A Philosophy of Domain Science & Engineering

An Interpretation of Kai Sørlander's Philosophy

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Abstract

- We show how the domain analysis & description calculi of [1]
  - satisfy Kai Sørlander's Philosophy,
  - but also that Sørlander's Philosophy, notably [2] and [3]
  - mandates extensions to the calculi
  - in order to form a more consistent "whole".
- Where discrete parts were just that,
  we must now distinguish between three kinds of parts:
  - (i) **physical parts**,
  - (ii) **living species parts**, and
  - (iii) **artifacts**.

- (i) The **physical parts** are not made by man,
  - but are in *space* and *time*;
  - these are *endurants* that are subject to
    - the *laws* of physics
      as formulated by for example *Newton* and *Einstein*,
    - and also subject to the *principle of causality*
    - and *gravitational pull*
    – but were not so explicated.
  - They are the parts we treated in [1].

- (ii) The **living species parts** are
  - *plants* and *animals*;
  - they are still subject to the laws and principles of physics,
  - but additionally *unavoidably* endowed
    with such properties as *causality of purpose*.
  - Animals have
    - *sensory organs*,
    - *means of motion*,
    - *instincts*,
    - *incentives* and
    - *feelings*.

- Among animals we single out **humans** as parts that are further characterisable:
  - possessing *language*,
  - *learning skills*,
  - being *consciousness*, and
  - having *knowledge*.
- These aspects were somehow, by us, subsumed
  - in our analysis & description by partially
  - endowing *physical parts* with such properties.

- (iii) Then there are the parts made by humans, i.e., **artifacts**.
  - *Artifacts* have a usual set of attributes
  - of the kind *physical parts* can have;
  - but in addition they have a *distinguished attribute:*
  - **attr_Intent** – expressed as a set of intents
  - by the *humans* who constructed them according to some *purpose*.
  - This more-or-less "standard" *property of intents*
  - determines a form of *counterpart* to the *gravitational pull* of *physical parts*
  - namely, what we shall refer to as *intentional "pull"*.
- Also these were subsumed in [1] –
  - by either partially endowing *physical parts* with such properties,
  - or by *ignoring* them!

- We thus suggest a **philosophy basis** for **domain science & engineering**.
- This paper is based on recent research [4, 1, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14] into methods for analysing and describing human-centered universes of discourses such as
  - transport nets, container lines, pipelines, drones, urban planning, etc.
  - The present lectures are motivated by speculations about possible "interfaces" between domain analysis & description methods and the reality they model.
  - The paper is otherwise based on the philosophy of Kai Sørlander [15, 16, 17, 18]

- In the first part of the lectures we present two calculi,
  - one for **analysing** manifest "worlds" and
  - one for **describing** those "realities".
- And we "interpret"
  - *manifest endurant entities*
  - as *behaviours* i.e., as *perdurants*.
- This interpretation is, from the point-of-view of post-Kantian philosophy,
  - a **transcendental deduction**,
  - i.e. cannot be logically explained,
  - but can be understood meta-physically.
- In a more-or-less summary section we shall then show
  - that the calculi are necessary and sufficient,
  - in that they have a basis in philosophical reasoning.

- But, what is to us more interesting,
  - we show how the Sørlander Philosophy "kicks back"
  - and either mandates or requires domain properties
  - not covered in my earlier papers on the
  - domain analysis & description method [4, 1].

Initial versions of this document are in the form of a report.

- As such it collects far more material than should be contained in a proper paper.
- Most of the "extra" report material is collected from various sources but drastically edited by me.
- Most of the material of Sect. **9** is extracted
  - from [18]
  - some from [15, 19, 20, 21].

1 Introduction

Definition 1 Domain: *By a* **domain** *we shall understand*

- *a* **rationally describable** *segment of*
- *a* **human assisted** *reality, i.e., of the world,*
  - *its* **physical parts**,
  - *and* **living species**.
- *These are*
  - **endurants** *("still"), existing in space,*
  - *as well as* **perdurants** *("alive"), existing also in time.*

- *Emphasis is placed on* **"human-assistedness"**,
  - *that is, that there is* at least one (man-made) **artifact**
  - *and that* **humans** *are a primary cause for*
    - *change of endurant* **states**
    - *as well as perdurant* **behaviours** ■

- The *science and engineering of domain analysis & description*
  - is *different* from the science of physics and the core of its derived engineerings:
    - building (civil),
    - mechanical,
    - electronics,
    - chemical,
    - electrical,
    - et cetera.
  - All of these engineerings emerged out of *the natural sciences*.
    - These classical engineering disciplines have increasingly included many facets of *man-machine interface* concerns,
    - but their core is still in the *the natural sciences*.
- We assume that the listeners are familiar with the above notions.

- The core of *domain science & engineering*
  - such as we shall pursue it, is in two disciplines:
    - *mathematics*, notably
      - *mathematical logic* and
      - *abstract algebra*,

      and
    - *philosophy*, notably
      - *meta physics* and
      - *epistemology*.
- We assume that the listeners are familiar with the above-mentioned notions of mathematics.

Definition 2 Metaphysics:

- *By* metaphysics *we shall understand*
  - *a branch of* philosophy *that explores fundamental questions, including the nature of concepts like*
  - being*,* existence*, and* reality*.*
- *Traditional metaphysics seeks to answer,*
  - *in a "suitably abstract and fully general manner",*
  - *the questions:*
    - *What is there ? and*
    - *And what is it like ?*[1] ■

[1] https://en.wikipedia.org/wiki/Metaphysics

- Topics of metaphysical investigation include
  - existence,
  - objects and their properties,
  - space and time,
  - cause and effect, and
  - possibility.

Definition 3 Epistemology:

- *By* epistemology
  - *[from epistēmē, 'knowledge', and logos, 'logical discourse']*
  - *is the branch of philosophy concerned with*
  - *the theory of knowledge* ■[2]
- The philosophy aspect of our study is primarily epistemological,
- i.e., not metaphysical.

[2] https://en.wikipedia.org/wiki/Epistemology

- Epistemology studies the nature of
  - knowledge, justification, and the rationality of belief.
  - Much of the debate in epistemology centers on four areas:
    - (1) the philosophical analysis of the nature of knowledge and how it relates to such concepts as truth, belief, and justification,
    - (2) various problems of skepticism,
    - (3) the sources and scope of knowledge and justified belief, and
    - (4) the criteria for knowledge and justification.[3]
  - A central branch of epistemology is ***ontology***,
    - the investigation into
    - the basic categories of being
    - and how they relate to one another.[4]

[3] https://en.wikipedia.org/wiki/Epistemology
[4] https://en.wikipedia.org/wiki/Metaphysics

- Observe the distinction in the definitions of metaphysics and epistemology between
  - [metaphysics] *"explores fundamental questions, including the nature of concepts like being, existence, and reality"* and
  - [epistemology] *"the philosophical analysis of the nature of knowledge and how it relates to such concepts as truth, belief, and justification, etc."*.

- Epistemology addresses such questions as
  - *What makes justified beliefs justified ?*";
  - *"What does it mean to say that we know something ?"* and, fundamentally,
  - *"How do we know that we know ?"*[5]

[5] https://en.wikipedia.org/wiki/Epistemology

1.1 Two Views of Domains

- There are two aspects to this talk:
  - (i) the analysis & description of fragments of the context in which software, to be developed, is to serve,
  - (ii) and the general, basically philosophical, problem of the absolutely necessary conditions for describing the world.

1.1.1 The Computing Science View

- In twelve papers we have put forward a method for analysing and describing the domains for which software is developed:
  - [4, 1] Manifest Domains: Analysis & Description **FAoC, March 2017**
  - [5, 6] Domain Facets: Analysis & Description
  - [7, 8] Formal Models of Processes and Prompts
  - [9, 10] To Every Manifest Mereology a CSP Expression **LAMP, Jan. 2018**
  - [11, 12] From Domain Descriptions to Requirements Prescriptions
  - [13, 14] Domains: Their Simulation, Monitoring and Control

- These methods involve new principles, techniques and tools – the *calculi*.
- The calculi has been applied in around 20+ experimental researches to as diverse domains as
  - railways,
  - IT security,
  - container lines,
  - “the market”,
  - pipelines,
  - road transport systems,
  - stock exchanges,
  - credit card systems,
  - swarms of drones,
  - documents and
  - urban planning.
- The calculi, we claim, has withstood some severe “tests”.
- The experiments are referenced in Sect. **13.1** [Slide 451].

1.1.2 The Philosophy View

- In four books the Danish philosopher Kai Sørlander has investigated the philosophical issues alluded to above.
  - [15] Kai Sørlander . *Det Uomgængelige – Filosofiske Deduktioner [The Inevitable – Philosophical Deductions] Forord/Foreword: Georg Henrik von Wright.* Munksgaard · Rosinante, 1994. 168 pages.
  - [16] Kai Sørlander . *Under Evighedens Synsvinkel [Under the viewpoint of eternity].* Munksgaard · Rosinante, 1997. 200 pages.
  - [17] Kai Sørlander . *Den Endegyldige Sandhed [The Final Truth].* Rosinante, 2002. 187 pages.
  - [18] Kai Sørlander . *Indføring i Filosofien [Introduction to The Philosophy].* Informations Forlag, 2016. 233 pages.

- A main contribution of Sørlander is, on the philosophical basis of the *possibility of truth* (in contrast to Kant's *possibility of self-awareness*)
  - to *rationally* and *transcendentally deduce*
  - **the absolutely necessary conditions for describing any world**.
- These conditions presume a *principle of contradiction*
- and lead to the *ability*
  - to *reason* using *logical connectives* and
  - to *handle asymmetry, symmetry* and *transitivity*.
  - *Transcendental deductions* then lead to
  - *space* and *time*,
  - not as priory assumptions, as with Kant,
  - but derived facts of any the world.

- From this basis Sørlander then, by further transcendental deductions arrive at
  - kinematics,
  - dynamics and
  - the bases for Newton's Laws.
- And so forth.
- We build on Sørlander's basis to argue
  - that the domain analysis & description calculi are necessary and sufficient and
  - that a number of relations between domain entities
  - can be understood transcendentally and
  - as "variants" of Newton's Laws!

1.1.3 First Two Independent Treatments, then An Interpretation

- First we present the two views independent of one-another.
  - In Segment **I**
    - we present the *domain analysis & description method:* its *principles, techniques* and *tools*, Sects. **2**–**5**,
    - and a *substantial example*, Sect. **6**, to *support understanding* the *domain analysis & description method*.

- In Segment **III** we present
  - in Sect. **8** a brief motivation of the task of philosophy;
  - in Sect. **9** an extensive review is presented of metaphysical and epistemological issues in philosophy, from the ancient Greeks up til the mid 1900's;
  - in Sect. **10** an extensive review is then given of Sørlander's Philosophy.

- Then, in Segment **IV**'s Sect. **11**, we bring the two studies —
  - the *domain analysis & description calculi* and
  - the *Kai Sørlander Philosophy* —

  together:
  - It is here that, as a consequence of Sørlander's Philosophy,
  - we modify the domain analysis & description method, of Segment **I**, in suggesting extensions.

The Main Contribution

- With Segment **IV** the *the main contribution* is achieved:
  - (i) establishing *a basis* for *domain science & engineering* in *philosophy*; and
  - (ii) the *specific modifications* required by and the *founding* of the domain analysis & description calculi in *philosophy*.

- In Segment **II**, in-between Segments **I** and **III**, we present
  - in Sect. **7**, a short review of *space* and *time*.

1.2 The Computing Science Background

1.2.1 Computer & Computing Science

- By **computer science** I understand the study and knowledge of the "things" that can "exist inside" computing devices (i.e., data and computations) – and the study and knowledge of these computing devices.
- By **computing science** I understand the study and knowledge of how to construct "those things", i.e., **programming methodology**.

I consider myself a computing scientist primarily interested in programming methodology.

1.2.2 Formal Methods

- By a **method** I understand a set of **principles** for **selecting** and **applying** a set of **techniques** and **tools** for the **construction** of an artifact, as here, software.
- By a **formal method** I understand I understand a method whose principles, techniques and tools can be understood in a mathematical framework – for example where, among the tools, the **specification languages** can be given a **mathemtical syntax**, a **mathematical semantics** and a **mathematical proof system**.

I consider myself to have primarily contributed to the area of formal methods, as exemplified by `VDM` and `RAISE`.

1.2.3 A Triptych of Engineering

- Before software can be designed we must be familiar with its requirements.
- Before requirements can be prescribed we must be familiar with the context of the software to be developed, that is, the domain.

- Hence the triptych of software development:
  - first (ideally) the domain engineering of an appropriate domain description;
  - then (ideally) the requirements engineering of the requirements prescription – formally related to the domain description;
  - finally the software design "derived" from the requirements prescription and (ideally) formally reasoned to meet customers' expectations, that is, to satisfy the domain description and be correct wrt. the requirements prescription.

- My contributions in the last many years has been to establish a proper domain science & engineering.
- My main focus, since 1977, has been on the development of "large" software:
  - compilers (like for `CHILL` and `Ada`), and
  - infrastructure software –
    - for pipelines,
    - health care,
    - road traffic,
    - railways,
    - banking,
    - etc.

1.3 Domains, their Analysis & Description, and a Method

- In Definition 1 [Slide 10] we gave a rough characterisation of what we man by domain.
- In this section we shall brief outline
  - what we mean by **domain analysis & description**, and
  - what we mean by a **method for analysing & describing domains**.

1.3.1 Domain Analysis & Description

Definition 4: **Domain Analysis and Description:** By **domain analysis and description** we shall understand

- the analysis & description
- of domains ■

1.3.2 A Domain Analysis & Description Method

Definition 5: **A Domain Analysis and Description Method:** By a **domain analysis and description method** we shall understand

- a set of principles, techniques and tools
- for the construction,
- i.e., analysis & description
- of a domain model ■

- The terms *description* and *model* are here considered synonymous.

Segment I: The Domain Analysis & Description Calculi

2 Endurants

- In a series of *definitions*,
  - most of which are rather like *characterisations*[6],
  - we shall *explicate* a number of domain concepts.
- These definitions will lead to the introduction of
  - first *domain analysis prompts*,
  - then also *domain description prompts*.

[6] Usually, in computer science papers, definitions are terse and based on more-or-less implicit reference to a mathematically precise model. Since domains do not have an a-priori mathematically precise model our definitions cannot be precise. Most of the definitions are taken from such dictionaries as [22, *The Oxford Shorter English Dictionary*] and from the Internet based [23, *The Stanford Encyclopedia of Philosophy*].

- Think of a **prompt** as a *cue*, a *hint*, a *suggestion*,
  - in German, a *stichwort, suchbegriff*,
  - in French, a *signal théâtre*,
  - that the domain analyser is told,
  - by the principles of the domain analysis & description method,
  - to act upon.

2.1 The Universe of Discourse

Analysis Prompt 1 *is_universe_of_discourse:*

- *By a* universe of discourse *for domain science & engineering*
  - *we shall mean a human-centered area of concern,*
  - *one that involves, as "main players":*
    - *endurants and*
    - *perdurants*
  - *such that at least*
    - *one of the endurants is man-made and*
    - *and either represents a human or*
    - *at least another one is a human* ■

Example 1 Man-made Automobiles and Drivers:

- In the large example of Sect. **6**
  - automobiles and road nets are endurants,
  - and automobiles "subsume" their human drivers ■

Domain Description Prompt 1
observe_universe_of_discourse:

- *The domain-of-interest needs first be briefly narrated.*
  - *Just a simple story.*
  - *One that emphasises the "main players":*
    - *the endurants and*
    - *the perdurants*
  - *such that at least*
    - *one of the endurants is man-made and*
    - *and either represents a human or*
    - *at least another one is a human* ■

2.2 Basic Domain Concepts

Definition 6 Entity:

- *By an* **entity** *we shall understand a* **phenomenon**, *i.e., something*
  - *that can be* observed, *i.e., be*
    - *seen or touched by humans,*
    - or *that can be* conceived
    - *as an* abstraction *of an entity;*
  - *alternatively,*
    - *a phenomenon is an entity,* if it exists, it is **"being"**,
    - it is that which makes a "thing" what it is: essence, essential nature ■

Example 2 Entities and Non-entities:

- The following are entities:
  - a stone, say, laying on the ground – which is an entity;
  - a pencil, say, that I, a humen entity, hold in my hand;
  - a rhododendron, in my garden – which is an entity.
- The following are not entities:
  - the blue sky of my imagination;
  - a fleeting moment of sadness;
  - being drunk ■

Analysis Prompt 2 *is_entity:*

- *The domain analyser analyses "things" (θ) into either entities or non-entities.*
- *The method can thus be said to provide the* **domain analysis prompt***:*
  - ***is_entity*** *– where* **is_entity(θ)** *holds if θ is an entity* ■[7]

[7] Analysis prompt definitions and description prompt definitions and schemes are delimited by ■.

Definition 7 Endurant*:*

- *By an* **endurant** *we shall understand an entity*
  - *that can be observed or conceived and described as a "complete thing" at no matter which given snapshot of time;*
  - *alternatively an entity is endurant if it is capable of* **enduring***, that is* **persist***, "***hold out***".*

Were we to "freeze" time

- *we would still be able to observe the full endurant* ■

Example 3 Endurants:

- The following are examples of endurants:
  - the lake of a landscape
    such as a tourist (i.e., an amimal entity) photographs it;
  - the engine train of an automobile
    such as an automobile mechanic (a human entity) repairs it; and
  - the horse
    such as a jockey (a human entity) prepares it for a race ■

Analysis Prompt 3 *is_endurant:*

- *The domain analyser analyses an entity, e, into an endurant as prompted by the* **domain analysis prompt***:*
  - *is_endurant – ϕ is an endurant if* **is_endurant**(*e*) *holds.*
- **is_entity** *is a prerequisite prompt for* **is_endurant** ■

Definition 8 **Perdurant***:*

- *By a* **perdurant** *we shall understand an entity*
  - *for which only a fragment exists if we look at or touch them at any given snapshot in time, that is,*
  - *were we to freeze time we would only see or touch a fragment of the perdurant,*
  - *alternatively*
    - *an entity is perdurant*
    - *if it endures continuously, over time, persists, lasting* ■

Example 4 **Perdurants**:

- The following are examples of perdurants:
  - the flow of water in a river;
  - the human life, from birth to death;
  - the car driving down a road ■

Analysis Prompt 4 *is_perdurant:*

- *The domain analyser analyses an entity e into perdurants as prompted by the* **domain analysis prompt***:*
  - *is_perdurant – e is a perdurant if* **is_perdurant**(*e*) *holds.*
- **is_entity** *is a prerequisite prompt for* **is_perdurant** ■

Definition 9 Discrete Endurant:

- *By a* **discrete endurant** *we shall understand an endurant which is*
  - *separate,*
  - *individual or*
  - *distinct*

  in form or concept ■

Example 5 Discrete Endurants:

- The following are examples of discrete endurants:
  - planets in space;
  - automobiles (in a car sales office); and
  - students at a lecture in a college classroom.

Analysis Prompt 5 `is_discrete`:

- *The domain analyser analyses endurants e into discrete entities as prompted by the* **domain analysis prompt***:*
  - `is_discrete` – *e is discrete if* `is_discrete(e)` *holds* ■

Definition 10 Continuous Endurant:

- *By a* **continuous endurant** *we shall understand an endurant which is*
  - *prolonged, without interruption,*
  - *in an unbroken series or pattern* ■

Example 6 Continuous Endurants:

- The following are examples of continuous endurants:
  - springs, brooks, rivers and lakes of a landscape; and
  - gas in a pipeline.

