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Lecture 5: Domain Engineering: First of Five Parts

Phone: +45 4542 2141, E-mail: bjorner@gmail.com, URL: www.imm.dtu.dk/~db

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Domain Engineering

- Domain engineering is a new element of software engineering.
- Domain engineering is to be performed prior to requirements engineering
  - ⋆ for the case where there is no relevant domain description
  - ⋆ on which to base the requirements engineering.
- For the case that such a description exists
  - ⋆ that description has to first be checked:
  - ⋆ its scope must cover at least that of the desired requirements.

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[Domain Engineering]

- The next three–four lectures shall outline
  - ⋆ the stages and steps of development actions to be taken
  - ⋆ in order to arrive, in a proper way,
  - ⋆ at a proper domain description.

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Discussions of The Domain Concept

The Novelty

- The idea of domain engineering preceding requirements engineering is new.
- Well, in some presentations of requirements engineering there are elements of domain analysis.
- But basically those requirements engineering-based forms of analysis
  - ⋆ do not expect the requirements engineer to write down,
  - ⋆ that is, to seriously describe the domain,
  - ⋆ and certainly not in a form which is independent of,
  - ⋆ that is, separated from the requirements prescriptions.

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[Discussions of The Domain Concept, The Novelty]

- As also outlined in earlier lectures (Lectures #1 and #4),
  - ⋆ domain models
  - ⋆ are as necessary for requirements development and —
  - ⋆ thus also —
  - ⋆ for software design,
  - ⋆ as physics is for the classical branches of
    - ◇ electrical and electronics,
    - ◇ mechanics,
    - ◇ civil, and
    - ◇ chemical

    engineering.

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Implications

- This new aspect of software engineering implies
  - ⋆ that software engineers, as a group, engaged in a software development project,
    - ◇ from (and including) domain engineering
    - ◇ via requirements engineering
    - ◇ to (and including) software design,
  - ⋆ must possess the necessary formal and practical bases:
    - ◇ the science skills of domain engineering,
    - ◇ the R&D skills of requirements engineering, and
    - ◇ the (by now) engineering skills of software design.

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[Discussions of The Domain Concept]

The Domain Dogma

- *Before software can be designed*
  - ⋆ *one must understand its requirements.*
- *Before requirements can be expressed*
  - ⋆ *one must understand the application domain.*

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Stages of Domain Engineering

An Overview of "What to Do ?"

- How do we then construct a domain description ?
- That is, which are the stages of domain engineering ?
- The answer is:
  - ⋆ there are a number of stages,
  - ⋆ which, when followed in some order, some possibly concurrently,
  - ⋆ will lead you reasonably disciplined way from scratch to goal !
- Before enumerating the stages
  - ⋆ let us argue their presence
  - ⋆ and basic purpose.

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Stages of Domain Engineering, What to Do ?

[1] Domain Information

- We are here referring to the construction of informative documents.
- We have already, in earlier lectures, extensively (Slides 24–116) covered this area of mostly management activities.
- Suffice it here to restate that
  - ⋆ each and every of the items listed on Slide 28
  - ⋆ must be kept up-to-date during the full development cycle.
- This means that this activity is of "continuing concern"'
- all during development.

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Stages of Domain Engineering, What to Do ?

[2] Domain Stakeholder Identification

- The domain is populated with
  - ⋆ staff,
  - ⋆ customers,
  - ⋆ providers,
  - ⋆ the public at large,
  - ⋆ regulatory agencies,
  - ⋆ politicians,
  - ⋆ etcetera.
- There are many kinds of staff, many kinds of customers, many kinds of providers, etc.
- All these need be identified so that
  - ⋆ as complete a coverage of sources of domain knowledge can be established and used
  - ⋆ when actively acquiring, that is, soliciting and eliciting knowledge about the domain.

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Stages of Domain Engineering, What to Do ?

