Type
Requirement	of	with	Attribute
Requirement	of	with	Theme
Requirement	of	with	Commodity
Requirement	of	with	Facility
Requirement	of	with	Duration
Requirement	of	with	Location
Requirement	is a	subsumes	T
Requirement	of	with	Star Rating
Requirement	of	with	Room and Board

Requirement	of	with	Budget
Requirement	of	with	Period
Requirement	of	with	Price
Restaurant	is a	subsumes	Facility
RFP	has	of	Description
RFP	valid for	validity of	Period
RFP	lead by	leads	Person
RFP	has	of	Entry
RFP	is a	subsumes	T
RFP	has	of	Budget
Room	is a	subsumes	T
Room	has	of	Room Type
Room	provides	provided by	Facility
Room and Board	is a	subsumes	T
Room Service	is a	subsumes	Facility
Room Type	is a	subsumes	T
Safe	is a	subsumes	Facility
Sauna	is a	subsumes	Facility
School	is a	subsumes	Housing Civilian Facility
Sea	is a	subsumes	Sea Area
Sea Area	is a	subsumes	Location
Second	is a	subsumes	T
Service	is a	subsumes	Commodity
Short Name	is a	subsumes	T
Size	is a	subsumes	Quantity
Ski Area	with	of	Lift Service
Ski Area	with minimum at bottom	minimum at bottom of	Snowfall
Ski Area	with	of	Piste
Ski Area	has	of	Size
Ski Area	with	of	Luge
Ski Area	is a	subsumes	Region
Ski Area	with bottom	at bottom of	Snowfall
Ski Area	with	of	Cross Country Skiing
Ski Area	with top	at top of	Snowfall
Ski Pass	is a	subsumes	Product
Ski Pass	has	of	Number of Days
Ski Resort	with	of	Slope To Resort
Ski Resort	with	of	Lift To Areas
Ski Resort	is a	subsumes	Village

Ski Resort	with	of	Car Free
Slope To Resort	is a	subsumes	Attribute
Snowfall	minimum at top of	with minimum at top	Ski Area
Snowfall	is a	subsumes	Quantity
Soft Requirement	with	of	Value
Soft Requirement	is a	subsumes	Requirement
Star Rating	is a	subsumes	T
State	with	of	State Code
State	is a	subsumes	Geographic Area
State Code	is a	subsumes	T
Status	is a	subsumes	T
Strait	is a	subsumes	Sea Area
Street	is a	subsumes	T
Swimming Pool	is a	subsumes	Recreation
Swimming Pool In Complex	is a	subsumes	Facility
Telephone	is a	subsumes	T
Telephone	with	of	Telephone Number
Telephone Number	is a	subsumes	T
Television	is a	subsumes	Facility
Tent	is a	subsumes	T
Theme	is a	subsumes	T
Theme	with	of	Status
Time	is a	subsumes	Descriptor
Time	has	of	Second
Time	has	of	Hour
Time	has	of	Minute
Title	is a	subsumes	T
Train	is a	subsumes	Transportation
Transportation	is a	subsumes	T
Transportation	with	of	Transportation Name
Transportation Name	is a	subsumes	T
Type	is a	subsumes	T
Unit	is a	subsumes	T
Value	is a	subsumes	T
Village	is a	subsumes	Geographical Area
Water Area	is a	subsumes	Geographic Area
Web Page	is a	subsumes	T
Wellness In Complex	is a	subsumes	Facility
Welness Center	is a	subsumes	Recreation

Whirlpool	is a	subsumes	Facility
Wintersport	is a	subsumes	Theme
Work Telephone	is a	subsumes	Telephone
Year	is a	subsumes	T