Analysis Prompt 6 *is_continuous:*

- *The domain analyser analyses endurants e into continuous entities as prompted by the* **domain analysis prompt***:*
  - *is_continuous – e is continuous if* is_continuous*(e) holds* ■

- Continuity shall here not be understood in the sense of mathematics.
  - Our definition of 'continuity' focused on
    - *prolonged,*
    - *without interruption,*
    - *in an unbroken series or*
    - *pattern.*
  - In that sense
    materials (water, oil, sand, gravel, ...)
    shall be seen as 'continuous',

2.3 An Upper Ontology Diagram of Domains – A Preview

- Figure 1 [facing slide] shows a so-called upper ontology for manifest domains.
  - So far we have covered only a fraction of this ontology, as noted.
  - By ontologies we shall here understand
  - *formal representations*
    of a set of concepts within a domain
    and the relationships between those concepts.

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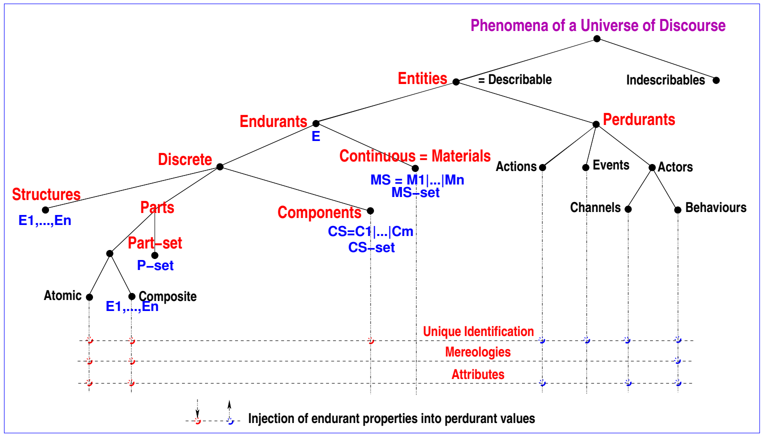


Figure 1: An Upper Ontology for Domains

2.4 Structures

Definition 11 Structure: *By a* **structure** *we shall understand*

- *a discrete endurant*
- *which the domain engineer chooses*
- *to describe as itself consisting of structures, parts, components and materials*
- *but to* **not** *endow itself with* **internal qualities***:*
  - *unique identifiers,*
  - *mereology or*
  - *attributes* ■

We shall soon define the terms
parts, components and materials, as well as
unique identification, mereology and attributes.

- Structures are introduced in
  the domain analysis & description method for pragmatic reasons.
  - When modelling an endurant as a structure
    - we are disragarding that the endurant
      may have a physically "separate" form,
    - treating that endurant as a concept
      rather than someting manifest.
  - Endurants "first" modelled as structures
    - may, subsequently, or also,
    - be modelled as (usually composite) parts
      (see below).

Analysis Prompt 7 *`is_structure:`*

- *The domain analyser analyse endurants, e, into structure entities as prompted by the* **domain analysis prompt***:*
  - `is_structure` ■

- Structures are thus composite endurants which consist of other endurants:
  - discrete as well as continuous, i.e.,
  - structures, [physical] parts[, living species] and components,
  - as well as materials.
- Parts, components and material will soon be defined.
- The [...] bracketed concepts will not be defined till late in these lectures.

2.5 Parts, Components and Materials

2.5.1 Parts

Characterisation 1 Parts:

- *Parts are manifest in the sense that*
  - *we can see them, touch them:*
    - *we can uniquely identify them (unique identification);*
    - *relate them to other parts (mereology); and*
    - *"measure" some of their characteristics (attributes);*
- Parts are going to be the "work horse" of domain descriptions.
  - Our primary focus will be on man-made parts (artifacts).
  - We leave it to physics (i.e., physicists) to model natural parts.

Definition 12 Part:

- *By a* **part** *we shall understand*
  - *a discrete endurant*
  - *which the domain engineer chooses*
  - *to endow with all three* **internal qualities**:
    - *unique identification,*
    - *mereology, and*
    - *one or more attributes* ■

Example 7 Examples of Parts:

- Examples of natural parts are:
  - a raw diamond (as found in the ground);
  - the *Rock of Gibraltar*[8];
  - *The Equator*[9].
- Examples of man-made parts, that is, artifacts are:
  - an armchair;
  - the *Empire State Building*; and
  - a canal lock.

[8]Later, when having introduced continuous endurants, i.e., materials, one may claim that the physical aspects of the enclave of *Gibraltar* could also be modelled as a material.

[9]One may claim that *The Equator* is a non-physical concept. To this one may counter-claim that *The Equator* is physically delineable: can be "marked down"!

Analysis Prompt 8 *is_part:*

- *The domain analyser analyse endurants, e, into part entities as prompted by the* **domain analysis prompt***:*
  - *is_part* ■

Definition 13 **Atomic Part***:*

- **Atomic part***s are those which,*
  - *in a given context,*
  - *are deemed to not consist of meaningful, separately observable proper sub-parts.*
- *A* **sub-part** *is a part* ■

Example 8 **Atomic Parts**:

- These are examples of atomic (man-made) parts:
  - a bolt, a screw, a nail;
  - an automobile as bought by the owner; and
  - a pipe, valve, pump, fork, and join of a pipeline.

Analysis Prompt 9 *is_atomic:*

- *The domain analyser analyses a discrete endurant, i.e., a part p into an atomic endurant:*
  - *is_atomic: p is an atomic endurant if* `is_atomic(p)` *holds* ■

Definition 14 Composite Part*:*

- ***Composite parts** are those which,*
  - *in a given context,*
  - *are deemed to indeed consist of meaningful, separately observable proper sub-parts* ■

Example 9 Composite Parts:

- These are examples of composite (man-made) parts:
  - a nut (bolt) and screw assembly;
  - an automobile
    as put together or serviced by a factory, resp. a mechanic; and
  - a pipeline (consisting of pipes, valves, pumps, forks, joins etc.).

Analysis Prompt 10 *`is_composite`:*

- *The domain analyser analyses a discrete endurant, i.e., a part p into a composite endurant:*
  - *`is_composite`: p is a composite endurant if `is_composite(p)` holds* ■

Analysis Prompt 11 *`observe_endurants`:*

- *The **domain analysis prompt**:*
  - *`observe_endurants`*
- *directs the domain analyser to observe the sub-endurants of an endurant e and to suggest their sorts.*
- *Let, schematically, `observe_endurants`(e) be* $\{e_1{:}E_1, e_2{:}E_2, \ldots, e_m{:}E_m\}$ ■

Domain Description Prompt 2 *observe_endurant_sorts*:

- *If is_composite(p) holds, then the analyser "applies" the* **domain description prompt**
  - *observe_endurant_sorts(p)*

  resulting in the analyser writing down the endurant sorts and endurant sort observers *domain description text according to the following schema:*

2. observe_endurant_sorts schema

Narration:

[s] ... narrative text on sorts ...
[o] ... narrative text on sort observers ...
[η] ... narrative text on sort type observers ...
[i] ... narrative text on sort recognisers ...
[p] ... narrative text on proof obligations ...

Formalisation:

type
[s] P,
[s] E_i i:[1..m] **comment:** E_i i:[1..m] abbreviates E_1, E_2, ..., E_m
value
[o] **obs_endurant_sorts**_E_i: P → E_i i:[1..m]
[η] **if** is_part(e_i): η(e_i) ≡ ≪ E_i ≫ i:[1..m]
[i] **is**_E_i: $(E_1|E_2|...|E_m) \rightarrow$ **Bool** i[1..m]

proof obligation [Disjointness of endurant sorts]
[p] $\mathcal{PO}: \forall\, e$:($E_1$|$E_2$|...|$E_m$) •
[p] $\bigwedge$ {**is**_E_i(e) ≡ $\bigwedge$ {∼**is**_E_j(p) | j:[1..m] \ {i}} | i:[1..m]}

Example 10 Observe Transport System Endurants: We refer to

- example Sect. **6.2.1** [Slide 169]
  annotation and formalisation Items 8–10; and to
- example Sect. **6.2.2** [Slide 170]
  annotation and formalisation Items 11–12a. ■

- Some composite parts can suitably be modelled as sets of parts of the same sort.

Analysis Prompt 12 *has_concrete_type:*

- *The domain analyser*
  - *may decide that it is expedient, i.e., pragmatically sound,*
  - *to render a part sort,* P*, whether atomic or composite, as a concrete type,* T*.*
  - *That decision is prompted by the holding of the* **domain analysis prompt***:*
    - *has_concrete_type(p).*
  - *is_discrete is a* **prerequisite prompt***has_concrete_type of has_concrete_type* ■

Domain Description Prompt 3 *observe_part_type*:

- *The domain analyser applies the* **domain description prompt***:*
  - *observe_part_type(p)*[10]
- *to parts p:P which then yield the* part type and part type observers *domain description text according to the following schema:*

[10] has_concrete_type is a *prerequisite prompt* of observe_part_type.

3. observe_part_type schema

Narration:

[t_1] ... narrative text on sorts and types S_i ...
[t_2] ... narrative text on types T ...
[t_3] ... narrative text on type of value observer
[o] ... narrative text on type observers ...

Formalisation:

type
[t_1] $S_1, S_2, ..., S_m, ..., S_n,$
[t_2] $T = \mathcal{E}(S_1,S_2,...,S_n)$
[t_3] $\eta(s_i) \equiv \lll S \ggg$, i:[1..n],s_i:S_i
value
[o] **obs_part**_T: P → T ■

2.5.2 Components

- Some discrete composite endurants can suitably be modelled
  - as sets of parts of possibly different sorts
  - but for which there is no need to model their mereology,
  - that is, how the parts in the set relate to one another.

Definition 15 Component*:*

- *By a* **component** *we shall understand*
  - *a discrete endurant*
  - *which we, the domain analyser cum describer chooses*
  - *to* **not** *endow with* **mereology** ■

- Parts may or may not contain, i.e., "have", components.

Example 11 Components of Parts:

- a part, like a mail-box, may contain letters, newspapers, small packages, advertisement brochures, etc.;
- a part, like a household shop shelf, may contain bread toasters, blenders, coffee grinders, coffee machines, etc.; and
- a part, like a book case, may contain books, journals, bric-à-brac, etc. ■

Analysis Prompt 13 *has_components:*

- *The domain analyser inquire endurants e as to whether they have, i.e., contain, components, as prompted by the* **domain analysis prompt***:*
  - *has_components* ■

Analysis Prompt 14 *is_component:*

- *The domain analyser analyse endurants e into component entities as prompted by the* **domain analysis prompt***:*
  - *is_component* ■

Domain Description Prompt 4 *observe_component_sorts***:**

- *The* **domain description prompt***:*
  - *observe_component_sorts_P(p)*
  - *yields the* component sorts and component sort observer *domain description text according to the following schema –*
  - *whether or not the actual part p contains any components:*

4. observe_component_sorts_P schema

Narration:
[s] ... narrative text on component sorts ...
[o] ... narrative text on component observers ...
[i] ... narrative text on component sort recognisers ...
[u] ... narrative text on unique identifier ...
[p] ... narrative text on component sort proof obligations ...

Formalisation:
type
[s] K1, K2, ..., Kn
[s] K = K1| K2 | ... | Kn
[s] KS = K-**set**
value
[o] **obs_components**_P: P → KS
[i] **is**_K_i: $(K_1|K_2|...|K_n) \to$ **Bool** i:[1..n]
[u] **uid**_K_i

Proof Obligation: [Disjointness of Component Sorts]
[p] $\mathcal{PO}$: $\forall\ k_i$:$(K_1|K_2|...|K_n)$ •
[p] $\bigwedge$ {**is**_$K_i(k_i) \equiv \bigwedge\{\sim$**is**_$K_j(k_j)$|j:[1..n] \ {i}}} i:[1..n] ■

Example 12 Observe Transport System Component Sorts: We refer to

- example Sect. **6.2.4** [Slide 174]
- annotation and formalisation
- Items 16–17 ■

2.5.3 Materials

Definition 16 Material:

- *By a* **material** *we shall understand a continuous endurant* ■

- Parts may or may not contain, i.e., "have", materials.

  Example 13 Materials of Parts:

  - a part, like a pipe-line pipe, may contain oil;
  - a part, like a timber yard, may contain boards, lumber, etc., of different sizes and qualities; and
  - a part, like a building materials shop, may contain concrete, sand, gravel, bricks, etc., in different bags, containers and sizes ■

Example 14 Observe Transport Component Sorts: We refer to

- example Sect. **6.2.4** [Slide 174]
- annotation and formalisation
- Items 16–17 ■

Analysis Prompt 15 *has_materials:*

- *The domain analyser inquire endurants e as to whether they have, i.e., contains, material, as prompted by the* **domain analysis prompt***:*

  ◈ *has_materials* ■

Analysis Prompt 16 *is_material:*

- *The domain analyser analyse endurants e into material entities as prompted by the* **domain analysis prompt***:*

  ◈ *is_material* ■

Domain Description Prompt 5 *observe_material_sorts_P*:

- *The* **domain description prompt***:*

  ◈ *observe_material_sorts_P(e)*

  yields the material sorts and material sort observers' domain description text according to the following schema whether or not part p actually contains materials:

5. observe_material_sorts_P schema

Narration:

[s] ... narrative text on material sorts ...
[o] ... narrative text on material sort observers ...
[i] ... narrative text on material sort recognisers ...
[p] ... narrative text on material sort proof obligations ...

Formalisation:

type
[s] M1, M2, ..., Mn
[s] M = M1 | M2 | ... | Mn
[s] MS = M-**set**
[a] Ai = A11 | A12 | ... | A1n
value
[o] **obs_mat_sort**_M_i: P → M, [i:1..n]
[o] **obs_materials**_P: P → MS
[i] **is**_M_i: M → **Bool** [i:1..n]
[a] **attr**_A_{i_j}: M_i → A_{i_j} [i:...,j:...]
proof obligation [Disjointness of Material Sorts]
[p] $\mathcal{PO}$: ... ■

Example 15 **Observe Transport System Materials**: We refer to

- example Sect. **6.2.5** [Slide 176]
- annotation and formalisation
- Items 18–19 ■

2.6 Unique Part and Component Identifiers

- We introduce a notion of unique identification of parts and components.
- We assume
  - (i) that all parts and components, p, of any domain P, have *unique identifiers*,
  - (ii) that *unique identifiers* (of parts and components p:P) are *abstract values* (of the *unique identifier* sort PI of parts p:P),
  - (iii) such that distinct part or component sorts, P_i and P_j, have distinctly named *unique identifier* sorts, say PI_i and PI_j,
  - (iv) that all π_i:PI_i and π_j:PI_j are distinct, and
  - (v) that the observer function **uid**_P applied to p yields the unique identifier, say π:PI, of p.

Analysis Prompt 17 *type_name*:

- *The description language function* **type_name**
  - *applies to unique identifiers,* p_{ui}:P_{UI}*, and*
  - *yield the name of the type, P, of the parts*
  - *having unique identifiers of type* P_{UI}*:*
  - *type_name – where* type_name(p_{ui}) *yields P* ■

Representation of Unique Identifiers:

- Unique identifiers are abstractions.
  - When we endow two parts (say of the same sort) with distinct unique identifiers
  - then we are simply saying that these two parts are distinct.
  - We are not assuming anything about how these identifiers otherwise come about.

Domain Description Prompt 6 *observe_unique_identifier*:

- *We can therefore apply the* **domain description prompt***:*
  - *observe_unique_identifier*
- *to parts p:P*
  - *resulting in the analyser writing down*
  - *the* ***unique identifier type and observer*** *domain description text according to the following schema:*

6. observe_unique_identifier schema

Narration:

[s] ... narrative text on unique identifier sort PI ...
[u] ... narrative text on unique identifier observer **uid**_P ...
[η] ... narrative text on type name, an RSL$^+$Text observer ...
[a] ... axiom on uniqueness of unique identifiers ...

Formalisation:

type
[s] PI
value
[u] **uid**_P: P → PI
[u] η PI → ≪ P ≫
axiom [Disjointness of Domain Identifier Types]
[a] $\mathcal{A}$: $\mathcal{U}$(PI,PI_i,PI_j,...,PI_k) ■

Example 16 Observe Transport System Identifiers: We refer to

- example Sect. 6.2.7 [Slide 179]
- annotation and formalisation
- Items 26–28d. ■

2.7 Part Mereologies

- Mereology is the study and knowledge of parts and part relations.
  - Mereology, as a logical/philosophical discipline,
    can perhaps best be attributed to the
    Polish mathematician/logician
    Stanisław Leśniewski [24, 25].

2.7.1 Part Relations

- Which are the relations that can be relevant for part-hood ?
- We give some examples.
  - (i) Two otherwise distinct parts may *"share"* values.
    - By *'sharing'* values we shall, as a generic example, mean that two parts of different sorts has the same attributes
    - but that one *'defines'* the attribute, like, for example *'programming'* its values, cf. df.27 pp.123,
    - whereas the other *'uses'* these values, like, for example considering them *'inert'*, cf. df.22 pp121.
  - (ii) Two otherwise distinct parts may be said to, for example, be topologically "adjacent" or one "embedded" within the other.

- These examples are in no way indicative
  of the "space" of part relations that may be relevant for part-hood.
- The domain analyser is expected to do a bit of experimental
  research
  in order to discover
  necessary, sufficient and pleasing "mereology-hoods" !

2.7.2 Part Mereology: Types and Functions

Analysis Prompt 18 *has_mereology:*

- *To discover necessary, sufficient and pleasing "mereology-hoods" the analyser can be said to endow a truth value,* **true**, *to the* **domain analysis prompt***:*
  - *has_mereology*
- When the domain analyser decides that
  - some parts are related in a specifically enunciated mereology,
  - the analyser has to decide on suitable
    - *mereology types* and
    - *mereology observers* (i.e., part relations).

Domain Description Prompt 7 *observe_mereology***:**

- *If* has_mereology*(p) holds for parts p of type P,*
  - *then the analyser can apply the* **domain description prompt***:*
    - *observe_mereology*
  - *to parts of that type*
  - *and write down the* mereology types and observer *domain description text according to the following schema:*

7. observe_mereology schema

Narration:
[t] ... narrative text on mereology type ...
[m] ... narrative text on mereology observer ...
[a] ... narrative text on mereology type constraints ...
Formalisation:
type
[t] MT[11]
value
[m] **obs_mereo**_P: P → MT
axiom [Well−formedness of Domain Mereologies]
[a] $\mathcal{A}$: $\mathcal{A}$(MT)

Example 17 Observe Transport System Mereology: We refer to

- example Sect. **6.2.9** [Slide 185]
- annotation and formalisation
- Items 40–43 ■

2.8 Part Attributes

- To recall: there are three sets of **internal qualities**:
  - unique part identifiers,
  - part mereology and
  - attributes.
- Unique part identifiers and part mereology are rather definite kinds of internal endurant qualities.
- Part attributes form more "free-wheeling" sets of **internal qualities**.

Example 18 Example Part Attributes:

- These are examples of part attributes:
  - the carat of a diamond;
  - the number of residents of Gibraltar;
  - the medium diameter and length of the equator; and
  - the length and location[12] of a street segment (i.e., a link).

[12] Note that we do not presently describe what a location is.

2.8.1 Inseparability of Attributes from Parts and Materials

- Parts and materials are
  - typically recognised because of their spatial form
  - and are otherwise characterised by their intangible, but measurable attributes.
- We equate all endurants which, besides possible type of unique identifiers (i.e., excepting materials) and possible type of mereologies (i.e.,, excepting components and materials), have the same types of attributes, with one sort.
- Thus removing a quality from an endurant makes no sense:
  - the endurant of that type
  - either becomes an endurant of another type
  - or ceases to exist (i.e., becomes a non-entity)!