[3] Domain Acquisition

- The software engineers need a domain description.
- Software engineers, today, are basically the only ones who have the tools, techniques and experience in creating large scale specifications.
- But the software engineers do not possess the domain knowledge.
- They must acquire this knowledge from the domain stakeholders.

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Characterisation 46 (Domain Acquisition (I)) By *domain acquisition* we understand

- a process in which
- documents, interviews, etc.,
- informing — "in any shape or form" —
- about the domain
- entities, functions, events and behaviours
- are collected
- from the domain stakeholders

. ■

Compare the above characterisation to that of Characterisation 50 on page 241.

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Stages of Domain Engineering, What to Do ?

[4] Domain Analysis and Concept Formation

- The acquired domain knowledge is then analysed,
- that is, studied with a view towards discovering
  - ⋆ inconsistencies and incompleteness of what has been acquired
  - ⋆ as well as concepts that capture properties of knowledge
  - ⋆ about the phenomena and concepts being analysed.

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Stages of Domain Engineering, What to Do ?

[5] Domain Business Processes

- On the basis of acquired knowledge,
  - ⋆ sometimes as part of its acquisition
  - ⋆ one is either presented with or constructs rough sketches
  - ⋆ of the business processes of the domain.
- An aim of describing these business processes
  - ⋆ is to check the acquired knowledge
  - ⋆ for inconsistencies and completeness
  - ⋆ and whether proposed concepts help improve the informal understanding.

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Stages of Domain Engineering, What to Do ?

[6] Domain Terminology

- Out of the
  - ⋆ domain acquisition,
  - ⋆ analysis and
  - ⋆ business process rough-sketching

  processes emerges a domain terminology.
- That is, a set of terms that cover
  - ⋆ entities,
  - ⋆ functions,
  - ⋆ events and
  - ⋆ behaviours

  of the domain.

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[Stages of Domain Engineering, What to Do ?, Terminology]

- It is an important aspect of software development
  - ⋆ to establish,
  - ⋆ use and
  - ⋆ maintain
  - ⋆ a variety of terminologies.
- And first comes the domain terminology.

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Stages of Domain Engineering, What to Do ?

[7] Domain Modelling

- Based on properly analysed domain acquisitions
  - ⋆ these are "domain description units"
- we can now model the domain.
- The major stage of the domain engineering phase
  - ⋆ is that of domain modelling, that is,
  - ⋆ of precisely describe
    - ◇ in narrative and possibly also in formal terms
  - ⋆ the domain as it is.
  - ⋆ Several principles, many techniques and many tools
    - ◇ can be given for describing domains.

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Stages of Domain Engineering, What to Do ?

[8] Domain Verification

- While describing a domain one may wish to verify properties of what is being described.
- The use here of the term 'verification' covers
  - ⋆ (i) formal testing,
    - ◇ that is, testing
    - ◇ (symbolic executions of descriptions)
    - ◇ based on formally derived test cases and test answers,
  - ⋆ (ii) model checking,
    - ◇ that is, executions of simplified,
    - ◇ but crucial models of what is being described,

    and
  - ⋆ (iii) formal verification
    - ◇ that is, formal, possibly mechanisable proof of theorems
    - ◇ (propositions etc.) about what is being described.

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Stages of Domain Engineering, What to Do ?

[9] Domain Validation

Characterisation 47 (Validation) By *validation* we shall mean

- a systematic process —
- involving representatives of all stakeholders
- and the domain engineers —
- going carefully through all the narrative descriptions
- and confirming or rejecting these descriptions

. ■

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Stages of Domain Engineering, What to Do ?

[10] Domain Verification versus Domain Validation

- Verification
  - ⋆ serves to ensure that
  - ⋆ the domain model is right.
- Validation
  - ⋆ serves to ensure that
  - ⋆ one obtains the right model.

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Stages of Domain Engineering, What to Do ?

[11] Domain Theory Formation

- Describing a domain,
  - ⋆ precisely, and even
  - ⋆ formally,
  - ⋆ verifying propositions and theorems,

  is tantamount to establishing a basis for a domain theory.
- Just as in physics, we need theories also of the man-made universes.