11.9. Appendix VIII: Online Travel Domain Software Descriptions

Source: COMDRIVE RFP Final Report

11.9.1. Automated Group Buying Module

The automated group-buying module enables communities to organise a group buying action for a variety of products. The software allows the community leader to handle most time intensive tasks himself, adding scalability for iChoosr and a chance for the community leader to provide added value to his community. A group buying web application has been developed using the MonoRail framework for the Microsoft .net platform. During development, releases have been deployed on a two-weekly basis. This has allowed us to iteratively introduce features and improve them based on user feedback, either explicit or via statistics. The group buying application is designed to be quickly customizable. A community group buying action with the logo and brand colours of the organizing partner can be set up in minutes. The application contains a FAQ section, product specific information pages which can be tuned to the community if needed and a prominent placement of community specific content on the homepage which can be used as a community blog. The AGB Module holds various functionalities for community leaders and members. Leaders have a range of administration functionalities at their disposal. Community leaders can do first line support for their members. This enables the community leader to engage their members and reduces the overall time spent by iChoosr on individual group buying actions, which increases scalability. A screen will be added to the Personal Group Buying application where community leaders can use the Rapid Node Cloud Navigation to define an RFP for a product for which they want to organise a Group Buying action. This request can then be used by us as the basis for a group buying action. Via this mechanism the community leader uses his domain knowledge to define the right product for his community and iChoosr uses their expertise in finding vendors and

getting them on board for the auction. Members can participate in a group buying action. The applications contains social software integration with with at the end of the subscription procedure a member can invite his friends and family on LinkedIn, Hyves, Facebook, Hotmail and Gmail to participate too. Every action that is taken by the user or in which the user is involved gets added to the user's history. Based on this history we can define selections of users to send messages to. This allows us to communicate with very specific groups of users and deliver the information they need. During the auction, vendors can log in and make an offer. The users can follow the auction live on line. The names of the participating vendors are anonymized, to ensure the best possible result and remove the fear with vendors that losing an auction could hurt their reputation.

11.9.2. Fuzzy Semantic Matching Engine

The Fuzzy Semantic Matching Engine (FSME) is an advanced search engine for analyzing structured, semi-structured and free text data and is comprised of Code, Software and Algorithms. Contrary to classic searching and querying technology, matching functionality take into account the semantic context of concepts to match upon and it will also return *close* matches if no *exact* matches can be found. The FSME scores and ranks the matches based on the degree in which they match, taking into account configuration parameters such as weights, thresholds and optionality/requiredness of conditions.

The FSME makes use of an ontology service to translate multiple data formats into a unified match object format, processable by the engine. This requires an input mapping for each format, as well as an output format defined by the match engine. The mapping used by the engine is quite straightforward and simply maps each matchable concept to a match property of the corresponding type, using the path in the ontology as ID.

The FSME runs on an Apache Tomcat application server, version 6.0 or higher, using Sun JDK 6.0 or higher. While the actual match engine can be deployed as a stand-alone component, it requires the application server to expose its interfaces as web services to other non-Java applications.

11.9.3. Rapid Semantic Node Cloud Navigation

RSNCN is a navigation module that visualises the data and allows the user to create RFP‟s. The core functionality addressed by the navigation module is the creation of RFP‟s based on available metamodel data. After creating the RFP, it is sent to the matching engine, which returns an adequate response. The emphasis will be on ease of use, speed and aesthetics. This is thearea of graphical designers that know the ways of creating an efficient human-computer interface based on a set of requirements. We have used storyboarding techniques and focus group research to develop the appropriate interface.

The goal of the node cloud navigation interface is to allow the customer to create RFP's, based on an ontology. As ontologies can be very extensive and hard to grasp, the challenge of designing this user interface was in making it as straightforward and easy to use as possible, while providing the customer with a flexible way to create RFP's. In addition, the interface should be generic and should allow the user to create RFP's based on any ontology that complies to the standards, set in this project. We used various scenarios and wireframes for use testing, and have updated the document multiple times.

The whole COMDRIVE user interface is a web application written with the popular Ruby on Rails framework. The RSNCN is a client side widget. Meaning that the RSNCN is presented to the user as part of the web application, but does not require frequent reloading of the page, since it's logic is executed in the browser, not on the server. This allows for a more uninterrupted experience.

In the initial work plan, we assumed complex graphical representation and saw the Adobe Flex technology as a good technology to realize such a widget. During the paper prototyping sessions most of these advanced visualisation techniques had to be replaced by less confusing ones. This removed the necessity for using Flex altogether. We were thus able to implement the RSNCN with standard web technologies: HTML, CSS and JavaScript. This

opens the platform to mobile devices like the Apple iPad where the Adobe Flex technology, which makes use of Adobe Flash, is not available.