Example 19 Inseparability of Attributes:

- Let the part be a link (i.e., street segment).
  - It must have a length a link without a length is meaningless.
  - It must have a location a link without a location is meaningless.

2.8.2 Attribute Quality and Attribute Value

- We distinguish between
  - an attribute (as a logical proposition, of a name, i.e.) type, and
  - an attribute value, as a value in some value space.

Analysis Prompt 19 *attribute_types:*

- *One can calculate the set of attribute types of parts and materials with the following* **domain analysis prompt***:*
  - *attribute_types*
- *Thus for a part p we may have* **attribute_types**$(p) = \{A_1, A_2, ..., A_m\}$.

Example 20 Example Attribute Sorts:

- Let the part be a pipeline unit such as a pipe, a pump, a valve, a fork, or a join.
  - the ***material*** "flowed" by the pipeline;
  - the ***location*** of the unit;
  - the ***diameter*** of a pipe;
  - the [dynamically changeable] ***valve position*** (`open`, `closed`, ...);
  - the current and (for guaranteeing laminar flow) maximal in- and out-flows[13] of the pipeline units;
  - et cetera.
- Notice that there are possibly very many other attributes:
  - we may model some of these;
  - others we may choose to ignore.

[13] Note that we do not presently describe the units in which flow are measured.

2.8.3 Part and Material Attributes: Types and Functions

- Let us recall that attributes cover qualities other than unique identifiers and mereology.
- Let us then consider that parts and materials have one or more attributes.
  - These attributes are qualities
  - which help characterise "what it means" to be a part or a material.
- Note that we expect every part and material to have at least one attribute.
- The question is now, in general, how many and, particularly, which.

Domain Description Prompt 8 *observe_attributes***:**

- *The domain analyser experiments, thinks and reflects about part attributes.*
- *That process is initiated by the* **domain description prompt***:*
  - ***observe_attributes***.
- *The result of that* **domain description prompt** *is that the domain analyser cum describer writes down the* attribute (sorts or) types and observers *domain description text according to the following schema:*

8. `observe_attributes` **schema**

Narration:

[t] ... narrative text on attribute sorts ...
[o] ... narrative text on attribute sort observers ...
[v] ... narrative text on set **of** attribute **value** observers ...
[i] ... narrative text on attribute sort recognisers ...
[p] ... narrative text on attribute sort proof obligations ...

Formalisation:

type
[t] A_i [$1 \leq i \leq n$]
value
[o] **attr**_A_i:P→A_i i:[1..n]
[v] **obs_attrib_values**_P(p) ≡ { **attr**_A_1(p),**attr**_A_2(p),...,**attr**_A_n(p) }
[i] **is**_A_i:(A_1|A_2|...|A_n)→**Bool** i:[1..n]
proof obligation [Disjointness of Attribute Types]
[p] $\mathcal{PO}$: **let** P be any part sort **in** [the domain description]
[p] **let** a:(A_1|A_2|...|A_n) **in** **is**_A_i(a) ≠ **is**_A_j(a) **end end** [i≠i, i,j:[1..n]]

Example 21 Road Transport System Attribute Observers:

- We refer to example Sect. 6.2.10
  - narrative and formulas
  - Items 46 [Slide 189] to 55d. [Slide 197].

2.8.4 Attribute Categories

- Michael A. Jackson [26] has suggested a hierarchy of attribute categories:
  - static or
  - dynamic values – and within the dynamic value category:
    - inert values or
    - reactive values or
    - active values – and within the dynamic active value category:
      - autonomous values or
      - biddable values or
      - programmable values.
- We now review these attribute value types.
  The review is based on [26, M.A. Jackson].

- **Part attributes** are either constant or varying, i.e., **static** or **dynamic** attributes.

Analysis Prompt 20 *is_static_attribute:*

- *By a* **static attribute**, *a:A,*
  we shall understand an attribute whose values
  - *are constants, i.e., cannot change.*

Analysis Prompt 21 *is_dynamic_attribute:*

- *By a* **dynamic attribute**, *a:A,*
  we shall understand an attribute whose values
  - *are variable, i.e., can change.*

  Dynamic attributes are either inert, reactive *or* active *attributes.*

Analysis Prompt 22 *is_inert_attribute:*

- *By an* **inert attribute**, *a:A,*
  we shall understand a dynamic attribute whose values
  - *only change as the result of external stimuli where*
  - *these stimuli prescribe new values.*

Analysis Prompt 23 *is_reactive_attribute:*

- *By a* **reactive attribute**, *a:A,*
  we shall understand dynamic attributes whose value,
  - *if they vary, change in response to external stimuli,*
  - *where these stimuli come from outside the domain of interest.*

Analysis Prompt 24 *is_active_attribute:*

- *By an* **active attribute**, *a:A,*
  we shall understand a dynamic attribute whose values
  - *change (also) of its own volition.*

  Active attributes are either autonomous, biddable *or* programmable *attributes.*

Analysis Prompt 25 *is_autonomous_attribute:*

- *By an* **is_autonomous_attribute**(a), *we shall understand a dynamic active attribute*
  - *whose values change value only "on their own volition".*[14]

[14] The values of an autonomous attributes are a "law onto themselves and their surroundings".

Analysis Prompt 26 *is_biddable_attribute:*

- *By a* **biddable attribute**, *a:A,*
  we shall understand a dynamic active attribute whose values
  - *are prescribed*
  - *but may fail to be observed as such.*

Analysis Prompt 27 *is_programmable_attribute:*

- *By a* **programmable attribute**, *a:A,*
  we shall understand a dynamic active attribute whose values
  - *can be prescribed.*

- Figure 2 captures an attribute value ontology.

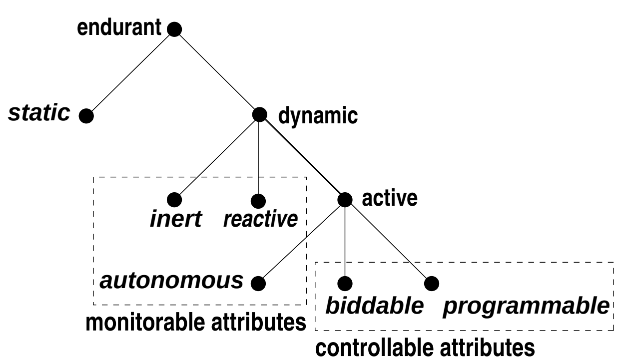


Figure 2: Attribute Value Ontology

Example 22 Road Transport System Attribute Categories:

- These are examples of attribute categories of the road transport system of Sect. **6**:
  - *static:* link and hub locations, link lengths, automobile brand names;
  - *inert:* ... TO COME ...;
  - *reactive:* ... TO COME ...;
  - *autonomous:* ... TO COME ...;
  - *biddable:* ... TO COME ...;
  - *programmable:* automobile position and automobile, link and hub histories.

1 Given a part p we can calculate its **static attributes**.

2 Given a part p we can calculate its **controllable attributes**, i.e., the biddable and programmable attributes.

3 And given a part p we can calculate its **monitorable attributes**, i.e., the inert, reactive and autonomous attributes.

4 These three sets make up all the attributes of part p.


```
value
1   stat_attr_typs: P → ≪ SA1×SA2×...×SAs ≫
2   ctrl_attr_typs: P → ≪ CA1×CA2×...×CAc ≫
3   mon_attr_typs: P → ≪ MA1×MA2×...×MAm ≫
axiom
4   ∀ p:P ·
4       let ≪ SA1×SA2×...×SAs ≫ = stat_attr_typs(p),
4           ≪ CA1×CA2×...×CAc ≫ = ctrl_attr_typs(p),
4           ≪ MA1×MA2×...×MAm ≫ = mon_attr_typs(p) in
4       card{SA1,SA2,...,SAs}+card{CA1,CA2,...,CAc}+card{MA1,MA2,...
4       = card{SA1,SA2,...,SAs,CA1,CA2,...,CAc,MA1,MA2,...,MAm} end
```


5 Given a part p we can calculate its static attribute values.

6 Given a part p we can calculate its controllable, i.e., the biddable and programmable attribute values.

```
value
5   stat_attr_vals: P → SA1×SA2×...×SAs
5   stat_attr_vals(p) ≡
5       let ≪ SA1×SA2×...×SAs ≫ = stat_attr_typs(p) in
5       (attr_SA1(p),attr_SA2(p),...,attr_SAs(p)) end

6   ctrl_attr_vals: P → CA1×CA2×...×CAc
6   ctrl_attr_vals(p) ≡
6       let ≪ CA1×CA2×...×CAc ≫ = ctrl_attr_typs(p) in
6       (attr_CA1(p),attr_CA2(p),...,attr_CAc(p)) end
```

3 A Transcendental Transformation

- It should be clear to the reader that in *domain analysis & description*
  - we are reflecting on a number of *philosophical issues*.
  - First and foremost on those of *epistemology* and *ontology*.
  - In this section on a sub-field of epistemology,
  - namely that of a number of issues of *transcendental* nature.

Definition 17 Transcendental: *By* **transcendental** *we shall understand the philosophical notion:* **the a priori or intuitive basis of knowledge, independent of experience.**

- A priori knowledge or intuition is central:
  - By *a priori* we mean that it not only precedes,
  - but also determines rational thought.

Definition 18 Transcendental Transformation: *By a* **transcendental transformation** *we shall understand the philosophical notion:* **a transcendental "conversion" of one kind of knowledge into a seemingly different kind of knowledge.**

Definition 19 Transcendentality: *By* **transcendentality** *we shall here mean the philosophical notion:* the state or condition of being transcendental.

Example 23 Transcendentality:

- We can speak of a bus in at least three *senses:*
  - (i) The bus as it is being "serviced" (maintained) at an automobile garage;
  - (ii) the bus as it "speeds" down its route; and
  - (iii) the bus as it "appears" (listed) in a bus time table.
- The three *senses* are:
  - (i) as an **endurant** (here a *part*),
  - (ii) as a **perdurant** (as we shall see a *behaviour*), and
  - (iii) as an **attribute**[15] ■

[15]– in this case rather: as a fragment of a bus time table *attribute*

- Example 23, we claim, reflects *transcendentality* as follows:
- We have knowledge of an endurant (i.e., a part) being an endurant.
- We are then to assume that the perdurant referred to in (ii) is an aspect of the endurant mentioned in (i) – where perdurants are to be assumed to represent a different kind of knowledge.
- And, finally, we are to further assume that the attribute mentioned in (iii) is somehow related to both (i) and (ii) – where at least this attribute is to be assumed to represent yet a different kind of knowledge.

4 Perdurants

- So the transcendental deduction to be performed here is that of
  - associating with each part – "existing" in space –
  - a behaviour – "existing" in time.
- Perdurants can thus be explained in terms of
  - a notion of ***state*** and
  - a notion of ***time***.
- We refer to Sect. **7.2** for a discussion of the concept of time.

- To speak about behaviours,
  - that is, to describe behaviours,
  - we choose a model for behaviours.
    - We choose that of `CSP` [27].
    - With `CSP` is associated the notions of
      - ***processes*** (which serve to model behaviours),
      - ***channels***, ch, (which serve to model communication between behaviours), and
      - ***output/input*** clauses:
      - ch ! v, respectively ch ?
      - which serves to express the offering of a value, v on channel ch,
      - respectively the offering to accept such a value.
  - We shall use these notions freely.

4.1 States

Definition 20 State: *By a* **state** *we shall understand*

- *any collection of* **parts**
- *or* **components**
- *or* **materials** ■

4.2 On Actions, Events, Behaviours and Actors

- To us perdurants are further, pragmatically, analysed into
  - ***action***s,
  - ***event***s, and
  - ***behaviour***s.
- We shall define these terms below.
- Common to all of them is that they potentially change a state.
- Actions and events are here considered atomic perdurants.
- For behaviours we distinguish between
  - discrete and
  - continuous

  behaviours.

4.2.1 Actors

Definition 21 Actor: *By an* **actor** *we shall understand*

- *something that is capable of initiating and/or* **carrying out**
  - *actions,*
  - *events or*
  - *behaviours* ■

- Actors will play an important rôle in our domain analysis & description.
  - By what we learn from our study of Sørlander's Philosophy some endurants
  - (of a kind we shall introduce much later[16])
  - can, by a ***transcendental deduction***,
  - "become" perdurants
  - some of which
  - thereby "acting" in rôles of ***actors***.

[16] ***humans*** [Sect. **10.5** Slide 370] and, although not a concept in [15, 18], their ***artifacts*** [Sect. **10.7** Slide 374]

Example 24 Actors:

- Automobile
  - ***endurants "transmogrify"*** into
  - automobile ***perdurants***
  - which "subsume" rôles of ***humans***
  - in that we "include" humans in the form of automobile drivers
  - in the non-deterministic behaviour automobile perdurants ■

4.2.2 Discrete Actions

Definition 22 Discrete Action: *By a* **discrete action** *we shall understand*

- *a* **foreseeable** *thing*
- *which deliberately and*
- *potentially changes a well-formed state, in one step,*
- *usually into another, still well-formed state, and*
- *for which an actor can be made responsible* ■

Example 25 Discrete Actions:

- Here are some examples of discrete actions:
  - the removal, i.e., closing of a street segment, i.e., a link, from a road net;
  - the insertion of a street segment between two street intersections, i.e., hubs, of a road net; and
  - the removal of an automobile from the road net.

4.2.3 Discrete Events

Definition 23 Event: *By an* **event** *we shall understand*

- *some* **unforeseen** *thing,*
- *that is, some 'not-planned-for' "action", one*
- *which surreptitiously, non-deterministically changes a well-formed state*
- *into another, but usually not a well-formed state, for which*
- *no particular domain actor can be made responsible* ■

Example 26 Discrete Events:

- Here are some examples of discrete events:
  - a mud slide which effectively blocks, i.e., closes, a link; and
  - the crashing of two automobiles.

4.2.4 Discrete Behaviours

Definition 24 Discrete Behaviour: *By a* **discrete behaviour** *we shall understand*

- *a set of sequences of potentially interacting sets of discrete*
  - *actions,*
  - *events and*
  - *behaviours* ■

Example 27 Discrete Behaviours:

- Here are some examples of discrete behaviours:
  - the drive of an automobile along a road net;
  - the sequence of pumping and not-pumping, concurrent with and/or before/after opening and closing valves of a pipeline system;
  - the waiting of an automobile stopped at a traffic light for it turning green; and
  - the road (hub or link) "carrying" automobiles ■

• • •

- In these lectures we shall omit consideration of concepts of continuous actions, events and behaviours.

4.3 Channels

- **The fact**
  - that a part, p of sort P with unique identifier p_i,
  - has a mereology, for example the set of unique identifiers $\{q_{a_i}, q_{b_i}, ..., q_{d_i}\}$
  - identifying parts $\{q_a, q_b, ..., q_d\}$ of sort Q,
  - **may mean**
  - that parts p and $q \in \{qa, qb, ..., qd\}$
  - may wish to exchange – for example, attribute – values,
  - one way (from p to the q's) or the other (vice versa) or in both directions.

- Figure 3 Slide 147 shows
  - (left) two dotted rectangle box (part) and
  - (right) two corresponing, rounded box (behaviour and channel)

  diagrams.

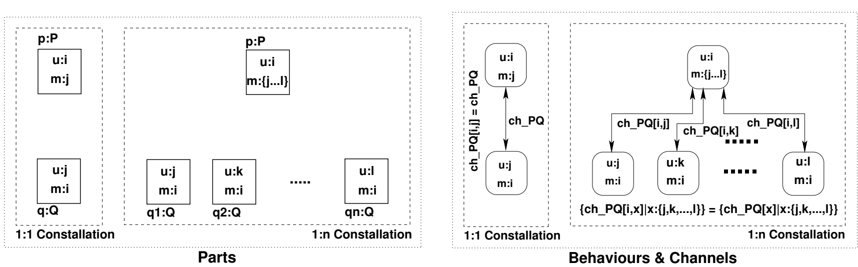


Figure 3: Two Part and Behaviour/Channel Constellations

- We explain the figure:
  - The left fragment of the figure intends to show a `1:1 Constellation` of a single p:P box and a single q:Q part, respectively, indicating, within these parts, their unique identifiers and mereologies.
  - The right fragment of the figure intends to show a `1:n Constellation` of a single p:P box and a set of q:Q parts, now with arrowed lines connecting the p part with the q parts.
  - These lines are intended to show channels.
  - We show them with two way arrows.
  - We could instead have chosen one way arrows, in one or the other direction.
  - The directions are intended to show a direction of value transfer.
  - We have given the same channel names to all examples, ch_PQ.
  - We have ascribed channel message types MPQ to all channels.[17]

[17] Of course, these names and types would have to be distinct for any one domain description.

⟐ Figure 4 shows an arrangement similar to that of Fig. 3 [Slide 147], but for an `m:n Constellation`.

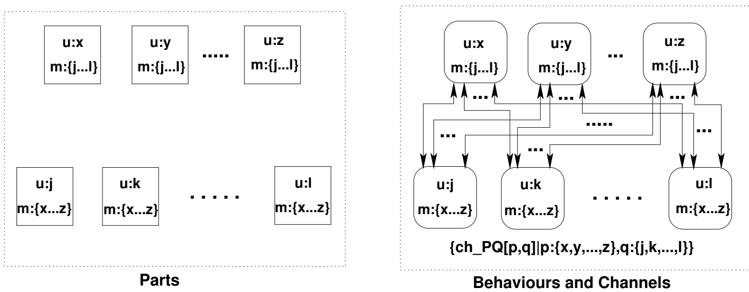


Figure 4: Multiple Part and Behaviour/Channel Constellations

- The channel declarations corresponding to Figs. 3 and 4 are:

channel
[1] ch_PQ[i,j]:MPQ
[2] { ch_PQ[i,x]:MPQ | x:{j,k,...,l} }
[3] { ch_PQ[p,q]:MPQ | p:{x,y,...,z}, q:{j,k,...,l} }

- Since there is only one index i and j for channel [1], its declaration can be reduced.
- Similarly there is only one i for declaration [2]:

channel
[1] ch_PQ:MPQ
[2] { ch_PQ[x]:MPQ | x:{j,k,...,l} }

7 The following description identities holds:

7 { ch_PQ[x]:MPQ | x:{j,k,...,l} } ≡ ch_PQ[j],ch_PQ[k],...,ch_PQ[l],

7 { ch_PQ[p,q]:MPQ | p:{x,y,...,z}, q:{j,k,...,l} } ≡
7 ch_PQ[x,j],ch_PQ[x,k],...,ch_PQ[x,l],
7 ch_PQ[y,j],ch_PQ[y,k],...,ch_PQ[y,l],
7 ...,
7 ch_PQ[z,j],ch_PQ[z,k],...,ch_PQ[z,l]

4.4 Behaviours
4.4.1 Behaviour Signatures

- We associate with each part, $p{:}P$, a behaviour $\mathcal{M}_P$.
- Behaviours have, as first argument, their unique part identifier: **uid**_P(p).
- Behaviours evolves around a state in the form of a set of values:
  - ⟐ its possibly changing mereology, mt:MT and
  - ⟐ the attributes of the part.[18]

[18] We leave out consideration of possible components and materials of the part.

- A behaviour signature is therefore:

  $\mathcal{M}_P$: ui:UI×me:MT×sa:stat_attr_typs(p) → ca:ctrl_attr_typs(p) → calc_i_o_chn_refs(p) **U**

  where

  - (i) ui:UI is the unique identifier value and type of part p;
  - (ii) me:MT is the value and type mereology of part p;
  - (iii) sa:stat_attr_typs(p): *static attribute* types of part p:P;
  - (iv) ca:ctrl_attr_typs(p): *controllable attribute* types of part p:P;
  - (v) calc_i_o_chn_refs(p) calculates channel references to
    - the **in**put channels reflecting the *monitorable attributes* of p
    - and the **in**put/**out**put and the **out**put channels designated in the mereology, me, of p.