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[Stages of Domain Engineering]

A Summary Enumeration

- We can now summarise the relevant stages of domain engineering:

1. Domain Information
2. Domain Stakeholder Identification,
3. Domain Acquisition,
4. Domain Analysis and Concept Formation,
5. Domain [i.e., Business] Processes,
6. Domain Terminology,
7. Domain Modelling,
   (a) Intrinsics (Slide 277)
   (b) Support Technologies (Slide 302)
   (c) Management & Organistation (Slide 319)
   (d) Rules & Regulations (Slide 355)
   (e) Scripts (Slide 374)
   (f) Human Behaviour (Slide 466)
8. Domain Verification,
9. Domain Validation and
10. Domain Verification Versus Domain Validation and
11. Domain Theory Formation

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Domain Information

- We have earlier, as mentioned earlier, extensively (Slides 24–116) covered the general issues of informative documents.
- Suffice it here to emphasize the following.
- **Current Situation:**

Cf. Slides 34–36

  - ⋆ As mentioned on Slide 34 the context in which the domain developments starts must be emphasized.
  - ⋆ Focus on just that.
  - ⋆ Please no reference to possible requirements or software designs.

MORE TO COME

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[Domain Information]

• Needs and Ideas:

Cf. Slides 37–41

⋆

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⋆

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[Domain Information]

• Concepts and Facilities:

Cf. Slides 42–44

⋆

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[Domain Information]

• Scope and Span:

Cf. Slides 45–48

⋆

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⋆

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[Domain Information]

• Assumptions and Dependencies:

Cf. Slides 49–51

⋆

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⋆

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[Domain Information]

• Implicit/Derivative Goals:

Cf. Slides 52–55

⋆

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[Domain Information]

• Synopsis:

Cf. Slides 56–58

⋆

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[Domain Information]

• Software Development Graphs:

Cf. Slides 61–70

⋆

⋆ TO BE WRITTEN

⋆

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[Domain Information]

• Resource Allocation:

Cf. Slides 71–74

- ⋆
- ⋆ TO BE WRITTEN
- ⋆

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[Domain Information]

• Budget (and Other) Estimates:

Cf. Slide 75

⋆

⋆ TO BE WRITTEN

⋆

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• Standards Compliance:

Cf. Slides 76–84

- ⋆
- ⋆ TO BE WRITTEN
- ⋆

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[Domain Information]

• Contracts and Design Briefs:

Cf. Slides 85–107

- ⋆
- ⋆ TO BE WRITTEN
- ⋆
- •

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Domain Stakeholders

Characterisations

Characterisation 48 (Stakeholder) By a domain *stakeholder* we shall understand

- a person, or a group of persons, "united" somehow in their common interest in, or dependency on the domain; or
- an institution, an enterprise, or a group of such, (again) characterised (and, again, loosely) by their common interest in, or dependency on the domain

. ■

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Characterisation 49 (General Application Domain Stakeholder)

By *general application domain stakeholders* we understand stakeholders whose primary interest

- ⋆ is neither the projects which develop software (from domains, via requirements to software design),
- ⋆ nor the products evolving from such projects.

- Instead we mean stakeholders from
- typically non-IT business areas

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Why Be Concerned About Stakeholders ?

- The domain stakeholders are the main sources of domain knowledge.
- So the domain engineers must acquire as much and more than the knowledge relevant to describe the domain.
- And the domain stakeholders must eventually validate the domain engineers' domain description.

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How to Establish List of Stakeholders ?

- Awareness, by the domain engineers,
  - ⋆ of who and which are the main and the subordinate domain "players",
  - ⋆ is obtained by the same initial processes that first acquire domain knowledge,
  - ⋆ namely
    - ◇ by reading about the domain,
    - ◇ from books, journals, the Internet,
    - ◇ by talking to stakeholders, and
    - ◇ by interviewing these systematically.
- The process is an iterative one.
- One cannot know till "deep" into domain modelling whether one has obtained a reasonably complete list.