11.9.4. Integrated COMDRIVE RFP platform

The web application is hosted on an virtual Linux server at Slicehost. The web application embeds the rapid node cloud navigation (RNCN) and makes use of the ontology on the STARLab server and the matching engine on the same server as the web application itself. The ontology is being fetched over SOAP and transformed into a format suitable for use by the RSNCN. This resulting document is kept in cache until the ontology changes. The whole COMDRIVE user interface is a web application written with the popular Ruby on Rails framework.

The Rapid semantic node cloud navigation (RSNCN) is part of that as a client side widget. Meaning that the RSNCN is presented to the user as part of the web application, but does not require frequent reloading of the page, since it's logic is executed in the browser, not on the server. This allows for a more uninterrupted experience. The RSNCN only makes use of the matching engine and the ontology server indirectly through the web application.

The matching engine is hosted on the same virtual Linux server as the web application. It makes use of the transformation methods offered by the ontology over SOAP. The matching engine offers a method to the web application to get matching offers for an RFP. This is a RESTful webservice. The matching engine also depends on the RIDL file maintained by STARLab for the commitments to the ontology.

In order to have software agents interpret the information in RFPs to (semi-) automatically match this information with data in the vendors‟ product database based on their semantics, an ontology (or common vocabulary) needs to be shared and constructed by the vendors and buyers. To allow the matcher to perform the transformation within the COMDRIVE RFP platform or the different components retrieve the (different parts of the) ontology, STARLab has developed a SOAP Web service.

The COMDRIVE system relies on data provided by vendor to find fitting offers for RFPs. In order to earn the trust of our users, we must have data from several different vendors. In order to give the users a good experience through highly relevant, tailored results, we must have access to highly detailed data. We decided to tackle this by getting a broad selection of vendors through affiliate marketing data channels for the width of the data.

11.10. Appendix IX: AAL Domain Rule Base

Available online at
https://www.researchgate.net/publication/236094880_AALPatientRecommendations

(14 pages)

11.11. Appendix X: AAL Domain Patient Profiles and their Recommendations

Available online at
https://www.researchgate.net/publication/236094880_AALPatientRecommendations

(162 pages)

11.12. Appendix XI: AAL Domain Patient/FCs Mappings

Available online at
https://www.researchgate.net/publication/236094754_AALPatientFCMappings

(46 page

11.13. Appendix XII: AAL Domain Service/FC Mappings

Available online at
https://www.researchgate.net/publication/236095266_AALServiceMappings

11.14. Appendix XIII: AAL Personas

Available online at
https://www.researchgate.net/publication/236109008_Personas-ACCESSIBLEbased and
https://www.researchgate.net/publication/236109011_Personas-AEGISbased

11.15. Appendix XIV: Rudimentary AAL Domain Model

Also digitally available at
https://www.researchgate.net/publication/236095096_AALRudimentaryDomainModel

Accelerometer	is a	subsumes	Sensor
Accelerometer	isa	subsumes	Sensor
Accelerometer	usedin	uses	Detection
Actor	isa	subsumes	T
Actor	is a	subsumes	T
Adhesive	isa	subsumes	Property
Adhesive	is a	subsumes	Property
Assistance	is a	subsumes	Process
Assistance	isa	subsumes	Process
AssistiveSoftware	isa	subsumes	Software
AssistiveSoftware	is a	subsumes	Software
AutonomyEnhancement	providedby	provides	Dressing
AutonomyEnhancement	is a	subsumes	Needs
AutonomyEnhancement	providedby	provides	Training
AutonomyEnhancement	providedby	provides	Cleaning
AutonomyEnhancement	providedby	provides	Assistance
AutonomyEnhancement	isa	subsumes	Needs
AutonomyEnhancement	providedby	provides	Eating
AutonomyEnhancement	providedby	provides	Shopping
AutonomyEnhancement	providedby	provides	Cooking
AutonomyEnhancement	providedby	provides	Medication
AutonomyEnhancement	providedby	provides	Drinking
Bathing	is a	subsumes	Process
Bathing	isa	subsumes	Process
Cleaning	is a	subsumes	Process
Cleaning	isa	subsumes	Process
Comfort	providedby	provides	HomeAutomation
Comfort	providedby	provides	Infotainment
Comfort	is a	subsumes	Needs
Comfort	providedby	provides	FindingThings
Comfort	providedby	provides	Safety
Comfort	isa	subsumes	Needs
Comfort	providedby	provides	SocialContacts
ContinuousGlucoseMonitoringSystem	haspart	partof	InsulinPump

