Abstract

We present “standard” domain description and requirements prescription examples using the RAISE [112] Specification Language, RSL [110]. The illustrated example is that of transportation networks.

These notes shall serve as lecture notes for my lectures at Uppsala, Nov.8-19, 2010. The present document is the ordinary “book-form”-like notes. A separate document, compiled from the same files, presents 11 sets of lecture slides. The “funny” small numbers you see in the present document, in margins and at almost end of display lines refer to slide page numbers of the slides document.
A Tentative Lecture Schedule

Lecture 1: Introduction Mo.8.11.2010
Lecture 2: Specification Ontology Mo.8.11.2010
  Entities: Simple Entities, Actions, Events, Behaviours
Lecture 3: Domain Facets I Tu.9.11.2010
  Intrinsics, Support Technologies, Rules & Regulations
Lecture 4: Domain Facets II We.10.11.2010
  Scripts, Management & Organisation, Human Behaviour
Lecture 5: Requirements Facets I Th.11.11.2010
  Domain Requirements I: Projection, Instantiation, Determiniation
Lecture 6: Requirements Facets II Fr.12.11.2010
  Domain Requirements II: Extension, Fitting
  Interface Requirements
  Machine Requirements
Lecture 7: RSL I Mo.15.11.2010
  Types
Lecture 8: RSL II Tu.16.11.2010
  Values and Operations
Lecture 9: RSL III We.17.11.2010
  Logic, A-Calculus, Other Applicative Constructs
Lecture 10: RSL IV Th.18.11.2010
  Imperative Constructs, Process Constructs, Specifications
Lecture 11: Conclusion Fr.19.11.2010
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1 Introduction

1.1 The Problem

The problem to be solved by this technical note is to present in one specific formal specification language, RSL [112], a domain description and a requirements prescription developed according to the “triptych approach” [34].

1.2 General Remarks

Before we can design software we must have a robust understanding of its requirements. And before we can prescribe requirements we must have a robust understanding of the environment, or, as we shall call it, the domain in which the software is to serve – and as it is at the time such software is first being contemplated.

In consequence we suggest that software, “ideally”\(^1\), be developed in three phases.

First a phase of domain engineering. In this phase a reasonably comprehensive description is constructed from an analysis of the domain. That description, as it evolves, is analysed with respect to inconsistencies, conflicts and completeness on one hand, and, on the other hand, in order to achieve pleasing concepts in terms of which to abstractly model the domain (Sect. 3).

Then a phase of requirements engineering. This phase is strongly based, as we shall see (in Sect. 4), on an available, necessary and sufficient domain description. Guided by the domain and requirements engineers the requirements stakeholders point out which domain description parts are to be left (projected) out of the domain requirements, and of those left what forms of instantiations, determinations and extensions are required. Similarly the requirements stakeholders, guided by the domain and requirements engineers, inform as to which domain entities, actions, events and behaviours are shared between the domain and the machine, that is, the hardware and the software being required. In these notes we shall only very briefly cover aspects of machine requirements.

And finally a phase of software design. We shall not cover this phase in these notes.

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\(^1\)Section 5.7 will discuss practical renditions of “idealism”!

Methodology

These notes focus on methodology – where a method is seen as a set of principles (applied by engineers, not machines) for selecting and applying (often with some tool support) techniques (and tools) for the efficient construction of some artifact – here software.

1.2.1 What are Domains

By a domain we shall thus understand a universe of discourse, an area of nature subject to laws of physics and studies by physicists, or an area of human activity (subject to its interfaces with nature). There are other domains which we shall ignore. We shall focus on the human-made domains. “Large scale” examples are the financial service industry:
banking, insurance, securities trading, portfolio management, etc., health care: hospitals, clinics, patients, medical staff, etc., transportation: road, rail/train, sea, and air transport (vehicles, transport nets, etc.); oil and gas systems: pumps, pipes, valves, refineries, distribution, etc. “Intermediate scale” examples are automobiles: manufacturing or monitoring and control, etc.; and heating systems.

The above explication was “randomised”: for some domains, to wit, the financial service industry, we mentioned major functionalities, for others, to wit, health care, we mentioned major entities. An objection can be raised, namely that the above characterisation – of what a domain is – is not sufficiently precise. We shall try, in the next section, to partially meet this objection.

1.2.2 What is a Domain Description

By a domain description we understand a description of the entities, the actions, the events and the behaviours of the domain, including its interfaces to other domains. A domain description describes the domain as it is. A domain description does not contain requirements let alone references to any software. Michael Jackson, in [139], refers to domain descriptions as indicative (stating objective fact), requirements prescriptions as optative (expressing wish or hope) and software specifications as imperative (“do it!”). A description is syntax. The meaning (semantics) of a domain description is usually a set of domain models. We shall take domain models to be mathematical structures (theories). The form of domain descriptions that we shall advocate “come in pairs”: precise, say, English, i.e., narrated text (narratives) alternates with clearly related formula text.

Description Languages Besides using as precise a subset of a national language, as here English, as possible, and in enumerated expressions and statements, we “pair” such narrative elements with corresponding enumerated clauses of a formal specification language. We shall be using the RAISE Specification Language, RSL, [112], in our formal texts. But any of the model-oriented approaches and languages offered by Alloy [138], Event B [3], VDM [107] and Z [234], should work as well. No single one of the above-mentioned formal specification languages, however, suffices. Often one has to carefully combine the above with elements of Petri Nets [200], CSP: Communicating Sequential Processes [128], MSC: Message Sequence Charts [137], Statecharts [120], and some temporal logic, for example either DC: Duration Calculus [236] or TLA+ [148]. Research into how such diverse textual and diagrammatic languages can be meaningfully and proof-theoretically combined is ongoing [9].