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[Domain Stakeholders]

Form of Contact With Stakeholders

- Later lectures outline
  - ⋆ the regular interactions between domain stakeholders and domain engineers
  - ⋆ from the early stages of domain acquisition
  - ⋆ to the late stage of domain validation.
- This form of domain stakeholder and engineers interaction alternates between
  - ⋆ one-on-one meetings,
  - ⋆ e-mails,
  - ⋆ the joint filling out of larger questionnaires, and
  - ⋆ joint multi-stakeholder group and domain engineer presentations.
- The domain engineers shall carefully keep record of all that is communicated.

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Domain Acquisition

Another Characterisation

Characterisation 50 (Domain Acquisition (II)) By *domain acquisition* we shall here understand

- the systematic solicitation and elicitation of knowledge about the chosen domain and
- the systematic vetting, recording and classification of this knowledge

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Compare the above characterisation to that of Characterisation 46 on page 213.

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Sources of Domain Knowledge

- To return to the issue of stakeholders,
  - ⋆ from where does the domain engineer acquire the domain knowledge ?
- The answer is:
  - ⋆ from many (stakeholder) sources.
- We suggest some sources:
  - ⋆ from the Internet,
  - ⋆ from books, papers, etc.,
  - ⋆ from owners and staff of the client,
  - ⋆ from customers of the client,
  - ⋆ possibly from domain regulators,
  - ⋆ from consultancy, equipment and service providers for and to the client and
  - ⋆ possibly others.

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Forms of Solicitation and Elicitation

Solicitation

- How can the domain engineer solicit the desired domain knowledge ?
  - ⋆ By searching the Internet, looking up books, papers and reports; and
  - ⋆ by contacting and by asking to be referred to domain knowledgeable client and customer staff.

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Elicitation

- How does the domain engineer elicit the desired domain knowledge ?
  - ⋆ By studying hopefully relevant
    - ◇ Internet Web pages, books, papers and reports and
    - ◇ by forming "impressions of" the domain;

    and
  - ⋆ by interviewing ("questionnairing") contacted domain stakeholders,
    - ◇ with interviews being based on the prior 'impressions'.

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Solicitation and Elicitation

- Solicitation and elicitation is an iterative process:
  - ⋆ Impressions obtained early in the process may turn out to be wrong.
  - ⋆ Hence they must be scrapped and lead to reevaluation of the acquisition process,
  - ⋆ and to it being repeated.

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Aims and Objectives of Elicitation

- The aims of elicitation
  - ⋆ is to cover the span of the domain
  - ⋆ as accurately and fully as possible.
- The objectives of elicitation
  - ⋆ is to obtain "bits and pieces" — and hopefully much more –
  - ⋆ of relevant domain knowledge within the scope of the domain being studied.
- We shall refer to the 'bits and pieces' of domain knowledge as domain description units.

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Domain Description Units

Characterisation

Characterisation 51 (Domain Description Unit) By a domain description unit

- we shall mean an as far as possible well-formed sentence,
- something which names and describes some
  - ⋆ entity,
  - ⋆ function,
  - ⋆ event or
  - ⋆ behaviour

  of the domain,
- that is, something expressible which "makes sense",
- that is, which can contribute to the modelling of
  - ⋆ an entity,
  - ⋆ a function,
  - ⋆ an event or
  - ⋆ a behaviour

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Domain Acquisition, Domain Description Units

Handling

- Thus domain acquisition amounts to
  - ⋆ the laborious,
  - ⋆ painstaking
  - ⋆ process of
  - ⋆ collecting (storing)
  - ⋆ "zillions"
  - ⋆ of domain description units.
- In preparation
  - ⋆ for the ongoing, say concurrent
  - ⋆ domain analysis and concept formation process
  - ⋆ domain description units are provided with attributes such as
    - ◇ name(s),
    - ◇ kinds,
    - ◇ source, and
    - ◇ date(s).