4.4.2 Behaviour Definitions

- Let P be a composite sort defined in terms of endurant[19] sub-sorts E_1, E_2, . . . , E_n.
  - The behaviour description *translated* from p:P, is composed from
    - a behaviour description, $\mathcal{M}_P$, relying on and handling the unique identifier, mereology and attributes of part p
    - to be *translated* with behaviour descriptions $\beta_1, \beta_2, \ldots, \beta_n$:
      - β_1 is *translated* from e_1:E_1,
      - β_2 is *translated* from e_2:E_2,
      - ..., and
      - β_n is *translated* from e_n:E_n.
- The domain description *transcendental schema* below "formalises" the above.

19– structures or composite

Transcendental Schema 1

Abstract **is_composite(p)**

```
value
  Translate_P: P → RSL+Text
  Translate_P(p) ≡
    let ui = uid_P(p), me = obs_mereo_P(p),
        sa = stat_attr_vals(p), ca = ctrl_attr_vals(p),
        MT = mereo_type(p), ST = stat_attr_typs(p), CT = ctrl_attr_typs(p),
        IOR = calc_i_o_chn_refs(p), IOD = calc_all_ch_dcls(p) in
    ≪ channel
        IOD
      value
        M_P: P_UI × MT × ST  CT  IOR  Unit
        M_P(ui,me,sta)(ca) ≡ B_P(ui,me,sta)(ca)
         ,≫ Translate_P1(obs_endurant_sorts_E1(p))
        ≪≫ Translate_P2(obs_endurant_sorts_E2(p))
        ≪≫ ...
        ≪≫ Translate_Pn(obs_endurant_sorts_En(p))
    end
```


- Expression $\mathcal{B}_P$(ui,me,sta)(ca,pa) stands for
  - the *behaviour definition body*
  - in which the names ui, me, sta, ca and pa
  - are bound to the *behaviour definition head*,
  - i.e., the left hand side of the ≡.
- Endurant sorts E_1, E_2, ..., E_n are obtained from the `observe_endurant_sorts` prompt, Slide 78.
- We informally explain the **Translate**$_{\mathsf{P}_i}$ function.
  - It takes endurants and produces RSL$^+$Text.
  - Resulting texts are bracketed: ≪rsl_text≫

- For the case that an endurant is a structure
- there is only its elements to compile;
- otherwise Schema 2 is as Schema 1 ■

Transcendental Schema 2

is_structure(e)

```
value
  Translate_P(p) ≡
          Translate_P1(obs_endurant_sorts_P1(p))
    ‖     Translate_P2(obs_endurant_sorts_P2(p))
    ‖     ...
    ‖     Translate_Pn(obs_endurant_sorts_Pn(p))
```


- Let P be a composite sort defined in terms of the concrete type **Q-set**.
  - The process definition compiled from p:P, is composed from
    - a process, $\mathcal{M}_P$, relying on and handling the unique identifier, the mereology and the attributes of process p as defined by P
    - operating in parallel with processes q:**obs_part**_Qs(p).
- The domain description "compilation" schematic below "formalises" the above ■

Transcendental Schema 3

Concrete is_composite(p)

```
type
  Qs = Q-set
value
  qs:Q-set = obs_part_Qs(p)
  Translate_P(p) ≡
    let ui = uid_P(p), me = obs_mereo_P(p),
        sa = stat_attr_vals(p), ca = ctrl_attr_vals(p)
        ST = stat_attr_typs(p), CT = ctrl_attr_typs(p),
        IOR = calc_i_o_chn_refs(p), IOD = calc_all_ch_dcls(p) in
   ≪ channel
       IOD
     value
       M_P: P_UI×MT×ST  CT  IOR  Unit
       M_P(ui,me,sa)(ca) ≡ B_P(ui,me,sa)(ca)  ≫
       { ≪,≫ Translate_Q(q)|q:Q·q ∈ qs }
   end ■
```


Transcendental Schema 4

is_atomic(p)

```
value
  Translate_P(p) ≡
   let ui = uid_P(p), me = obs_mereo_P(p),
       sa = stat_attr_vals(p), ca = ctrl_attr_vals(p),
       ST = stat_attr_typs(p), CT = ctrl_attr_typs(p),
       IOR = calc_i_o_chn_refs(p), IOD = calc_all_chs(p) in
   ≪ channel
       IOD
     value
       M_P: P_UI×MT×ST  PT  IOR  Unit
       M_P(ui,me,sa)(ca) ≡ B_P(ui,me,sa)(ca)  ≫
   end ■
```

Transcendental Schema 5 — **Core Behaviour**

- *The core processes can be understood as never ending, "tail recursively defined" processes:*

$\mathcal{B}_P$: uid:P_UI×me:MT×sa:SA
  → ct:CT
  → **in** in_chns(p) **in**,**out** in_out_chns(me) **Unit**
$\mathcal{B}_P$(p)(ui,me,sa)(ca) ≡
  let (me′,ca′) = $\mathcal{F}_P$(ui,me,sa)(ca) **in** $\mathcal{M}_P$(ui,me′,sa)(ca′) **end**

$\mathcal{F}_P$: P_UI×MT×ST → CT→ in_out_chns(me) → MT×CT ■

4.5 Initial Running Systems

- To round it all off
  - a narrative and a formalisation

  must be done of *"a running system"*.
  - Up till now the behaviours for all relevant parts have been defined.
  - Now a decision must be made as to which of these are the basis for an initial system.
    - There may be several candidates for initial running systems,
    - that is, collection of concurrently operating behaviours.
    - So the domain analyser cum describer selects all or some candidates.
    - For each the chosen behaviours are properly initialised.
- And that is that!

5 A Coin Has Two Sides

- The transcendental deduction
  - that "turns" parts
  - into behaviours

  can also be interpreted as follows:
  - The part and the "corresponding" behaviour "exist" at one and the same time:
  - the part is characterised by its *internal qualities*,
  - and these are the arguments, in one form or another of the behaviour.
  - The properties of the internal qualities of parts, expressed, for example, in the form of **axioms**, hold for all times (a concept not present in the treatment of endurants),
  - and are to be maintained by the corresponding behaviours, as expressed, for example, in **pre/post** conditions.

- Let us recall essential "features" of parts and behaviours.
- For parts, p:P, we can generally express the following:

Pg. 87:	**uid**_P: P → PI	
Pg. 106:	**obs_mereo**_P: P → $\mathcal{E}$(PI$_1$,PI$_2$,...,PI$_m$)	
Pg. 116:	**attr**_sA$_1$: P → sA$_1$	is_static_attribute
	...	is_static_attribute
	attr_sA$_n$: P → sA$_{n_s}$	is_static_attribute
	attr_cA$_1$: P → cA$_1$	is_controllable_attribute
	...	is_controllable_attribute
	attr_cA$_{n_c}$: P → cA$_{n_c}$	is_controllable_attribute
	attr_mA$_1$: P → mA$_1$	is_monitorable_attribute
	...	is_controllable_attribute
	attr_mA$_{n_m}$: P → mA$_{n_m}$	is_monitorable_attribute

where $n_s \geq 0$, $n_c \geq 0$, and $n_m \geq 0$.

- For "corresponding" behaviours, $\mathcal{M}_P$, we have (cf. Process Schema 1 [Slide 155]):

```
let ui = uid_P(p), me = obs_mereo_P(p),
    sv = stat_attr_vals(p), cv = ctrl_attr_vals(p),
    MT = mereo_type(p), ST = stat_attr_typs(p), CT = ctrl_attr_typs(p),
    IOR = calc_i_o_chn_refs(p), IOD = calc_all_ch_dcls(p) in
≪ channel
      IOD
   value
      M_P: ui:P_UI × me:MT × sv:ST  cv:CT  IOR  Unit
      M_P(ui,me,sv)(cv) ≡ B_P(ui,me,sv)(cv)  ≫
end
```

- We leave it to the listener to study these two sets of formulas.

6 An Example: A Road Transport System

.

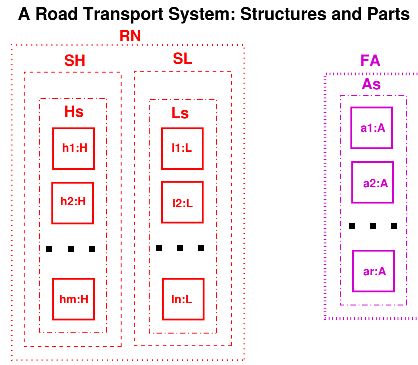


Figure 5: A Road Transport System

6.1 The Universe of Discourse

- The universe of discourse is *road transport systems*.
  - We analyse & describe not the class of all road transport systems
  - but a representative subclass, UoD, is *structured* into such notions as
    - a road net, RN, of hubs, H, (intersections) and links, L, (street segments between intersections);
    - a fleet of automobiles, FA, of automobiles, A;
    - et cetera.
  - See Fig. 5 Slide 166

- The delineation of *the universe of discourse*
  - satisfies the characterisation of what a domain
  - must "at least" contain –
  - only if we assume that automobiles include humans —
  - in a sense we do not have to explicate.

6.2 Endurants
6.2.1 Structures

.

8 There is the *universe of discourse*, UoD.
It is structured into

9 a *road net*, RN, a structure, and

10 a *fleet of automobiles*, FA, a structure.

```
type
8  UoD  axiom ∀ uod:UoD · is_structure(uod).
9  RN   axiom ∀ rn:RN · is_strucure(rn).
10  FA   axiom ∀ fa:FA · is_structure(fa).
value
9  obs_RN: UoD → RN
10  obs_FA: UoD → FA
```


6.2.2 Parts, Components and Materials

.

11 The road net consists of

a. a structure, SH, of hubs and

b. a structure, SL, of links.

12 The fleet of automobiles consists of

a. a set, As of automobiles.


```
type
11a.  SH  axiom ∀ sh:SH · is_structure(sh)
11b.  SL  axiom ∀ sl:SL · is_structure(sl)
12a.  As = A-set
value
11a.  obs_SH: RN → SH
11b.  obs_SL: RN → SL
12a.  obs_As: FA → As
```


6.2.3 Parts

.

13 The structure of hubs is a set, sH, of atomic hubs, H.

14 The structure of links is a set, sL, of atomic links, L.

15 The structure of automobiles is a set, sA, of atomic automobiles, A.

type
13 H, sH = H-**set** **axiom** ∀ h:H · is_atomic(h)
14 L, sL = L-**set** **axiom** ∀ l:L · is_atomic(l)
15 A, sA = A-**set** **axiom** ∀ a:A · is_atomic(a)
value
13 obs_sH: SH → sH
14 obs_sL: SL → sL
15 obs_sA: SA → sA

6.2.4 Components

.

- To illustrate the concept of components
  - we describe timber yards, waste disposal areas, road material storage yards, automobile scrap yards, and the like
  - as special "cul de sac" hubs with components.
  - Here we describe road material storage yards.

16 Hubs may contain components, but only if the hub is connected to exactly one link.

17 These "cul-de-sac" hub components may be such things as Sand, Gravel, Cobble Stones, Asphalt, Cement or other.

value
16 has_components: H → **Bool**
type
17 Sand, Gravel, CobbleStones, Asphalt, Cement, ...
17 KS = (Sand|Gravel|CobbleStones|Asphalt|Cement|...)-**set**
value
16 obs_components_H: H → KS
16 **pre**: obs_components_H(h) ≡ **card** mereo(h) = 1

6.2.5 Materials

.

- To illustrate the concept of materials
  - we describe waterways (river, canals, lakes, the open sea) along links
  - as links with material of type water.

18 Links may contain material.

19 That material is water, W.

type
19 W
value
18 obs_material: L → W
18 **pre**: obs_material(l) ≡ has_material(h)

6.2.6 States

20 Let there be given a universe of discourse, rts. It is an example of a state.

From that state we can calculate other states.

21 The set of all hubs, hs.

22 The set of all links, ls.

23 The set of all hubs and links, hls.

24 The set of all automobiles, as.

25 The set of all parts, ps.

value
20 rts:UoD
21 hs:H-**set** ≡ ≡ obs_sH(obs_SH(obs_RN(rts)))
22 ls:L-**set** ≡ ≡ obs_sL(obs_SL(obs_RN(rts)))
23 hls:(H|L)-**set** ≡ $hs \cup ls$
24 as:A-**set** ≡ obs_As(obs_FV(rts))
25 ps:(H|L|BC|B|A)-**set** ≡ $hls \cup bcs \cup bs \cup as$

6.2.7 Unique Identifiers

26 We assign unique identifiers to all parts.

27 By a road identifier we shall mean a link or a hub identifier.

28 Unique identifiers uniquely identify all parts.

a. All hubs have distinct [unique] identifiers.

b. All links have distinct identifiers.

c. All automobiles have distinct identifiers.

d. All parts have distinct identifiers.

type
26 H_UI, L_UI, A_UI
27 R_UI = H_UI | L_UI
value
28a. uid_H: H → H_UI
28b. uid_L: L → L_UI
28c. uid_A: A → A_UI

29 From the unique identifier of a part we can retrieve, $\wp$, the part having that identifier.

type

29 P = H | L | A

value

29 $\wp$: H_UI→H | L_UI→L | A_UI→A

29 $\wp$(ui) ≡ **let** p:(H|L|A)·p∈ps∧uid_P(p)=ui **in** p **end**

We can calculate:

30 the set, $h_{ui}s$, of unique hub identifiers;

31 the set, $l_{ui}s$, of unique link identifiers;

32 the map, $hl_{ui}m$, from unique hub identifiers to the set of unique link iidentifiers of the links connected to the zero, one or more identified hubs,

33 the map, $lh_{ui}m$, from unique link identifiers to the set of unique hub iidentifiers of the two hubs connected to the identified link;

34 the set, $r_{ui}s$, of all unique hub and link, i.e., road identifiers;

35 the set, $a_{ui}s$, of unique automobile identifiers;

value

30. $h_{ui}s$:H_UI-**set** ≡ {uid_H(h)|h:H•h ∈ hs}
31. $l_{ui}s$:L_UI-**set** ≡ {uid_L(l)|l:L•l ∈ ls}
34. $r_{ui}s$:R_UI-**set** ≡ $h_{ui}s$∪$l_{ui}s$
32. $hl_{ui}m$:(H_UI $\overrightarrow{m}$ L_UI-**set**) ≡
32. [h_ui↦luis|h_ui:H_UI,luis:L_UI-**set**•h_ui∈$h_{ui}s$∧(_,luis,_)=mereo_H(η(h_ui))] [cf. Item 40]
33. $lh_{ui}m$:(L+UI $\overrightarrow{m}$ H_UI-**set**) ≡
33. [l_ui↦huis | h_ui:L_UI,huis:H_UI-**set** • l_ui∈$l_{ui}s$ ∧ (_,huis,_)=mereo_L(η(l_ui))] [cf. Item 41]
35. $a_{ui}s$:A_UI-**set** ≡ {uid_A(a)|a:A•a ∈ as}

6.2.8 Uniqueness of Part Identifiers

- We must express the following axioms:

36 All hub identifiers are distinct.

37 All link identifiers are distinct.

38 All automobile identifiers are distinct.

39 All part identifiers are distinct.

axiom

36 **card** hs = **card** $h_{ui}s$

37 **card** ls = **card** $l_{ui}s$

38 **card** as = **card** $a_{ui}s$

39 **card** $\{h_{ui}s \cup l_{ui}s \cup a_{ui}s\}$

39 = **card** $h_{ui}s$+**card** $l_{ui}s$+**card** $a_{ui}s$

6.2.9 Part Mereologies

40 The mereology of hubs is a triple: (i) the set of all automobile identifiers[20], (ii) the set of unique identifiers of the links that it is connected to and the set of all unique identifiers of all automobiles.[21], and (iii) an empty set.[22]

41 The mereology of links is a triple: (i) the set of all automobile identifiers, (ii) the set of the two distinct hubs they are connected to, and (iii) an empty set.

[20]This is just another way of saying that the meaning of hub mereologies involves the unique identifiers of all the automobiles that might pass through the hub `is_of_interest` to it

[21]... its link identifiers designate the links, zero, one or more, that a hub is connected to `is_of_interest` to both the hub and that these links is `interested` in the hub.

[22]... the hubs are not "proactive", i.e., that the universe of discourse have no parts that are `interested` in the hub.

42 The mereology of an automobiles is a triple: (i) an empty set, (ii) an empty set, and (iii) the set of the unique identifiers of all links and hubs[23].

43 Empty sets are modelled as empty sets of tokens where tokens are further undefined.

[23]that the automobile might pass through

type

43 ES = TOKEN-**set**

43 **axiom** ∀ es:ES·es={}

40 H_Mer = V_UI-**set**×L_UI-**set**×ES

40 **axiom** ∀ (vuis,luis,_):H_Mer · luis⊆$l_{ui}s$ ∧ vuis=$v_{ui}s$

41 L_Mer = V_UI-**set**×H_UI-**set**×ES

41 **axiom** ∀ (vuis,huis,_):L_Mer ·

41 vuis=$v_{ui}s$ ∧ huis⊆$h_{ui}s$ ∧ **card**huis=2

42 A_Mer = ES×ES×R_UI-**set**

42 **axiom** ∀ (_,ruis,_):A_Mer · ruis=$r_{ui}s$

value

40 mereo_H: H → H_Mer

41 mereo_L: L → L_Mer

42 mereo_A: A → A_Mer

- We can express some additional axioms,
- in this case for relations between hubs and links:

44 If hub, h, and link, l, are in the same road net,

45 and if hub h connects to link l then link l connects to hub h.

axiom

44 ∀ h:H,l:L · h ∈ hs ∧ l ∈ ls ⇒

44 **let** (_,luis,_)=mereo_H(h),(_,huis,)=mereo_L(l)

45 **in** uid_L(l) ∈ luis ⇒ uid_H(h) ∈ huis **end**

- More mereology axioms need be expressed –
- but we leave, to the listener,
- to narrate and formalise those.

6.2.10 Part Attributes

- We treat part attributes, sort by sort.

Hubs: We show just a few attributes:

46 There is a hub state.

- It is a set of pairs, (l_f, l_t) of link identifiers, where these link identifiers are in the mereology of the hub.
- The meaning of the hub state, in which, e.g., (l_f, l_t) is an element, is that the hub is open, **"green"**, for traffic *f*rom link l_f *t*o link l_t.
- If a hub state is empty then the hub is closed, i.e., **"red"** for traffic from any connected links to any other connected links.

47 There is a hub state space.

- It is a set of hub states.
- The meaning of the hub state space is that its states are all those the hub can attain.
- The current hub state must be in its state space.

48 Hub traffic history:

- Since we can think rationally about it, it can be described.
- We model hub traffic history as a hub attribute:
  - the recording, per unique automobile identifier,
  - of the time ordered presence, APos,
  - in the hub of these automobiles.

49 The link identifiers of hub states must be in the set, $l_{ui}s$, of the road net's link identifiers.

type
46 $H\Sigma = (L\_UI \times L\_UI)$**-set** [programmable, df.27 pp.123]
axiom
46 $\forall$ h:H • obs_HΣ(h) $\in$ obs_HΩ(h)
type
47 $H\Omega = H\Sigma$**-set** [static, df.20 pp.120]
48 H_Traffic [programmable, df.27 pp.123]
48 H_Traffic = A_UI $\overrightarrow{m}$ $(\mathcal{T} \times \text{APos})^*$
axiom
48 $\forall$ ht:H_Traffic,ui:A_UI •
48 ui $\in$ **dom** ht $\Rightarrow$ time_ordered(ht(ui))
value
46 attr_HΣ: H $\rightarrow$ HΣ
47 attr_HΩ: H $\rightarrow$ HΩ
48 attr_H_Traffic: : $\rightarrow$ H_Traffic
axiom
49 $\forall$ h:H • h $\in hs \Rightarrow$
49 **let** hσ = attr_HΣ(h) **in** $\forall$ $(l_{ui}i, li_{ui}i')$:(L_UI×L_UI) • $(l_{ui}i, l_{ui}i') \in$ h$\sigma \Rightarrow \{l_{ui_i}, l'_{ui_i}\} \subseteq l_{ui}s$ **end**
value
48 time_ordered: $\mathcal{T}^* \rightarrow$ **Bool**
48 time_ordered(tvpl) $\equiv$ ...