ContinuousGlucoseMonitoringSystem	haspart	partof	GlucoseSensor
ContinuousGlucoseMonitoringSystem	is a	subsumes	Object
ContinuousGlucoseMonitoringSystem	isa	subsumes	Object
ContinuousGlucoseMonitoringSystem	haspart	partof	Transmitter
Cooking	is a	subsumes	Process
Cooking	isa	subsumes	Process
Detection	isa	subsumes	Process
Detection	is a	subsumes	Process
Dressing	isa	subsumes	Process
Dressing	is a	subsumes	Process
Drinking	isa	subsumes	Process
Drinking	is a	subsumes	Process
Eating	is a	subsumes	Process
Eating	isa	subsumes	Process
EmergencyAssistance	isa	subsumes	Needs
EmergencyAssistance	providedby	provides	Prediction
EmergencyAssistance	providedby	provides	Detection
EmergencyAssistance	providedby	provides	Prevention
EmergencyAssistance	is a	subsumes	Needs
EmergencyAssistance	providedby	provides	Assistance
FindingThings	isa	subsumes	Process
FindingThings	is a	subsumes	Process
Glucosesensor	isa	subsumes	Sensor
GlucoseSensor	usedin	uses	Prevention
GlucoseSensor	is a	subsumes	Sensor
GlucoseSensor	hasproperty	propertyof	Adhesive
Glucosesensor	is a	subsumes	T
GlucoseSensor	usedin	uses	Detection
HomeAutomation	isa	subsumes	Process
HomeAutomation	is a	subsumes	Process
Infotainment	is a	subsumes	Process
Infotainment	isa	subsumes	Process
Insulin	isa	subsumes	Medication
Insulin	is a	subsumes	Medication
InsulinPump	isa	subsumes	Object
InsulinPump	is a	subsumes	Object
Medication	isa	subsumes	Process
Medication	is a	subsumes	Process
Needs	isa	subsumes	Quality
Needs	is a	subsumes	Quality

Object	is a	subsumes	T
Object	isa	subsumes	T
Patient	isa	subsumes	Actor
Patient	is a	subsumes	Actor
Patient	performs	isperformedby	Process
Prediction	is a	subsumes	Process
Prediction	isa	subsumes	Process
Prevention	isa	subsumes	Process
Prevention	is a	subsumes	Process
Process	isa	subsumes	T
Process	is a	subsumes	T
Property	is a	subsumes	Quality
Property	isa	subsumes	Quality
Quality	is a	subsumes	T
Quality	isa	subsumes	T
Safety	isa	subsumes	Process
Safety	is a	subsumes	Process
Seismometer	isa	subsumes	Sensor
Seismometer	is a	subsumes	Sensor
Seismometer	usedin	uses	Detection
Sensor	is a	subsumes	Object
Sensor	isa	subsumes	Object
ServiceProvider	performs	isperformedby	Process
ServiceProvider	is a	subsumes	Actor
ServiceProvider	isa	subsumes	Actor
Shopping	is a	subsumes	Process
Shopping	isa	subsumes	Process
SmartPhone	isa	subsumes	Object
SmartPhone	is a	subsumes	Object
SocialContacts	is a	subsumes	Process
SocialContacts	isa	subsumes	Process
Software	isa	subsumes	Object
Software	is a	subsumes	Object
T	isa	subsumes	AssistiveSoftware
TemperatureSensor	is a	subsumes	Sensor
TemperatureSensor	isa	subsumes	Sensor
TemperatureSensor	usedin	uses	Detection
TextToSpeech	isa	subsumes	AssistiveSoftware
TextToSpeech	is a	subsumes	AssistiveSoftware
Training	isa	subsumes	Process

Training	is a	subsumes	Process
Transmitter	is a	subsumes	Object
Transmitter	isa	subsumes	Object
VoiceRecognition	is a	subsumes	AssistiveSoftware
VoiceRecognition	isa	subsumes	AssistiveSoftware