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Domain Analysis and Concept Formation

- Given a suitable set,
  - ⋆ not necessarily what may be believed to be a reasonably complete set,
- of reasonably related domain description units,
  - ⋆ where, by 'related', we mean domain description units that
  - ⋆ contain overlapping (names of) entities, functions, events and behaviours,
- one can start analysing these domain description units.

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Characterisations

- First some preliminaries.

Consistency

Characterisation 52 (Consistency) By *consistency* of a set of two or more domain description units

- we mean that no combination of any subset of these
- contradicts another combination of a subset of these

. ■

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Contradiction

Characterisation 53 (Contradiction) By two different sets of domain description units being in *contradiction* of one another

- we mean that one can claim a property
- and its negation
- to hold in the model of the domain description units

. ■

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Completeness

Characterisation 54 (Relative Completeness) By *relative completeness* of a set of domain description units

- we mean a consistent set of domain description units
- which allows a meaningful modelling of what is being described
- such that the model does not leave something accidentally undefined

. ■

- That is, we can perfectly well imagine that we leave
- some domain aspects purposely undefined.

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Conflict

Characterisation 55 (Conflict) By a *conflict* of a set of domain description units

- we mean an inconsistency
- that cannot be resolved by the domain engineer
- only discussing the conflicting domain description units
- with the stakeholders from whom the units are elicited

. ■

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- There are three cases of conflict resolution.
  - ⋆ (i) A single stakeholder is assumed not to generate conflicts.
  - ⋆ (ii) Two or more stakeholders from the same stakeholder group should be able, together with the domain engineers, to resolve the conflict.
  - ⋆ (iii) Two or more stakeholders from different stakeholder groups may, together with the domain engineers, have to refer to their management for resolution.

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Aims and Objectives of Domain Analysis

Aims of Domain Analysis

Characterisation 56 (Domain Analysis, Aims) By *domain analysis* we mean

- a systematic study of all domain description units,
- that is a "close reading and review" of these
- whose aim is to cover them all

. ■

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Objectives of Domain Analysis

Characterisation 57 (Domain Analysis, Objectives) By *domain analysis objectives* we mean

- a domain analysis
- whose objective it is
  - ⋆ to find [all] inconsistencies and [all] incompletenesses,
  - ⋆ to remove these, and
  - ⋆ to ensure a relatively scope-complete set of consistent domain description units

. ■

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Concept Formation

- In addition to detecting inconsistencies, conflicts and incompleteness
- of a set of domain description units,
- domain analysis also has as objective to possibly form concepts.

Characterisation 58 (Domain Concept) By a domain concept

- we mean a concept, an abstraction, a mental construction,
- which captures all essential properties
- and "suppresses" expression of properties deemed not essential

. ■

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Aims and Objectives of Domain Concept Formation

- The aim of domain concept formation
  - ⋆ is to focus on similarities of
  - ⋆ domain phenomena or already defined domain concepts
  - ⋆ and, from these possibly form new, usually more generic concepts.
- The objective of domain concept formation is to arrive
  - ⋆ at simpler domain models,
  - ⋆ at generic domain models, that is, models which cover several more concrete, i.e., instantiated domains.

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Domain, i.e., Business Processes

Characterisation

Characterisation 59 (Business Process) By a *business process* we understand

- the procedurally describable aspects, of one of the (possibly many) ways in which a business, an enterprise, a factory, etc.,
- conducts its yearly, quarterly, monthly, weekly and daily processes, that is, regularly occurring chores.
  - ⋆ The process may involve strategic, tactical or operational management and work-flow planning and decision activities; or
  - ⋆ the administrative, and, where applicable, the marketing, the research and development, the production planning and execution, the sales and the service (work-flow) activities — to name some

. ■

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Business Process Description

- A business process description is usually in the form of
  - ⋆ a behaviour description which covers
  - ⋆ core entities, functions and events.
- Usually one describes several (more or less related) business processes

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Aims & Objectives of Business Process Description

Aims

- The aims of describing a set of domain business processes
  - ⋆ is to cover all the "standard", i.e., all the most common
  - ⋆ as well as a reasonable number of the more special
  - ⋆ business processes of the chosen span and scope
  - ⋆ while covering most of the entities, functions and events
  - ⋆ that were identified is the full set of domain description units.