Links: We show just a few attributes:

50 There is a link state.

- It is a set of pairs, (h_f,h_t), of distinct hub identifiers,
- where these hub identifiers are in the mereology of the link.
- The meaning of a link state in which (h_f,h_t) is an element is that the link is open, **"green"**, for traffic *f*rom hub h_f *to* hub h_t.
- Link states can have either 0, 1 or 2 elements.

51 There is a link state space.

- It is a set of link states.
- The meaning of the link state space is that its states are all those the which the link can attain.
- The current link state must be in its state space.
- If a link state space is empty then the link is (permanently) closed.
- If it has one element then it is a one-way link.
- If a one-way link, l, is imminent on a hub whose mereology designates that link,
- then the link is a "trap", i.e., a "blind cul-de-sac".

52 Link traffic history:

- Since we can think rationally about it, it can be described.
- We model link traffic history as an attribute:
  - the recording, per unique automobile identifier,
  - of the time ordered positions, APos
  - (along the link (from one hub to the next)), of these automobiles.
- The hub identifiers of link states must be in the set, $h_{ui}s$, of the road net's hub identifiers.

type
50 $L\Sigma$ = H_UI-**set** [programmable, df.27 pp.123]
axiom
50 $\forall$ lσ:LΣ•**card** lσ=2
50 $\forall$ l:L • obs_LΣ(l) $\in$ obs_LΩ(l)
type
51 LΩ = LΣ-**set** [static, df.20 pp.120]
52 L_Traffic [programmable, df.27 pp.123]
52 L_Traffic = A_UI $\overrightarrow{m}$ ($\mathcal{T}$×APos)*
value
50 attr_LΣ: L → LΣ
51 attr_LΩ: L → LΩ
52 attr_L_Traffic: : → L_Traffic

axiom
52 $\forall$ lt:L_Traffic,ui:A_UI•ui $\in$ **dom** ht
52 $\Rightarrow$ time_ordered(ht(ui))
52 $\forall$ l:L • l $\in$ ls $\Rightarrow$
52 **let** lσ = attr_LΣ(l) **in** $\forall$ ($h_{ui}i$,$h_{ui}i'$):(H_UI×K_UI) • ($h_{ui}i$,$h_{ui}i'$) $\in$ lσ $\Rightarrow$ $\{h_{ui_i},h'_{ui_i}\} \subseteq h_{ui}s$ **end**

Automobiles: We show just a few attributes:

- We illustrate but a few attributes:

53 Automobiles have a time attribute.

54 Automobiles have static number plate registration numbers.

55 Automobiles have dynamic positions on the road net:

a. either *at a hub* identified by some h_ui,

b. or *on a link*, some *fraction, frac:Fract* down an *identified link, l_ui*, from one of its *identified connecting hub*s, fh_ui, in the direction of the other *identified hub*, th_ui.

c. Automobiles, like elephants, never forget: they remember their timed positions of the past,

d. and the current position is the first element of this past!

type
53 $\mathcal{T}$ [inert, df.22 pp.121]
54 RegNo [static, df.20 pp.120]
55 APos == atHub | onLink [programmable, df.27 pp.123]
55a. atHub :: h_ui:H_UI
55b. onLink :: fh_ui:H_UI×l_ui:L_UI×frac:Fract×th_ui:H_UI
55b. Fract = **Real**, **axiom** frac:Fract · 0<frac<1
55c. A_Hist = (T × APos)* [programmable, df.27 pp.123]
value
53 attr_T: A → $\mathcal{T}$
54 attr_RegNo: A → RegNo
55 attr_APos: A → APos
55c. attr_A_Hist: A → A_Hist
axiom
55d. ∀ a:A ·
55d. **let** (_,apos) = **hd**(attr_A_Hist(a)) **in**
55d. apos = attr_APos(a) **end**

- Obvious attributes that are not illustrated are those of
  - velocity and acceleration,
  - forward or backward movement,
  - turning right, left or going straight,
  - etc.
- The *acceleration, deceleration, even velocity*, or *turning right, turning left, moving straight*, or *forward* or *backward* are seen as *command actions*.
  - As such they denote actions by the automobile —
  - such as pressing the accelerator, or lifting accelerator pressure or *braking*, or *turning the wheel* in one direction or another, etc.
  - As actions they have a kind of counterpart in the velocity, the acceleration, etc. attributes.

6.2.11 Discussion of Edurants, I

- In Items 48 Slide 191 and 52 Slide 194, we illustrated an aspect of domain analysis & description that may seem, and at least some decades ago would have seemed, strange: namely that if we can think, hence speak, about it, then we can model it "as a fact" in the domain. The case in point is that we include among hub and link attributes their histories of the timed whereabouts of automobiles.[24]

[24] In this day and age of road cameras and satellite surveillance these traffic recordings may not appear so strange: We now know, at least in principle, of technologies that can record approximations to the hub and link traffic attributes.

6.2.12 Discussion of Endurants, II

- We have chosen to model some discrete endurants
  - as structures
  - others as parts (usually composite).
- Those choices are made mostly to illustrate that the domain analysis & description has a choice.
  - If a choice is made to model a discrete endurant as a structure
    - then it entails that the domain analysis & description does not wish to "implement" that discrete endurant as a behaviour separate from its sub-endurants;
  - If the choice is made to model a discrete endurant as a part
    - then it entails that the domain analysis & description wishes to "implement" that discrete endurant as a behaviour separate from its sub-endurants.

- The following discrete endurants which are modelled as structures above, could, instead, if modelled as parts, have the entailed behaviours reflect the following possibilities:
  - *road net*, rn:RN: The road net behaviour could be that of a road net authority charged with building, servicing, operating and maintaining the road net. Building and maintaining the road net could mean the insertion of new or removal of old links or hubs. Operating the road net could mean the gathering of automobile traffic statistics, the setting of hub states (traffic signal monitoring and control), etc.
  - *aggregate of automobiles*, ps:PA: The aggregate of automobiles could be that of one or more ***automobile clubs***, etc.

6.3 Transcendentality

- We refer to Sect. **6.3** Defn. 23 Page 131.

Example 28 A Case of Transcendentality:

- We refer to the following example:
  - We can speak of an automobile in at least three ***senses:***
    - The automobile as it is being maintained, serviced, refueled;
    - the automobile as it "speeds" down its route; and
    - the automobile as it "appears" (listed) in car registries or advertisements.
  - The three ***senses*** are:
    - as a part,
    - as a behaviour, and
    - as an attribute[25] ■

[25] in this case rather: as a fragment of an attribute

6.4 Perdurants

6.4.1 States

We refer to Sect. **6.2.6** Slide 177, and to App. **4.1** Slide 135

- We assume, as a constant, an arbitrarily selected universe of discourse, *uod*,
- and calculate from *uod* all its endurants.

value
20 rts:UoD
21 hs:**H-set** ≡:**H-set** ≡ obs_sH(obs_SH(obs_RN(rts)))
22 ls:**L-set** ≡:**L-set** ≡ obs_sL(obs_SL(obs_RN(rts)))
23 hls:(H|L)**-set** ≡ hs∪ls
24 as:**A-set** ≡ obs_As(obs_FV(rts))

- We shall

56 index automobiles

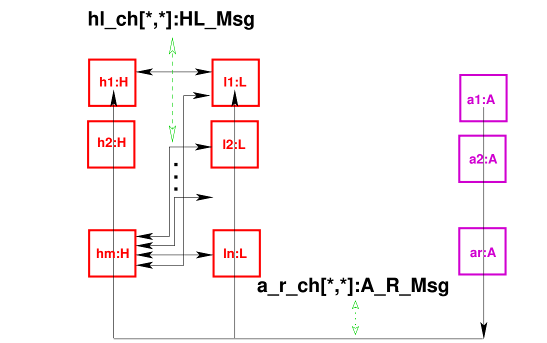
using the unique identifiers of these parts.

type
56 A_{ui}
value
56 ias:A_{ui}**-set** ≡
56 {a_{ui}|a:A,a:A_{ui}:A_{ui}·a∈as∧ui=uid_A(a)}

6.4.2 Channels

- We shall argue for hub-to-link channels based on the mereologies of those parts.
  - Hub parts may be topologically connected to any number, 0 or more, link parts.
  - Only instantiated road nets knows which.
  - Hence there must be channels between any hub behaviour and any link behaviour.
  - Vice versa: link parts will be connected to exactly two hub parts.
  - Hence there must be channels from any link behaviour to two hub behaviours.
- See the figure below:

1



Hub–to–Link Channels and Automobile to Road Channels

Channel Message Types:

- We ascribe types to the messages offered on channels.

57 Hubs and links communicate, both ways, with one another, over channels, `hl_ch`, whose indexes are determined by their mereologies.

58 Hubs send one kind of messages, links another.

59 Automobiles offer their current, timed positions to the road element, hub or link they are on, one way.

type

58 H_L_Msg, L_H_Msg

57 HL_Msg = H_L_Msg | L_F_Msg

59 A_R_Msg = T × APos

Channel Declarations

60 This justifies the channel declaration which is calculated to be:

channel

60 { hl_ch[h_ui,l_ui]:H_L_Msg

60 | h_ui:H_UI,l_ui:L_UI•i ∈ $h_{ui}s$∧j ∈ $lh_{ui}m$(h_ui) }

60 ∪

60 { hl_ch[h_ui,l_ui]:L_H_Msg

60 | h_ui:H_UI,l_ui:L_UI•l_ui ∈ $l_{ui}s$∧i ∈ $lh_{ui}m$(l_ui) }

- We shall argue for automobile to road element channels based on the mereologies of those parts.
  - Automobiles need communicate to
    - all hubs and
    - all links.

61 This justifies the channel declaration which is calculated to be:

channel
61 {a_r_ch[a_ui,r_ui]:A_R_Msg
61 |a_ui:A_UI,r_ui:R_UI•a_ui ∈ $a_{ui}s$ ∧ r_ui ∈ $r_{ui}s$}

6.4.3 Behaviour Signatures

- We first decide on names of behaviours.
  - In Sect. 4.4.2, Pages 154–160,
  - we gave schematic names to behaviours of the form $\mathcal{M}_P$.
  - We now assign mnemonic names: from part names to names of transcendentally interpreted behaviours
  - and then we assign signatures to these behaviours.

62 hub$_{h_{ui}}$:

a. there is the usual "triplet" of arguments: unique identifier, mereology and static attributes;
b. then there are the programmable attributes;
c. and finally there are the input/output channel references: first those allowing communication between hub and link behaviours,
d. and then those allowing communication between hub and automobile behaviours.

value
62 hub$_{h_{ui}}$:
62a. h_ui:H_UI×(auis,luis,_):H_Mer×HΩ
62b. → (HΣ×H_Traffic)
62c. → **in**,**out** { h_l_ch[h_ui,l_ui] | l_ui:L_UI:l_ui ∈ luis }
62d. { a_r_ch[h_ui,a_ui] | a_ui:A_UI•a_ui∈auis } **Unit**
62a. **pre**: auis = $a_{ui}s$ ∧ luis = $l_{ui}s$

63 $\mathsf{link}_{l_{ui}}$:

a. there is the usual "triplet" of arguments: unique identifier, mereology and static attributes;
b. then there are the programmable attributes;
c. and finally there are the input/output channel references: first those allowing communication between hub and link behaviours,
d. and then those allowing communication between link and automobile behaviours.

value

63 $\mathsf{link}_{l_{ui}}$:
63a. l_ui:L_UI×(auis,huis,_):L_Mer×LΩ
63b. → (LΣ×L_Traffic)
63c. → **in**,**out** { h_l_ch[h_ui,l_ui] | h_ui:H_UI:h_ui ∈ huis }
63d. { a_r_ch[l_ui,a_ui] | a_ui:A_UI•a_ui∈auis } **Unit**
63a. **pre**: auis = $a_{ui}s$ ∧ huis = $h_{ui}s$

64 $\mathsf{automobile}_{a_{ui}}$:

a. there is the usual "triplet" of arguments: unique identifier, mereology and static attributes;
b. then there is the one programmable attribute;
c. and finally there are the input/output channel references: first the input time channel,
d. then the input/output allowing communication between the automobile and the hub and link behaviours.

value

64 $\mathsf{automobile}_{a_{ui}}$:
64a. a_ui:A_UI×(_,_,ruis):A_Mer×rn:RegNo
64b. → apos:APos
64c. → **in** attr_T_ch
64d. **in**,**out** {a_r_ch[a_ui,r_ui]
64d. | r_ui:(H_UI|L_UI)•r_ui∈ruis} **Unit**
64a. **pre**: ruis = $r_{ui}s$ ∧ a_ui ∈ $a_{ui}s$

6.4.4 Behaviour Definitions

- We define the behaviours in a different order than the treatment of their signatures.
- We "split" definition of the automobile behaviour
  - into the behaviour of automobiles when positioned at a hub, and
  - into the behaviour automobiles when positioned at on a link.
  - In both cases the behaviours include the "idling" of the automobile, i.e., its "not moving", standing still.

Automobiles:

65 We abstract automobile behaviour at a Hub (hui).

66 The automobile remains at that hub, "idling",

67 informing the hub behaviour,

68 or, internally non-deterministically,

a. moves onto a link, tli, whose "next" hub, identified by th_ui, is obtained from the mereology of the link identified by tl_ui;

b. informs the hub it is leaving and the link it is entering of its initial link position,

c. whereupon the automobile resumes the automobile behaviour positioned at the very beginning (0) of that link,

69 or, again internally non-deterministically,

70 the automobile "disappears — off the radar" !


```
65   automobile_{a_ui}(a_ui,({},(ruis,auis),{}),rn)
65            (apos:atH(fl_ui,h_ui,tl_ui)) ≡
66      (ba_r_ch[a_ui,h_ui] ! (attr_T_ch?,atH(fl_ui,h_ui,tl_ui));
67       automobile_{a_ui}(a_ui,({},(ruis,auis),{}),rn)(apos))
68     ⌈⌉
68a.     (let ({fh_ui,th_ui},ruis′)=mereo_L(℘(tl_ui)) in
68a.           assert: fh_ui=h_ui ∧ ruis=ruis′
65       let onl = (tl_ui,h_ui,0,th_ui) in
68b.      (ba_r_ch[a_ui,h_ui] ! (attr_T_ch?,onL(onl)) ‖
68b.       ba_r_ch[a_ui,tl_ui] ! (attr_T_ch?,onL(onl))) ;
68c.       automobile_{a_ui}(a_ui,({},(ruis,auis),{}),rn)
68c.            (onL(onl)) end end)
69     ⌈⌉
70       stop
```


71 We abstract automobile behaviour on a Link.

a. Internally non-deterministically, either

  i the automobile remains, "idling", i.e., not moving, on the link,

  ii however, first informing the link of its position,

b. or

  i **if** if the automobile's position on the link *has not yet reached the hub*, **then**

    A then the automobile moves an arbitrary small, positive **Real**-valued *increment* along the link

    B informing the hub of this new position,

    C while resuming being an automobile at the new position, or ii **else**,

A while obtaining a “next link” from the mereology of the hub (where that next link could very well be the same as the link the automobile is about to leave),

B the vehicle informs both the link and the imminent hub that it is now at that hub, identified by th_ui,

C whereupon the automobile resumes the vehicle behaviour positioned at that hub;

c. or

d. the automobile “disappears — off the radar” !


```
71          automobile_aui(a_ui,({},ruis,{}),rno)
71                      (vp:onL(fh_ui,l_ui,f,th_ui)) ≡
71(a.)ii    (ba_r_ch[ thui,aui ]!atH(lui,thui,nxt_lui) ;
71(a.)i      automobile_aui(a_ui,({},ruis,{}),rno)(vp))
71b.      ⌈⌉
71(b.)i     (if not_yet_at_hub(f)
71(b.)i       then
71(b.)iA        (let incr = increment(f) in
65               let onl = (tl_ui,h_ui,incr,th_ui) in
71(b.)iB          a−r_ch[ l_ui,a_ui ] ! onL(onl) ;
71(b.)iC          automobile_aui(a_ui,({},ruis,{}),rno)
71(b.)iC                       (onL(onl))
71(b.)i          end end)
71(b.)ii      else
71(b.)iiA       (let nxt_lui:L_UI•nxt_lui ∈ mereo_H(℘(th_ui)) in
71(b.)iiB         a_r_ch[ thui,aui ]!atH(l_ui,th_ui,nxt_lui) ;
71(b.)iiC         automobile_aui(a_ui,({},ruis,{}),rno)
71(b.)iiC                      (atH(l_ui,th_ui,nxt_lui)) end)
71(b.)i      end)
71c.      ⌈⌉
71d.         stop
71(b.)iA     increment: Fract → Fract
```


Hubs: We model the hub behaviour vis-a-vis automobiles.

72 The hub behaviour

a. non-deterministically, externally offers

b. to accept timed automobile positions —

c. which will be at the hub, from some vehicle, v_ui.

d. The timed automobile hub position is appended to the front of that automobile's entry in the hub's traffic table;

e. whereupon the hub proceeds as a hub behaviour with the updated hub traffic table.

f. The hub behaviour offers to accept from any automobile.

g. A **post** condition expresses what is really a **proof obligation**: that the hub traffic, ht′ satisfies the **axiom** of the endurant hub traffic attribute Item 48 Slide 191.


```
value
72   hub_hui(h_ui,(,(luis,vuis)),hω)(hσ,ht) ≡
72a.      ⌈⌉
72b.        { let m = ba_r_ch[ h_ui,v_ui ] ? in
72c.            assert: m=(_,atHub(_,h_ui,_))
72d.          let ht′ = ht † [ a_ui ↦ ⟨m⟩⌢ht(a_ui) ] in
72e.          hub_hui(h_ui,(,(luis,auis)),(hω))(hσ,ht′)
72f.        | a_ui:A_UI•a_ui∈auis end end }
72g.    post: ∀ a_ui:A_UI•a_ui ∈ dom ht′
72g.            ⇒ time_ordered(ht′(a_ui))
```

Links: Similarly we model the link behaviour vis-a-vis automobiles.

73 The link behaviour non-deterministically, externally offers

74 to accept timed automobile positions —

75 which will be on the link, from some automobile, a_ui.

76 The timed automobile link position is appended to the front of that automobile's entry in the link's traffic table;

77 whereupon the link proceeds as a link behaviour with the updated link traffic table.

78 The link behaviour offers to accept from any automobile.

79 A **post** condition expresses what is really a **proof obligation**: that the link traffic, lt' satisfies the **axiom** of the endurant link traffic attribute Item 52 Slide 194.