1.2.3 Contributions of These Lecture Notes

We claim that the major contributions of the triptych approach to software engineering as presented in these notes are the following: (1) the clear identification of domain engineering, or, for some, its clear separation from requirements engineering (Sects. 3 and 4); (2) the identification and ‘elaboration’ of the pragmatically determined domain facets of
(a) intrinsics, (b) support technologies, (c) rules and regulations, (d) scripts (licenses and contracts), (e) management and organisation, and (f) human behaviour whereby ‘elaboration’ we mean that we provide principles and techniques for the construction of these facet description parts (Sects. 3.2–3.7); (3) the re-identification and ‘elaboration’ of the concept of business process reengineering (Sect. 4.1); (4) the identification and ‘elaboration’ of the technically determined domain requirements facets of (g) projection, (h) instantiation, (i) determination, (j) extension and (k) fitting requirements principles and techniques – and, in particular the “discovery” that these requirements engineering stages are strongly dependent on necessary and sufficient domain descriptions (Sects. 4.2.1–4.2.5); and (5) the identification and ‘elaboration’ of the technically determined interface requirements facets of (l) shared simple entity, (m) shared action, (n) shared event and (o) shared behaviour requirements principles and techniques (Sects. 4.3.2–4.3.5). We claim that the facets of (2, 3, 4) and (5) are all relatively new.

1.2.4 Relation to Other Engineering Disciplines

An aeronautics engineer – to be hired by Boeing to their design team for a next generation aircraft – must be pretty well versed in applied mathematics and in aerodynamics. A radio communications engineer – to be hired by Ericsson to their design team for a next generation mobile telephony antennas – must be likewise pretty well versed in applied mathematics and in the physics of electromagnetic wave propagation in matter. And so forth. Software engineers hired for the development of software for hospitals, or for railways, know little, if anything, about health care, respectively rail transportation (scheduling, rostering, etc.). The Ericsson radio communications engineer can be expected to understand Maxwell’s Equations, and to base the design of antenna characteristics on the transformation and instantiation of these equations. It is therefore quite reasonable to expect the domain-specific software engineer to understand formalisation of their domains, to wit: railways: www.railwaydomain.org, and pipelines: pipelines.pdf, logistics: logistics.pdf, transport nets: comet1.pdf, stock exchanges: tse-2.pdf and container lines: container-paper.pdf – these latter five at www.imm.dtu.dk/~db/.

1.3 The Triptych Approach

The “triptych approach” calls for a thorough description (cum analysis) of the domain before one attempts prescribing requirements for specific software.

As part of the triptych approach to domain engineering one starts by exploring the description ontology of specification entities: simple entities, actions, events and behaviours (Sect. 2) before delving into the description ontology of facets: intrinsics, support technologies, rules & regulations, scripts (licenses and contracts), management & organisation and human behaviour (Sect. 3).

And, as part of the triptych approach to requirements engineering one starts by exploring the reengineering of business processes before delving into domain requirements concepts of projection, instantiation, determination, extension and fitting – followed by
a number of interface requirements stages. The terms in slanted script are defined in Appendix B.

For a more pedagogic and didactical introduction to these terms we refer to either of [36, 50, 49, 45, 46, 47] or to [34, 39, 44].

1.4 On The Structure of These Lecture Notes

The presentation (i.e., structuring) of the technical material of these lecture notes is not meant to suggest that all domain descriptions and requirements prescriptions follow this mold. As mentioned just above our presentation follows the structure of simple entity, action, event, and behaviour specification ontology (Sect. 2), then the structure of the domain facets: intrinsics, support technology, rules & regulations, scripts (licenses, contracts), management & organisation and human behaviour (Sect. 3), and finally the structure of the business re-engineering (Sect. 4.1.3), the domain requirements concepts of projection, instantiation, determination, extension and fitting (Sect. 4.2), and a number of interface requirements facets (Sect. 4.3).

I expect such students who might be pursuing specifications based on the example of this document to do so, either, as here, in RSL [110], or according to approaches embodied in Alloy [138], CafeOBJ [109], Event B [3], VDM [107] and Z [234]. But I do not expect them to follow exactly the order used in this document – although it might well be a good idea, pedagogically and didactically.

Two remarks are in order:

• Rather I expect Alloy, CafeOBJ, Event B, VDM-SL and Z specifications to follow a “most natural order” appropriate for their approaches.

• The order in which I have chosen to present the current material reflects a both pedagogic and didactic views. In a commercial project I might very well choose another decomposition of the material — being guided, however, by the need to cover all the footnoted (Footnote 2) facets.

1.5 The Comparative Methodology Endeavour

These notes are intended to replace:

• http://www.imm.dtu.dk/~db/bjorner-8jan2010.pdf

• http://www.complang.tuwien.ac.at/bjorner/book.pdf

which were first suggested as a basis for the Comparative Methodology endeavour, cf.

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2The sequence of the simple entity, action, event, behaviour, domain facets: intrinsics, support technology, rules & regulations, scripts (licenses, contracts), management & organisation, human behaviour, domain requirements: projection, instantiation, determination, extension, fitting and the interface requirements facets reflect these views.
• http://www2.imm.dtu.dk/~db/comet/
• http://formalmethods.wikia.com/wiki/CoMet

Rewriting the above referenced earlier notes into the present notes were begun after Kokichi Futatsugi’s CafeOBJ lectures. I am happy to acknowledge being thus challenged.

1.6 Caveat

The many examples of Sect. A, the RSL Primer, stem from an earlier version of this attempt to give a ‘model’ presentation of domains and requirements. They have yet to coordinated with the the present rewrite of Sects. 2–4.