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Objectives

- The objectives of describing a set of domain business processes
  - ⋆ is to discover domain entities, functions and events
  - ⋆ that were omitted from, i.e., are not found in the
  - ⋆ the full set of domain description units;
  - ⋆ that is, to somehow "test" and validate
  - ⋆ the domain acquisition stage.

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Disposition

- So what do we do if and when we find that the
  - ⋆ full set of domain description units
  - ⋆ and the rough-sketched domain business processes
  - ⋆ are at odds ?
- We obviously have to inquire with the relevant domain stakeholders.
  - ⋆ Based on their "feedback" we have to modify
  - ⋆ the full set of domain description units
  - ⋆ as well as the rough-sketched domain business processes.
- This is an iterative process
  - ⋆ and may involve modifying
  - ⋆ the domain analysis and concept formation findings.

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Domain Terminology

The 'Terminology' Dogma

- It is an important aspect of domain engineering
  - ⋆ to establish,
  - ⋆ use and
  - ⋆ maintain
  - ⋆ a domain terminology.

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Characterisations

Characterisation 60 (Term) By a *term* is here meant:

- a word or phrase used in a definite or precise sense
- in some particular subject, as a science or art;
- a technical expression;
- by word or group of words expressing a notion or conception,
- or denoting an object of thought

. ■

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Characterisation 61 (Terminology) By *terminology* is meant:

- the doctrine or scientific study of terms;
- the system of terms belonging to a science or subject;
- technical terms collectively;
- nomenclature

. ■

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Term Definitions

- Thus a terminology is a set of definitions
  - ⋆ consisting of a "left-hand side" definiendum, usually a name, "the term", of that which is to be defined,
  - ⋆ and a "right-hand side" definiens, the expression which defines.
- The definiens expression
  - ⋆ may either contain ground terms,
    - ◇ that is, terms that are taken for understood,
    - ◇ and the definiens expression is then called an atomic expression;
  - ⋆ or it contains other terms
    - ◇ being defined in the terminology
    - ◇ and the definiens expression is then called a composite expression.

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[Domain Terminology, Term Definitions]

- A set of term definitions form a well-formed terminology
  - ⋆ if all professional, i.e., domain-specific terms are defined,
  - ⋆ and, although some terms may be (mutually) recursively defined,
  - ⋆ these recursions do terminate by means of alternative definition choices.

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Aims and Objectives of a Terminology

- The aims of a domain terminology (i.e., of domain terminologisation)
  - ⋆ is to cover all the terms that are specific to the domain.
- The objectives of a domain terminology (i.e., of domain terminologisation)
  - ⋆ is to ensure that all stakeholders,
  - ⋆ the developers and
  - ⋆ the domain description readers
  - ⋆ obtain as near, if not, the same understanding of the recorded terms.

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How to Establish a Terminology

- First a set of terms to be defined is selected.
- Then each term is defined,
  - ⋆ either atomically,
  - ⋆ or in composite manner, possibly recursively.
- The definition ends
  - ⋆ when all selected terms have been defined
  - ⋆ and all uses of domain-specific terms
  - ⋆ not already in the list of selected terms have been defined.

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- As can be seen from the above procedure
  - ⋆ it requires careful administration
  - ⋆ and usually ends up in a prolonged, iterated process.
- When defined informally,
  - ⋆ the domain engineer may wish to use pictures, diagrams.
- When defined formally
  - ⋆ one may have to prove that the definitions are sound.

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End of Lecture 5

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