73 $\text{link}_{l_{ui}}$(l_ui,(_,(huis,auis),_),lω)(lσ,lt) ≡
73 ⌷
74 { **let** m = ba_r_ch[l_ui,a_ui] ? **in**
75 **assert:** m=(_,onLink(_,l_ui,_,_))
76 **let** lt′ = lt † [a_ui ↦ ⟨m⟩⁀lt(a_ui)] **in**
77 $\text{link}_{l_{ui}}$(l_ui,(huis,auis),hω)(hσ,lt′)
78 | a_ui:A_UI•a_ui∈auis **end end** }
79 **post**: ∀ a_ui:A_UI•a_ui ∈ **dom** lt′
79 ⇒ time_ordered(lt′(a_ui))

6.4.5 A Running System

- We recall the *hub, link* and the *automobile states* first mentioned in Sect. **6.2.6** Page 178.

value
21 hs:**H-set** ≡ ≡ obs_sH(obs_SH(obs_RN(rts)))
22 ls:**L-set** ≡ ≡ obs_sL(obs_SL(obs_RN(rts)))
24 as:**A-set** ≡ obs_As(obs_FA(rts))

- We are reaching the end of this domain modelling example.
  - Behind us there are narratives and formalisations 8 Slide 169 – 79 Slide 225.
  - Based on these we now express the signature and the body of the definition
  - of a *"system build and execute"* function.

80 The system to be initialised is

a. the parallel composition (‖) of
b. the distributed parallel composition (‖{...|...}) of
c. all the hub behaviours,
d. all the link behaviours, and
e. all the automobile behaviours.

value

80 initial_system: **Unit** → **Unit**
80 initial_system() ≡
80c. ‖ { hub$_{h_{ui}}$(h_ui,me,hω)(htrf,hσ)
80c. | h:H•h ∈ hs,
80c. h_ui:H_UI•h_ui=uid_H(h),
80c. me:HMetL•me=mereo_H(h),
80c. hω:HΩ•hω=attr_HΩ(h),
80c. htrf:H_Traffic•htrf=attr_H_Traffic_H(h),
80c. hσ:HΣ•hσ=attr_HΣ(h)∧hσ ∈ hω
80c. }

80a. ‖
80d. ‖ { link$_{l_{ui}}$(l_ui,me,lω)(ltrf,lσ)
80d. l:L•l ∈ ls,
80d. l_ui:L_UI•l_ui=uid_L(l),
80d. me:LMet•me=mereo_L(l),
80d. lω:LΩ•lω=attr_LΩ(l),
80d. ltrf:L_Traffic•ltrf=attr_L_Traffic_H(l),
80d. lσ:LΣ•lσ=attr_LΣ(l)∧lσ ∈ lω
80d. }

80a. ‖
80e. ‖ { automobile$_{a_{ui}}$(a_ui,me,rn)(apos)
80e. a:A•a ∈ as,
80e. a_ui:A_UI•a_ui=uid_A(a),
80e. me:AMet•me=mereo_A(a),
80e. rn:RegNo•rno=attr_RegNo(a),
80e. apos:APos•apos=attr_APos(a)
80e. }

6.5 Space and Time Considerations: A Specific Critique

- We have not dealt with space and time in a fully satisfactory manner.

6.5.1 Space

- We have referred, in Sect. 2, more-or-less explicitly, to **space** in Items
  - 52 [Slide 194],
  - 55 [Slide 196],
  - 55b. [Slide 196],
  - 55c. [Slide 196], and
  - 55d. [Slide 196].

And in Sect. 4 we have also referred to space:

- 59 Slide 207,
- 68b. Slide 218,
- 71(a.)ii and
- 71(b.)i Slide 220;
- 71(b.)iB and
- 71(b.)iC Slide 220;
- 71(b.)iiC,
- 72b. and
- 72d. Slide 223;
- 74 and
- 76 Slide 225.

- The Sect. 2 references relate to the references of Sect. 4.

The problem here is the following:

- We have not analysed & described the fact
  - that links may be single, double, triple, or more lane links,
  - and hence not whether automobiles may be in identical link positions
    - either moving in different lanes in the same direction;
    - or "piling up" in crashes in the same lane
      - whether "moving" (i.e., being) in the same direction
      - or "moving" in opposite directions;
    - or moving in opposite directions in different lanes.

- That problem can, of course, be avoided.
  - One can simply augment the analysis & description
  - by introducing appropriate link attributes
  - and appropriate axioms concerning traffic and histories.
- We leave that the the listener.

6.5.2 Time

- We have In Sect. **2** referred to **time** in Items
  - 48 Slide 191,
  - 52 Slide 194;
  - 53 and
  - 55c. Slide 196.
- In Sect. **4** we have, correspondingly, also referred to **time** in Items
  - 59 Slide 207;
  - 64c. Slide 215;
  - 72b. Slide 223 and
  - 72d. Slide 223;
  - 74 Slide 225 and
  - 76 Slide 225.

- It is not the trivial matter of representation of time.
  - One representation of, for example the time this document was compiled, could be
  - May 20, 2018: 11:20 am.
  - Here we have only "refined" the time to within minutes.
  - One could easily represent time "down" to picoseconds!
- No, the problem is that of *how often we sample time.*
  - What do the formulas of Items 72b. and 72d. Slide 223, and 74 and 76 Slide 225 express?
  - *Are they sampled continuously or discretely?*

- We shall take the view, here, that the semantics of RSL$^+$
  - expresses a discrete sampling,
  - that is, that each iteration of the automobile, the hub and the link behaviours, *take time*, but
  - that the *concurrently behaving automobiles* indeed
  - *may assemble their timed positions simultaneously!*
- This means that positions
  - recorded for any one particular automobile
  - are all distinct with respect to time, have different time designations.

6.6 The End!

- Yes, this is the end of the main example.

Segment II: Space and Time

- We have separated out a treatment of the notions of
  - space and time

  as these are at the very basis of our ability to describe "the world".
- That is, has deep implications for our attempt to relate
  - the mundane activity of analysing & describing domains
  - to the philosophical issue of *"what can be described"*.

7 Space Time

- The presentation of the domain analysis & description calculi
  - avoided, in principle, references to space and time;
  - but these concepts are there:
  - "buried" as follows:
    - endurants can be said to "exist" in space and
    - perdurants to "exist" in time.
  - We shall briefly examine these two concepts as they have been the concern of mathematicians.
  - We shall not be interested in the physicists' *spacetime* mathematical model that fuses the three dimensions of space and the one dimension of time into a single four-dimensional continuum.

7.1 Space

Space is the boundless three-dimensional extent in which objects and events have relative position and direction[26]*. Physical space is often conceived in three linear dimensions, although modern physicists usually consider it, with time, to be part of a boundless four-dimensional continuum known as spacetime. The concept of space is considered to be of fundamental importance to an understanding of the physical universe. However, disagreement continues between philosophers over whether it is itself an entity, a relationship between entities, or part of a conceptual framework*[27]*.*

- To us *space* is a conceptual framework.
  - That is, it is not an entity, hence neither an endurant nor a perdurant.
  - Here we shall primarily look at space as a mathematical construction.
  - In Sect. **10** we shall widen that consideration considerably.

[26] https://www.britannica.com/science/space-physics-and-metaphysics
[27] https://en.wikipedia.org/wiki/Space

7.1.1 Topological Space

- One notion of space, in mathematics, is that of a Hausdorf (or topological) space:

Definition 25 Topological Space: *A* **topological space** *is an ordered pair (X, τ), where X is a set and τ is a collection of subsets of X, satisfying the following axioms:*[28]

- *The empty set and X itself belong to τ.*
- *Any (finite or infinite) union of members ofτ still belongs to τ.*
- *The intersection of any finite number of members of τ still belongs to τ* ■

The elements of τ are called **open sets** *and the collection τ is called a* **topology** *on X.*

[28] Armstrong, M. A. (1983) [1979]. Basic Topology. Undergraduate Texts in Mathematics. Springer. ISBN 0-387-90839-0.

7.1.2 Metric Space

- A metric spaces is a set for which distances between all members of the set are defined.
- Those distances, taken together, are called a metric on the set.
- A metric on a space induces topological properties like open and closed sets, which lead to the study of more abstract topological spaces.

Definition 26 Metric Space: *A* **metric space** *is an ordered pair (M, d) where M is a set and d is a metric on M, i.e., a function*

- $d : M \times M \to \mathbb{R}$

such that for any $x, y, z : M$, the following holds:[29]

- *1.* $d(x, y) \geq 0$ — *non-negativity or separation axiom*
- *2.* $d(x, y) = 0 \Leftrightarrow x = y$ — *identity of indiscernibles*
- *3.* $d(x, y) = d(y, x)$ — *symmetry*
- *4.* $d(x, z) \leq d(x, y) + d(y, z)$ — *subadditivity or triangle inequality* ■

[29] B. Choudhary (1992). The Elements of Complex Analysis. New Age International. p.20. ISBN 978-81-224-0399-2.

7.1.3 Euclidian Space

- The notion of *Euclidian Space* is due to *Euclid of Alexandria* [325–265].
- Euclid postulated

Example 29 Euclid's Postulates:

- To draw a straight line from any point to any point.
- To produce [extend] a finite straight line continuously in a straight line.
- To describe a circle with any centre and distance [radius].
- That all right angles are equal to one another.
- [The parallel postulate] That, if a straight line falling on two straight lines make the interior angles on the same side less than two right angles, the two straight lines, if produced indefinitely, meet on that side on which are the angles less than the two right angles ■

Example 30 Euclid's Plane Geometry: The Euclidean geometry informally described in Example 29 can be formally axiomatised by first introducing the sorts P and L:

type
 P, L
value
 [0] obs_Ps: L → P-**infset**
 parallel: L × L → **Bool**

- Observe how the informal axiom in Example 29 has been modelled by the *observer function* obs_Ps.
- It applies to lines and yields possibly infinite sets of points.

- Now we can introduce the axioms proper:

axiom
 [1] $\exists$ p,q:P · p $\neq$ q,
 [2] $\forall$ p,q:P · p $\neq$ q $\Rightarrow$
  $\exists!$ l:L · p $\in$ obs_Ps(l) $\wedge$ q $\in$ obs_Ps(l),
 [3] $\forall$ l:L · $\exists$ p:P · p $\notin$ obs_Ps(l),
 [4] $\forall$ l:L · $\exists$ p:P · p $\notin$ obs_Ps(l) $\Rightarrow$
  $\exists$ l′:L · l$\neq$l′ $\wedge$ p $\in$ obs_Ps(l′) $\wedge$ parallel(l,l′)

- The concept of being parallel is modelled by the predicate symbol of the same name, by its signature and by axiom [4] ■
- We leave it to the listener to reconcile the models of
  - topological space, Defn. 25 [Slide 243], and
  - metric space, Defn. 26 [Slide 244],
- with the axiom systems of examples 29 [Slide 245] and 30 [on the preceding slide].

7.2 Time

```
                                    (i) A moving image of eternity;
                                    (ii) The number of the movement
                               in respect of the before and the after;
           (iii) The life of the soul in movement as it passes
                 from one stage of act or experience to another;
                              (iv) A present of things past: memory,
                                a present of things present: sight,
                         and a present of things future: expectations.
```

[28, (i) Plato, (ii) Aristotle, (iii) Plotinus, (iv) Augustine].

7.2.1 Time — General Issues

- In the following we shall focus
  - on various models of time,
  - and we shall conclude with a simple view of the operations we shall assume when claiming that an abstract type models time.
- Our treatment are far from complete.
- They are necessary, but, as a general treatment of notions of time, they are not sufficient.

7.2.2 "A-Series" and "B-Series" Models of Time

- Colloquially, in ordinary, everyday parlance, we think of time as a dense series of time points.
- We often illustrate time by a usually horizontal line with an arrow pointing towards the right.
- Sometimes that line arrowhead is labeled with either a t or the word *time*, or some such name.
- J.M.E. McTaggart (1908, [29, 30, 31]) discussed theories of time around two notions:
  - **"A-series":** has terms like "past", "present" and "future".
  - **"B-series":** has terms like "precede", "simultaneous" and "follow".

- McTaggart argued that the B-series presupposes the A-series: If t precedes t' then there must be a "thing" t'' at which t is past and t' is present.
- He argued that the A-series is incoherent:
  - What was once 'future', becomes 'present' and then 'past';
- and thus events
  - 'will be events', 'are events' and 'were events',
- that is, will have all three properties.

7.2.3 A Continuum Theory of Time

- The following is taken from Johan van Benthem:
- Let P be a point structure (for example, a set).
- Think of time as a continuum;
- the following axioms characterise ordering ($<, =, >$) relations between (i.e., aspects of) time points.
- The axioms listed below are not thought of as an axiom system, that is, as a set of independent axioms all claimed to hold for the time concept, which we are encircling.
- Instead van Benthem offers the individual axioms as possible "blocks" from which we can then "build" our own time system — one that suits the application at hand, while also fitting our intuition.

- Time is transitive: If $p<p'$ and $p'<p''$ then $p<p''$.
- Time may not loop, that is, is not reflexive: $p \not< p$.
- Linear time can be defined: Either one time comes before, or is equal to, or comes after another time.
- Time can be left-linear, i.e., linear "to the left" of a given time.
  - The following is taken from Johan van Benthem:
  - Let P be a point structure (for example, a set).
  - Think of time as a continuum;
  - the following axioms characterise ordering ($<, =, >$) relations between (i.e., aspects of) time points.
  - The axioms listed below are not thought of as an axiom system, that is, as a set of independent axioms all claimed to hold for the time concept, which we are encircling.
  - Instead van Benthem offers the individual axioms as possible "blocks" from which we can then "build" our own time system — one that suits the application at hand, while also fitting our intuition.

- Time is transitive: If $p<p'$ and $p'<p''$ then $p<p''$.
- Time may not loop, that is, is not reflexive: $p \not< p$.
- Linear time can be defined: Either one time comes before, or is equal to, or comes after another time.
- Time can be left-linear, i.e., linear "to the left" of a given time.
- One could designate a time axis as beginning at some time, that is, having no predecessor times.
- And one can designate a time axis as ending at some time, that is, having no successor times.
- General, past and future successors (predecessors, respectively successors in daily talk) can be defined.
- Time can be dense: Given any two times one can always find a time between them.
- Discrete time can be defined.

axiom

[TRANS: Transitivity] ∀ p,p′,p″:P • p < p′ < p″ ⇒ p < p″
[IRREF: Irreflexitivity] ∀ p:P • p ≮ p
[LIN: Linearity] ∀ p,p′:P • (p=p′ ∨ p<p′ ∨ p>p′)
[L−LIN: Left Linearity] ∀ p,p′,p″:P • (p′<p ∧ p″<p) ⇒ (p′<p″ ∨ p′=p″ ∨ p″<p′)
[BEG: Beginning] ∃ p:P • ∼∃ p′:P • p′<p
[END: Ending] ∃ p:P • ∼∃ p′:P • p<p′
[SUCC: Successor]
  [PAST: Predecessors] ∀ p:P,∃ p′:P • p′<p
  [FUTURE: Successor] ∀ p:P,∃ p′:P • p<p′
[DENS: Dense] ∀ p,p′:P (p<p′ ⇒ ∃ p″:P • p<p″<p′)
[DENS: Converse Dense] ≡ [TRANS: Transitivity]
[DISC: Discrete]
  ∀ p,p′:P • (p<p′ ⇒ ∃ p″:P • (p<p″ ∧ ∼∃ p‴:P • (p<p‴<p″))) ∧
  ∀ p,p′:P • (p<p′ ⇒ ∃ p″:P • (p″<p′ ∧ ∼∃ p‴:P • (p″<p‴<p′)))

- A strict partial order, SPO, is a point structure satisfying TRANS and IRREF.
- TRANS, IRREF and SUCC imply infinite models.
- TRANS and SUCC may have finite, "looping time" models.

7.3 Wayne D. Blizard's Theory of Space–Time

- We now bring space and time together in an axiom system (Wayne D. Blizard, 1980 [32]) which relate abstracted entities to spatial points and time.
  - Let $A, B, \ldots$ stand for entitites, $p, q, \ldots$ for spatial points, and t, τ for times.
  - 0 designates a first, a begin time.
  - Let t' stand for the discrete time successor of time t.
  - Let $N(p, q)$ express that p and q are spatial neighbours.
  - Let $=$ be an overloaded equality operator applicable, pairwise to entities, spatial locations and times, respectively.
  - A^t_p expresses that entity A is at location p at time t.
  - The axioms — where we omit (obvious) typings (of A, B, P, Q, and T):
  - $'$ designates the time successsor function: t'.

(I)	$\forall A \forall t \exists p \ : \ A^t_p$	
(II)	$(A^t_p \wedge A^t_q) \supset p = q$	
(III)	$(A^t_p \wedge B^t_p) \supset A = B$	
$(IV)(?)$	$(A^t_p \wedge A^{t'}_p) \supset t = t'$	
$(V\ \ i)$	$\forall p, q \ : \ N(p,q) \supset p \neq q$	Irreflexivity
$(V\ \ ii)$	$\forall p, q \ : \ N(p,q) = N(q,p)$	Symmetry
$(V\ \ iii)$	$\forall p \exists q, r \ : \ N(p,q) \wedge N(p,r) \wedge q \neq r$	No isolated locations
$(VI\ \ i)$	$\forall t \ : \ t \neq t'$	
$(VI\ \ ii)$	$\forall t \ : \ t' \neq 0$	
$(VI\ \ iii)$	$\forall t \ : \ t \neq 0 \supset \exists \tau : t = \tau'$	
$(VI\ \ iv)$	$\forall t, \tau \ : \ \tau' = t' \supset \tau = t$	
(VII)	$A^t_p \wedge A^{t'}_q \supset N(p,q)$	
$(VIII)$	$A^t_p \wedge B^t_q \wedge N(p,q) \supset \sim (A^{t'}_q \wedge B^{t'}_p)$	

- We comment on these axioms:
  - II–IV,VII–VIII: The axioms are universally 'closed'; that is: We have omitted the usual $\forall A, B, p, q, t$s.
  - (I): For every entity, A, and every time, t, there is a location, p, at which A is located at time t.
  - (II): An entity cannot be in two locations at the same time.
  - (III): Two distinct entities cannot be at the same location at the same time.
  - (IV): Entities always move: An entity cannot be at the same location at different times. *This is more like a conjecture: Could be questioned.*
  - (V): These three axioms define N.
  - (V i): Same as $\forall p :\sim N(p,p)$. "Being a neighbour of", is the same as "being distinct from".
  - (V ii): If p is a neighbour of q, then q is a neighbour of p.
  - (V iii): Every location has at least two distinct neighbours.

- (VI): The next four axioms determine the time successor function $'$.
- (VI i): A time is always distinct from its successor: time cannot rest. There are no time fix points.
- (VI ii): Any time successor is distinct from the begin time. Time 0 has no predecessor.
- (VI iii): Every non–begin time has an immediate predecessor.
- (VI iv): The time successor function $'$ is a one–to–one (i.e., a bijection) function.
- (VII): The *continuous path axiom:* If entity A is at location p at time t, and it is at location q in the immediate next time (t'), then p and q are neighbours.
- (VIII): *No "switching":* If entities A and B occupy neighbouring locations at time t them it is not possible for A and B to have switched locations at the next time (t').

- Except for Axiom (IV) the system applies both to systems of entities that "sometimes" rests, i.e., do not move.
- These entities are spatial and occupy at least a point in space.
- If some entities "occupy more" space volume than others, then we may suitably "repair" the notion of the point space P (etc.).
- We do not show so here.

Segment III: A Philosophy Basis

8 A Task of Philosophy

- *Philosophy* is the study of
  - general and fundamental problems concerning matters such as
    - *existence*,
    - *knowledge*[30],
    - *values*,
    - *reason*,
    - *mind*, and
    - *language*.

[30] including Scientific Knowledge: Mathematics, Physics, Computer Science, etc.

8.1 Epistemology

- We shall focus on *existence*, specifically on *epistemology* –
  - meaning 'knowledge' and 'logical discourse' –
  - it is the branch of philosophy concerned with the theory of knowledge.

- Epistemology studies the nature of knowledge, justification, and the rationality of belief.
- Much of the debate in epistemology centers on four areas:
  - (1) the philosophical analysis of the nature of knowledge and how it relates to such concepts as truth, belief, and justification,
  - (2) various problems of skepticism,
  - (3) the sources and scope of knowledge and justified belief, and
  - (4) the criteria for knowledge and justification.
- Epistemology addresses such questions as
  - "What makes justified beliefs justified?",
  - "What does it mean to say that we know something?",

  and fundamentally
- "How do we know that we know?"

8.2 Ontology

- A *"corollary"* of epistemology is *ontology*:
  - the philosophical study of the nature of
    - *being*,
    - *becoming*,
    - *existence*, or
    - *reality*,
  - as well as the *basic categories of being and their relations.*

8.3 The Quest

- The ***quest*** is now threefold.
  - (i) First to prepare the ground for a discussion of possible philosophical issues of the domain analysis & description calculi.
    - We do so by a review of philosophy (Slides 270–324) focusing on epistemology and ontology problems –
    - from the ancient Greek philosophers till Bertrand Russell.

  - (ii) Then to follow that up with a review of the Philosophy of Kai Sørlander
    - as it is, most recently, expressed in [18], and
    - as refined from earlier works: [15, 16, 17].
    - This is done in Sect. **10**, Slides 324–381.
  - (iii) Finally to show, issue-by-issue
    - how concepts of the domain analysis & description calculi
    - more have a basis in philosophy
    - than in mathematics and computer science.
    - This is done in Sect. **11**, Slides 383–430.

8.4 Schools of Philosophy

- We shall only cover Western Philosophy to some depth.
  - A seven line summary will be give, in Sect. **8.4.2**,
  - of a possibly relevant aspect of Indian Philosophy.
  - We'll leave it at that.
  - The fact is that Indian Philosophy has not, it appears, influenced Western Philosophy.
  - That short summary are in line the choice of issues that we seek to uncover.

8.4.1 Western Philosophy

- Section **9** presents a "capsule" summary of Western Philosophy.
  - It is, at present, a "tour de force", seven pages.
  - One purpose of presenting it is that we are then able to enumerate and date the issues relevant to our quest while discarding some of the proposed theories.
  - Another purpose is to remind the reader of the depth, breadth and plurality of issues of Western Philosophy.

8.4.2 Indian Philosophy

- *Pramana, literally means "proof" and "means of knowledge",*
  - *refers to epistemology in Indian philosophies,*
  - *The focus of Pramana is how correct knowledge can be acquired,*
  - *how one knows, how one doesn't, and*
  - *to what extent knowledge pertinent about someone or something can be acquired.*
  - *Ancient and medieval Indian texts identify six pramanas as correct means of accurate knowledge and to truths:*
    - *(1) perception,*
    - *(2) inference,*
    - *(3) comparison and analogy,*
    - *(4) postulation,*
    - *(5) derivation from circumstances, non-perception, negative/cognitive proof, and*
    - *(6) word, testimony of past or present reliable experts*[31].

[31] https://en.wikipedia.org/wiki/Pramana

9 From Ancient to Kantian Philosophy and Beyond !

- The review of this section is based primarily on [15].
  - It is exclusively "slanted" towards those aspects
  - of the thinking of these philosophers with respect to
  - the ***task of philosophy*** as we defined it in Sect. **8**.
- In this review we reject the contributions of these great philosophers that is contradictory.
- This presentational "bias"
  - should in no way stand in way of our
  - general admiration for their otherwise profound thinking.

9.1 Pre-Socrates

- A number of pre-Socratian thinkers speculated on how the world was "constructed".
  - The earlier thinkers were pre-occupied with ***matter***,
  - that is, ***substance***;
  - what did the world consist of,
  - how was it constructed ?
- In doing that these thinkers
  - were trying to be scientists,
  - they were not, in this philosophers.

- We briefly review some of the pre-Socratian thinkers and philosophers.
- **Thales of Miletus, 624–546 BC**
  - *"claimed*[32] *that all existing, i.e.,* **base matter***, derived from* **water***"*;
- **Anaximander of Miletus, 610–546 BC**
  - *"that* **base matter** *all came from* **apeiron***,*
  - *some further unspecified substance"*;
- **Anaximenes of Miletus, 585–528 BC**
  - *"that* **base matter** *was* **air***"*;

[32] [18, pp 35] refers to Sørlander's book [18] Page 35.

- **Heraklit of Efesos, a. 500 BC**
  - *"claimed that* fire *was the* base matter*; and*
  - *extended the concern from* substance *to* permanence
  - *and based the thinking not only on* (empirical) observations *but also on* logical reasoning
    - *claiming that everything in the world*
    - *was in a constant struggle,*
    - *all the time changing –*
    - *so since all is* changing*, i.e., that nothing is* stable*,*
    - *he concludes that* nothing exists*."*
  - In that Heraklit was a philosopher.

- And, from now, philosophy reigned.
- **Parmenides of Elea, 501–470 BC**
  - *"counterclaimed that that which actually exists*
    - *is* eternal *and* unchanging *–*
  - *is logically impossible"*;

- **Zeno of Elea, 490–430 BC**
  - *"supported Parmenindes' claim by claiming some paradox,*
  - *i.e., the well-known Achilles and the tortoise –*
  - *thereby introducing* dialectic reasoning *and* proof by contradiction (reductio ad absurdum)*"*;
- **Demokrit, 460–370 BC**
  - *"tried to unify Heraklit's concept of* changeability *and Parmenides' concept of* permanence *in a new way;*
  - *everything in the world is built from, consists of* atoms
  - *and change is due to movement of atoms"*.

- **The Sophists, 5th Century BC**
  - *"doubted, or even refuted,*
  - *that we can arrive at universal truths*
  - *about the world purely through reasoning.*
- They refute
  - that there is an objectively true reality
  - which we can obtain knowledge about.
- So, instead, skepticism reigned".

• • •

What is interesting, to us, is that,

- the thinking of even the early Greek thinkers
- delineates the realms of religion and mythology
- on one side,
- and those of science and philosophy,
- on the other side.

9.2 Plato, Socrates and Aristotle

- **Socrates, 470–399 BC**
  - *"protested against the sophists' refusal of*
    - *reason,*
    - *common sense,*
    - *sanity and*
    - *prudence".*
  - We know of Socrates' thinking almost exclusively through

- **Plato, 427–347 BC**:
  - *"We shall focus on Plato's theory of ideas.*
    - *His argument is that non-physical (but substantial) ideas*
    - *represent the most accurate reality.*
    - *Abstract and common concepts obtain meaning*
    - *through standing for ideas that are eternal and unchangeable.*

- *In contrast to ideas Plato considers the concept of a phenomenon.*
  - *Phenomena are instances of ideas.*
  - *We recognize a phenomenon because it embodies an idea.*
- *So, according to Plato,*
  - *the changeable world that surrounds us,*
  - *one which we experience through our senses,*
  - *is only a reflection of a, or the, real world.*
  - *That real world is unchangeable*
  - *and "consists" of ideas".*[33]

[33] One may, rather crudely, interpret Plato's concept of ideas with that of types. A value of some type is then a 'phenomenon'.

- **Aristotle, 384–322 BC**.
  - *"For Aristotle it was*
    - *not Plato's **abstract ideas** that "existed"*
    - *but the **concrete world** of which we are a part of with our body.*
  - *The abstract ideas, however, in Aristotle's thinking, constitute a system for describing the world.*[34]

[34] It should be quite clear, to the listener, that, in this, we follow Aristotle: A main descriptional, in fact, specificational, tool is that of ***type definitions***.

- *We shall very briefly list two of the concept clusters that Aristotle made to our thinking of the world:*
  - *(i) **modalities** and*
  - *(ii) **explanations***
    – *the latter also referred to as **causes.***
- *The **modalities** are:*
  - *(i.1) **necessity**, that which is unavoidably so;*
  - *(i.2) **reality**, that which we observe; and*
  - *(i.3) **possibility**, that which might be.*
- *The **causes** (or **explanations**) are:*
  - *(ii.1) **matter** or **material cause**,*
  - *(ii.2) **form cause** or **formal cause***
  - *(ii.3) **agent cause** and*
  - *(ii.4) **end cause** or **purpose cause***

- (ii.1) By ***material cause*** Aristotle means
  - the aspect of the change or movement
  - which is determined by the material
  - that composes the moving or changing things.
- (ii.2) By ***form*** or ***formal cause*** Aristotle means
  - a change or movement's ***formal cause***,
  - is a change or movement caused by
  - the arrangement, shape or appearance
  - of the thing changing or moving.

- (ii.3) By ***agent cause*** Aristotle means
  - a change or movement's efficient or moving cause,
  - consists of things apart from the thing being changed or moved,
  - which interact so as to be an agency of the change or movement.
- (ii.4) By ***end cause*** or ***purpose cause*** Aristotle means
  - a change or movement's final cause,
  - is that for the sake of which a thing is what it is.

- Aristotle's contributions are, for us, decisive.
  - Aristotle reveals how *being* is
  - by revealing the *irreducible types of predicates*
  - which we can actually use when *describing the world*.
  - Aristotle thus examines the *categories*:
    - *substance* (human, horse),
    - *quantity* (6 feet tall),
    - *quality* (white, red),
    - *relation* (larger, shorter),
    - *location* (in Athens),
    - *time* (yesterday, last year),
    - *position* (lying, sitting),
    - *posture* (wearing shoes),
    - *action* (running, singing), and
    - *suffering* (being cut).
  - This enumeration[35] is certainly not definitive.

[35] *"Of things said without any combination, each signifies either substance or quantity or qualification or a relative or where or when or being-in-a-position or having or doing or being-affected. To give a rough idea, examples of substance are man, horse; of quantity: four-foot, five-foot; of qualification: white, grammatical; of a relative: double, half, larger; of where: in the Lyceum, in the market-place; of when: yesterday, last-year; of being-in-a-*

- Kant, two thousand years later,
  - revives this idea: a *system of unavoidable basic concepts*
  - for the description of the world and our situation in it."[36]

position: is-lying, is-sitting; of having: has-shoes-on, has-armour-on; of doing: cutting, burning; of being-affected: being-cut, being-burned." Ackrill, John (1963). Aristotle, Categories and De Interpretatione. Oxford: At the Clarendon Press. ISBN 0198720866.

[36] It should likewise be obvious to the listener that the notion of *categories* is central to our ontological structuring of domain entities.

9.3 The Stoics: 300 BC–200 AD

- We shall just focus on one aspect of their contribution to logic and philosophy, that of logic.
- *"They distinguish between*
  - *simple propositions and*
  - *composite propositions.*
- *They also distinguish between three kinds of propositions.*
  - *implication,*
  - *conjunction and*
  - *disjunction.*

- *They had a special understanding of implication:*
  - *A proposition is, to the Stoics, of the composite form:*
    - $A \Rightarrow B; A; B$. *For example:*
      - If it is day then it is light;
      - it is day;
      - therefore it is light.
  - *In this and many other ways they contributed to the philosophy of logic (from which, it seems Gottlob Frege was inspired)".*
- **Chrysippus of Soli: 279–206 BC** *was a prominent early Stoic.*

•••

- Almost two thousand years passed before philosophy again flourished.
  - *Christianity*, in Europe, in a sense, "monopolised" critical thinking.
  - With the *Renaissance* and *Martin Luther's Protestantism* thinkers again turned to philosophy.

9.4 The Rational Tradition: Descartes,

René Descartes: 1596–1650

- *"rejected the splitting of* corporeal substance *into* matter *and* form*.*
- *His main focus was on the relations between* mind *and* form*:*
  - *as thinking substance*
  - *we recognize material substance".*

Baruch Spinoza: 1632–1677

- *"rejected Descartes's two substances:*
- *there is, he claims, is only one substance;*
- *for Spinoza God and nature was one and the same".*

Gottfried Wilhelm Leibniz: 1646–1716

- *"introduced the* Law of the Indiscernability of Identicals*,*
- *It is still in wide use today.*
- *It states that*
  - *if some object x is identical to some object y,*
  - *then any property that x has, y will have as well".*[37]

[37] We refer, forward, to Sect. **10.2.1** [Slide 341], and, 'backward', to Sect. **2.6** [Slide 97] [*unique identifiers*], for our "response" to Leibniz's *Law of the Indiscernability of Identicals*.

9.5 The Empirical Tradition: Locke, Berkeley and Hume

John Locke: 1632–1704.

- We focus on Locke's ideas of ***sensing***.
- He defines himself[38]:

as that conscious thinking thing,
(whatever substance, made up of whether spiritual,
or material, simple, or compounded, it matters not)
which is sensible, or conscious of pleasure and pain,
capable of happiness or misery,
and so is concerned for itself,
as far as that consciousness extends.

[38] Locke, John (1997), Woolhouse, Roger, ed., *An Essay Concerning Human Understanding*, New York: Penguin Books

- *"According to Locke,*
  - *humans obtain their knowledge about the world through sensory perception.*
  - *At one level, he claims, the world is "mechanical",*
  - *so our sensory apparatus is influenced mechanically,*
  - *for example through tactile or visual means.*
- *This sense information is then communicated to our brains.*
  - *First the mechanical sense data become* **sense ideas**,
  - *The sense ideas then become* **reflection ideas**.*"*
  - In the "jargon" of our domain analysis & description method
    - the ***sense ideas*** are ***values*** and
    - the ***reflection ideas*** become ***types***.

- *So a central idea in Locke's theory is that*
  - *all* **cognition**
  - *builds on our* **reflection** *over* **sense ideas**.
- *In other words:*
  - *"Can we conclude anything*
  - *from our sense ideas to*
  - *knowledge about those "outer" things*
  - *which cause the sense ideas ?" [18, pg. 85]*
- *To answer that question Locke goes on to distinguish*[39] *between*
  - *"***primary qualities***[40] *and*
  - ***secondary qualities***[41].

[39] https://en.wikipedia.org/wiki/Primary/secondary_quality_distinction

[40] Primary qualities are thought to be properties of objects that are independent of any observer, such as solidity, extension, motion, number and figure. These characteristics convey facts. They exist in the thing itself, can be determined with certainty, and do not rely on subjective judgments. For example, if an object is spherical, no one can reasonably argue that it is triangular.

[41] Secondary qualities are thought to be properties that produce sensations in observers, such as color, taste, smell, and sound. They can be described as the effect things have on certain people. Knowledge that comes from secondary qualities does not provide objective facts about things.

- *In the jargon of domain analysis & description*
  - *the primary qualities correspond to "our"* **external qualities**,
  - *the secondary qualities to "our"* **internal qualities**,
  - *but not quite !*
- *"Locke views*
  - *primary qualities as measurable aspects of physical reality and*
  - *secondary qualities as subjective aspects of physical reality,*

  where "our" domain analysis & description takes both to be somehow measurable.
- *We must therefore claim that our distinction is purely pragmatic".*

- Locke now claims:
  - *"(i) that we can, with respect to the primary qualities, deduce from our sense ideas to the reality, the world behind these;*
  - *(ii) that the primary qualities exist in reality independent of whether we "experience" them or not; and*
  - *(iii) that this is not the case for the secondary qualities which exist only in our* **consciousness***".*

George Berkeley: 1685–1753

- *"points out a problem in Locke's theory:*
  - *namely that Locke's distinction between*
    - *primary qualities as being* objective *and*
    - *secondary qualities as being* subjective

    does not hold.
  - *He argues that primary qualities can be subjective.*

- *To solve that problem Berkeley*
  - *denied the existence of a reality "behind" the sense ideas:*
  - *there is no material reality;*
  - *reality is our sense ideas:* esse est precipi[42] *!*
  - *The material reality is there because it is continuously experienced by 'God'.*
- *The problem now is*
  - *can we, at all, determine fundamental characteristics*
  - *about the world and our situation as humans in that world*
  - *without assuming the concept of independently existing substance".*

[42] "to-be-is-to-be-perceived"

David Hume, 1711–1776.

- Hume's major work was *An Enquiry Concerning Human Understanding* [33].
- *"Where Berkeley eliminated* material substance
  - *Hume also eliminated Berkeley's concepts of 'God' and 'Consciousness'.*
  - *He claimed that the basic sense-impressions,*
  - *which to Hume were the basis for all valid human recognition,*
  - *made it impossible to arrive at a valid recognition*
  - *of 'God' and a substantial 'I'.*
  - *They must therefore be eliminated*
  - *when trying to describe the world and our situation in it.*

- *According to Hume all that we know are*
  - sense impressions
  - *and the* conceptions *derived from these.*
- *Hume further distinguishes between*
  - composite *and*
  - simple *(not-composite)*

  sense impressions.
- *Correspondingly Hume distinguishes between*
  - composite *and*
  - simple *(non-composite)*

  ideas.

- *As a consequence*
  - *there is no* **necessity** *in the world,*
  - *nor in possible relations between* **cause** *and* **effect**
  - *This renders Hume's thinking in this area very problematic".*

9.6 Immanuel Kant: 1720–1804

- *"Kant was "shaken" by Hume's critique of causality.*
  - *As a response – along one line of thought – Kant introduced two notions:*
    - "Das Ding an sich" *is the world that we know, that we sense, and*
    - "Das Ding für uns" *is a world prior to, outside our cognition.*
  - *Along another line of thought Kant claimed that there is our cognition.*
    - *By means of the cognitive tools with which our reason is equipped*
    - *we reach out for* "Das Ding an sich"
    - *and forms it according to our cognition.*
    - *The result is the world as we know it.*

- *This means that* **reality**
  - *never means the* "Das Ding an sich"*,*
  - *the world "outside" us, "independent" of us.*
  - *We are excluded from that world".*
- *"Kant turns the reasoning around.*
  - *What we empirically observe is determined by our "reasoning apparatus".*
  - *We do not observe "things" as they are in themselves (*"Das Ding an sich"*), but we "recognize" them as they are formed by our own reasoning apparatus.*

- *This "reasoning apparatus" includes some* **intuition forms:**
  - **space** *and*
  - **time.**
- *These, space and time, are therefore, to Kant,*
  - *not characteristics of the world as it is,*
  - *but are some* **intuition forms**
  - *that determine our view of the world.*

- *How can it now be possible*
  - *that we can have* self-awareness
  - *on the basis of what we are confronted with – what we see ?*
- *Here Kant introduces what he terms the* **transcendental deduction**.
  - *We can only have* self awareness
  - *under the assumption that we experience our* views (outlook)
  - *as expression of objects, "things", that exist*
  - *independent of our experiencing them !"*

- *"But Kant's concept of "*Das Ding an sich*" is inconsistent.*
  - *It is in* contradiction*,*
    - *because it itself is* knowable
    - *as being* unknowable*;*
  - *and it is in contradiction,*
    - *because it, in a mystical sense,*
    - *is the* cause *of the thing*
    - *which we know as a phenomenon,*
    - *but (we) cannot apply the* cause effect category *outside the world of phenomena".*

- *A main contribution of Kant however, is his concept of* Transcendental Schemata[43].
  - *"If pure concepts of the understanding (categories) and sensations are radically different, what common quality allows them to relate?"*
  - *Kant wrote the chapter on Schemata in his* Critique of Pure Reason *to solve the problem of "...how we can ensure that categories have 'sense and significance'".*

[43] In Kantian philosophy, a transcendental schema (plural: schemata; from Greek: $\sigma\chi\eta\mu\alpha$, "form, shape, figure") is the procedural rule by which a category or pure, non-empirical concept is associated with a sense impression. A private, subjective intuition is thereby discursively thought to be a representation of an external object. Transcendental schemata are supposedly produced by the imagination in relation to time https://en.wikipedia.org/wiki/Schema_(Kant)#Transcendental_schemata.

- *Transcendental schema are not related to empirical concepts or to mathematical concepts.*
  - *These schemata connect pure concepts of the understanding, or categories,*
  - *to the phenomenal appearance of objects in general,*
  - *that is, objects as such, or all objects*[44].

[44] Körner, S., Kant, Penguin Books, 1990. p. 72

- *Example* categorical schemas *are:*
  - *The categories of quantity all share the schema of number.*
  - *The categories of quality all have degrees of reality as their schema.*
  - *"The schema of the category of relation is the order of time"*[45].
  - *"The schema of the category of modality is time itself as related to the existence of the object"*[46].

[45] William Henty Stanley Monck, Introduction to the Critical Philosophy. Publ. Dublin, W. McGee, 1874, p.44.
[46] See footnote 45 above.

9.7 Post-Kant

- **Johann Gottlieb Fichte, 1752–1824**
  - *"tried to avoid Kant's* Das Ding an sich/Das Ding für uns *dualism*
    - *by letting the subject, the I, determine the object, the not-I,*
    - *but ends up in contradiction".*

- **Georg Wilhelm Friedrich Hegel, 1770–1831**
  - *"also dissolves the Kantian dualism.*
  - *He builds an impressive theory.*
  - *The basis for this theory is*
    - *the assumption of a deep-seated identity between*
    - reason *(*sense*) and* reality*:*
      - "the reasonable is real" *and*
      - "the real is reasonable"*.*
  - *Hegel saw his understanding of this duality in the light of* history*.*

- Hegel thus saw truth, reason and reality historically.
  - "Modern" dialectism was born.
  - Now two contradictory philosophies could now be both true.
  - From this Hegel developed an impressive "apparatus":
    - From "nothingness" via "creation", "quality", quantity"
    - to "essence", "cause", "reality", "causality",
    - and on to "concept", "life" and "cognition"
    - ending with the "absolute"" !

- And there we end!
  - We must reject Hegel's *thesis, antithesis, synthesis*.
  - By relativising philosophy wrt. history Hegel
    - has removed necessity.
  - By thus postulating that
    - *"it is an eternal truth that we cannot achieve eternal truths"*.

    Hegel's main contribution ends up in contradiction.

- **Friedrich Schelling, 1775–1854**,
  - *"goes further*
    - *by removing the* ***subject/object*** *distinction*
    - *claiming an underlying identity between these,*
    - *that is, between mind and matter:*
      - *nature is the visible mind, and*
      - *mind is the invisible nature.*
  - *Again this attempt brings Schelling's work into contradictions".*

- **Friedrich Ludwig Gottlob Frege, 1848–1925**.
  - Although primarily a mathematician and logician, Frege contributed to Philosophy.
  - Amongst his contributions were the distinction between
    - *"sinn"* (*sense*), and
    - *"bedeutung"* (*reference*).
  - The distinction[47] is:
    - the reference (or "referent"; bedeutung) of a proper name is the object it means or indicates (bedeuten),
    - its sense (Sinn) is what the name expresses.
    - The reference of a sentence is its truth value,
    - its sense is the thought that it expresses.

[47] *On Sense and Reference* [*"Über Sinn und Bedeutung"*], Zeitschrift für Philosophie und philosophische Kritik, vol. 100 (1892), pp. 25–50

- **Edmund Husserl, 1859–1938**,
  - *"founded a school of* ***phenomenology****.*
    - *To Husserl our conscience is characterised by* ***intentionality****.*
    - *Cognition is an* ***act*** *which is* ***directed*** *at something.*
      - *When I see, I see something.*
      - *When I think, I think something.*
    - *Philosophy, to Husserl, should build on this insight.*
      - *It should investigate that which conscience is directed at from "within", and without prejudice of what it might be.*
      - *Husserl expressed clearly the difference between* ***meaning*** *and* ***object****".*
    - *But as [15, pp 115-116] shows, Husserl thereby ends up in an inconsistent theory.*

- **Bertrand Russell, 1872–1970**,
  - *"amongst very many contributions put forward a* Philosophy of Logical Atomism *[34].*
  - *It is based on the formal logic developed Russell and Whitehead in [35, Principia Mathematica].*
  - *That formal logic distinguishes between simple and complex propositions; the latter being truth functions over simple propositions.*
  - Logical Atomism *now claims that the world must be describable by independent simple propositions.*
  - *This requires that simple empirical propositions must be logically independent of one another.*

- *This again requires that the meaning of a simple empirical proposition alone must depend on a relation between the simple proposition and that which it stands for in reality.*
- *The meaning of a word is that "object" which the word "denotes".*
- *This is similar to Wittgenstein's theory.*

- *The problem is that the requirement*
- *that the simple, elementary propositions must be*
- *logically independent of one another*
- *makes it impossible to find such elementary propositions.*
- *It is therefore impossible to find those "objects" that the elementary propositions are supposed to denote.*
- *The whole of* Logical Atomism *thus builds on an erroneous extrapolation from formal logic".*

- **Logical Positivism: 1920s–1936**
  - was a "circle" if philosophers, mostly based in Vienna, cf. **Wiener Kreis**.
  - *"They did not adopt Russell's* Logical Atomism*.*
  - *Instead they claimed that the meaning of a sentence is its conditions for being true:*
    - *i.e., a description of all facts that must be the case*
    - *in order for the sentence to be judged true;*
    - *that is, the* verification conditions*.*
  - *But the problem here is that if the* verification conditions *are a valid* meaning criterion*, then its own formulation cannot be meaningful !*
  - *So logical positivism ends up in contradiction".*

- **Ludwig Wittgenstein, 1889–1951** was not a member of the *Vienna Circle*, but his early work was much discussed in the Circle.
  - *"This work of Wittgenstein was Tractatus Logico-Philosophicus [36, 1921].*
    - *Tractatus, as did Logical Positivism, basically takes language as a departure point for a philosophical analysis of the world and our situation in it.*
    - *But both these theories build on self-refusing bases.*
    - *Wittgenstein understood that his Tractatus was built on a too simple meaning theory, i.e., a theory of how meaning is ascribed to sentences.*
  - *In Philosophische Untersuchungen [37] Wittgenstein explores new directions – which have no bearing on our quest."*

9.8 Bertrand Russell – Again !

- We bring an excerpt from Russell's *History of Western Philosophy*[48] [49]
  - *From all this it seems to follow that events, not particles, must be the 'stuff' of physics.*
  - *What has been thought of as a particle will have to be thought of as a series of events.*
  - *The series of events that replaces a particle has certain important physical properties, and therefore demands our attention;*
  - *but it has no more substantiality than any other series of events that we might arbitrarily single out.*
  - *Thus 'matter' is not part of the ultimate material of the world, but merely a convenient way of collecting events into bundles."*

[48] Chap. XXXI: The Philosophy of Logical Analysis, pp 786–788

[49] The excerpt reflects Russell's thinking, around 1945, influenced, it appears, by quantum physics.

- We cannot, but point out, the "similarity"
  - of these observations to our transcendental deduction
  - of behaviours from parts.

• • •

- We have surveyed ideas of 32 philosophers – ideas relevant to our quest:
  - that of understanding borderlines between
  - philosophical arguments and
  - formal, mathematical arguments
  - as they relate to domain analysis & description.
- We shall now turn to elucidate these.

10 The Kai Sørlander Philosophy

- We shall review an essence of [15, 18].
  - Kai Sørlander 's objective
    - *"is to investigate the philosophical question:*
    - *'what are the necessary characteristics of*
    - *each and every possible world*
    - *and our situation in it'.*
  - *We can reformulate this question into*
    - *the task of determining*
    - *the necessary logical conditions*
    - *for every possible description of*
    - *the world and our situation in it".*

10.1 The Basis

- In this section we shall mostly quote from [15].
  - "*The world is all that is the case. All that can be described in true propositions.*"
  - "*In science we investigate how the world is factually.*"
  - "*Philosophy puts forward another question. We ask of what could not consistently be otherwise.*" [50 :1,2,3]

[50] [15], : [1] pg. 13, ℓ 2–3, [2] pg. 13, ℓ 7–8, [3] pg. 13, ℓ 11–12

The Inescapable Meaning Assignment:

- "*It is thus the task of philosophy to determine the inescapable characteristics of the world and our situation in it.*"
  - In determining these inescapable characteristic "*we cannot refer to our experience ... since the experience cannot tell us anything that could not consistently be otherwise.*"
  - "*Two demands must be satisfied by the philosophical basis. The first is that it must not be based on empirical premises. The other is that it cannot consistently be refuted by anybody under any conceivable circumstances. These demands can only be satisfied by one assumption.*"

- We shall refer to this assumption as:

The Inescapable Meaning Assignment

- The *The Inescapable Meaning Assignment* is[51] the recognition of the mutual dependency between
  - *the meaning of designations and*
  - *the consistency relations between propositions.*

- As an example of what "goes into" *the inescapable meaning assignment* we bring, albeit from the world of computer science, that of the description of the *stack* data type (its entities and operations).

[51] [15], pg. 13-14, ℓ13-ℓ1

The Meaning of Designations Stacks - A Narrative

81 Stacks, s:S, have elements, e:E;
82 the empty_S operation takes no arguments and yields a result stack;
83 the is_empty_S operation takes an argument stack and yields a Boolean value result.
84 the stack operation takes two arguments: an element and a stack and yields a result stack.
85 the unstack operation takes an non-empty argument stack and yields a stack result.
86 the top operation takes an non-empty argument stack and yields an element result.

The consistency relations:

2

87 an empty_S stack is_empty,
and a stack with at least one element is not;

88 unstacking an argument stack, stack(e,s),
results in the stack s; and

89 inquiring as to the top of
a non-empty argument stack, stack(e,s),
yields e.

The meaning of designations:

3

type

81. E, S

value

82. empty_S: **Unit** $\rightarrow$ S
83. is_empty_S: S $\rightarrow$ **Bool**
84. stack: E $\times$ S $\rightarrow$ S
85. unstack: S $\stackrel{\sim}{\rightarrow}$ S
86. top: S $\stackrel{\sim}{\rightarrow}$ E

The consistency relations:

87. is_empty(empty_S()) = **true**
87. is_empty(stack(e,s)) = **false**
88. unstack(stack(e,s)) = s
89. top(stack(e,s)) = e

End of Example

Necessary and Empirical Propositions:

- *"That* the inescapable meaning assignment *is required in order to answer the question of how the world must necessarily be can be seen from the following."*
  - *"It makes it possible to distinguish between necessary and empirical propositions."*
  - *"***A proposition is necessary** *if its truth value depends only on the meaning of the designators by means of which it is expressed."*
  - *"***A proposition is empirical** *if its truth value does not so depend."*
  - *"An empirical proposition must therefore refer to something ... which exists independently of its designators, and it must predicate something about the thing to which it refers."*

- The definition *"the world is all that is the case. All that can be described in true propositions."*[52 :1,2,3,4,5] satisfies *the inescapable meaning assignment*.
- *"That which is described in* ***necessary*** *propositions is that which is common to [all] possible worlds. A concrete world is all that can be described in true* ***empirical*** *propositions."*[53]

[52] [15], : [1] pg. 13, ℓ 16–17; [2] pg. 13, ℓ 17–18; [3] pg. 13, ℓ 20–21; [4] pg. 14, ℓ 26–30; [5] pg. 13, ℓ 2–3
[53] [15], pg.15, ℓ15-18

Primary Objects:

- *"an empirical proposition must refer to an independently existing thing and must predicate something about that thing. On that basis it is then possible to deduce how those objects that can be directly referred to in simple empirical propositions must necessarily be. Those things are referred to as* **`primary objects`**.
- *A deduction of*
- *the* **`inevitable characteristics`** *of a possible world*
- *is thus identical to a deduction of*
- *how primary objects must necessarily be."*[54]

[54] [15], pg.15, ℓ23-30

Two Requirements to the Philosophical Basis:

- *"Two demands have been put to the philosophical basis for our quest.*
- *It must not contain empirical preconditions;*
- *and the foundation must not consistently be refuted.*
- *It must not consistently be false."*[55]
- **The inescapable meaning assignment:**
  - *'the meaning of designations and*
  - *the consistency relations between propositions'*[56]

  … satisfies this basis.[57]

[55] [15], pg. 30, ℓ 6–12
[56] [15], pg. 13-14, ℓ13-ℓ1
[57] [15], pg. 30, ℓ 16–28

The Possibility of Truth:

- Where Kant builds on the *contradictory* dichotomy of
  - *Das Ding an sich* and
  - *Das Ding für uns*,

  that is, the possibility of *self-awareness*,
- Kai Sørlander builds on the *possibility of truth*:
  - *"since the possibility of truth cannot in a consistent manner be denied*
  - *we can hence assume the* **contradiction principle:**
  - *'a proposition and its negation cannot both be true'.*
  - *We assume that the contradiction principle is a necessary truth*[58]*"*

[58] *"A necessary truth, on one side, follows from the meaning of the designations by means of which it is expressed, and, on the other side and at the same instance, define these designations and their mutual meaning."*

The Logical Connectives:

- Sørlander now deduces the logical connectives:
  - *conjunction* ('and' $\wedge$),
  - *disjunction* ('or', $\vee$), and
  - *implication* ($\Rightarrow$ or $\supset$).

Necessity and Possibility:

- *"A proposition is necessarily true,*
  - *if its truth follows from the definition of of the designations*
  - *by means of which it is expressed;*
  - *then it must be true under all circumstances.*
- *A proposition is possibly true,*
  - *if its negation*
  - *is not necessarily true".*

Empirical Propositions:

- An *empirical proposition*
  - refers to an independently existing entities
  - and predicates something that can be
  - either true or false
  - about the referenced entity.
- The entities that are referenced in empirical propositions
  - have not been completely characterised by these propositions;
  - they are simply
    those that can be referenced in empirical propositions.

10.2 Logical Conditions for Describing Physical Worlds

- So
  - which are the logical conditions
  - of descriptions of any world?
- In [15] and [18] Kai Sørlander ,
  - through a series of transcendental deductions
  - "unravels" the following logical conditions:
    - symmetry and asymmetry
    - transitivity and intransitivity,
    - space: direction, distance,
    - time: before, after,
    - states and causality,
    - kinematics, dynamics,
    - Newton's laws,
    - et cetera.

- We shall summarise Sørlander's deductions.
- To remind the listener:
  - the issue is that of deducing how
  - the *primary entities*
  - must necessarily be.

10.2.1 Symmetry and Asymmetry

- *"There can be different* **primary entities***.*
  - *Entity A is* **different** *from entity B*
    - *if A can be ascribed a predicate*
    - *in-commensurable with a predicate ascribed to B.*
  - *'Different from' is a* **symmetric predicate***.*
  - *If entity A is* **identical** *to entity B*
    - *then A cannot be ascribed a predicate*
    - *which is in-commensurable*
    - *with any predicate that can be ascribed to B;*

    and then B is identical to A.
  - *'Equal to' is a* **symmetric predicate***".*

10.2.2 Transitivity and Intransitivity

- *"If A is identical to B and B is identical to C*
  - *then A is identical to C*
  - *with* **identity** *then being a* **transitive relation***.*
  - *The relation* **different from** *is not transitive*
  - *it is an* **transitive relation***".*

10.2.3 Space

- *"The two relations* **asymmetric** *and* **symmetric***, by a transcendental deduction, can be given an interpretation:*
  - *The relation (spatial)* **direction** *is asymmetric; and*
  - *the relation (spatial)* **distance** *is symmetric.*
  - *Direction and distance can be understood as spatial relations.*
  - *From these relations are derived the relation* **in-between***.*
- *Hence we must conclude that* **primary entities exist in space***.*
- **Space** *is therefore an unavoidable characteristic of any possible world".*
- From the direction and distance relations one can derive **Euclidean Geometry**.

10.2.4 States

- *"We must assume that primary entities may be ascribed predicates which are not logically required.*
  - *That is, they may be ascribed predicates incompatible with predicates which they actually satisfy.*
  - *For it to be logically possible, that one-and-the-same* **primary entity** *can be ascribed incompatible predicates, is only logically possible if any primary entity can exist in different* **states***.*
  - *A* **primary entity** *may be*
    - *in one state where it can be ascribed one predicate, and*
    - *in another state where it can be ascribed another*
    - *incompatible predicate".*

10.2.5 Time

- *"Two such different states must necessarily be ascribed different incompatible predicates.*
  - *But how can we ensure so ?*
  - *Only if states stand in an asymmetric relation to one another.*
  - *This state relation is also transitive.*
  - *So that is an indispensable property of any world.*
  - *By a transcendental deduction we say that* primary entities exist in time.
- So every possible world must exist in time*".*

10.2.6 Causality

"States are related by the time relation*s "before" and "after".*

- *These are asymmetric and transitive relations.*
- *But how can it be so ?*
  - *Propositions about primary entities at different times*
  - *must necessarily be logically independent of one another.*
  - *This follows from*
    - *the possibility that a primary entity*
    - *necessarily be ascribed different,*
    - *incompatible predicates at different times.*
  - *It is therefore logically impossible*
    - *from the primary entities alone to deduce*
    - *how a primary entity is at on time point*
    - *to how it is at another time point.*

- *How, therefore, can these predicates*
  - *supposedly of one and the same entity*
  - *at different time points*
  - *be about the* same entity*?*
- *There can be no logical implication about this!*
- Transcendentally *therefore*
  - *there must be a* non-logical implicative
  - *between propositions about*
  - *properties of a primary entity*
  - *at different times.*

- *Such an* non-logical implicative
  - *must depend on* empirical circumstances
  - *subject to which the primary entity exists.*
- *There are no other circumstances.*
- *If the state on a primary entity changes*
  - *then there must be changes in its "circumstances"*
  - *whose consequences are that the primary entity changes state.*
  - *And such "circumstance"–changes will imply primary entity state changes.*

- *We shall use the term 'cause'*
  - *for a preceding "circumstance"–change*
  - *that implies a state change of a primary entity.*
  - *So now we can conclude*
    - *that every change of state of a primary entity*
    - *must have a cause,*
  - *and*
    - *that "equivalent circumstances"*
    - *must have "equivalent effects".*
- *This form of implication is called* **causal implication**.
- *And the principle of implication for* **causal principle**.

- *So every possible world enjoys the* causal principle.
  - *Kant's transcendental deduction is fundamentally built on the the* possibility of self-awareness.
  - *Sørlander 's transcendental deduction is fundamentally built on the* possibility of truth.
  - *In Kant's thinking the* causal principle *is a prerequisite for possibility of self-awareness".*
- *In this way Sørlander avoids Kant's* solipsism, *i.e.,*
  - "that only one's own mind is sure to exist"

  a solipsism that, however, flaws Kant's otherwise great thinking.

10.2.7 Kinematics

- *"So* primary entities *exist in* space *and* time.
  - *They must have* spatial extent *and* temporal extent.
  - *They must therefore be able to* change *their* spatial properties.
  - *Both as concerns* form *and* location.
  - *But a spatial change in form presupposes a change in location – as the more fundamental.*
  - *A* primary entity *which changes location is said to be* in movement.
  - *If a* primary entity *which does not change location is said to be* at rest.

  - *The* velocity[59] *of a primary entity expresses the distance and direction it moves in a given time interval.*
  - *Change in velocity of a primary entity is called its* acceleration.
  - *Acceleration involves either*
    - *change in velocity, or*
    - *change in direction of movement, or*
    - *both."*
- *So far we have reasoned us to fundamental concepts of* kinematics.

[59] Velocity has a *speed* and a *vectorial direction*. *Speed* is a scalar, for example of type `kilometers per hour`. *Vectorial direction* is a scalar structure, for example for a spatial direction consisting of geographical elements: x `degrees North`, y `degrees East` ($x + y = 90$), `and` z `degrees Up or Down` ($0 \leq z \leq 90$, `where, if` $z = 90$ `we have that both` x `and` y `are` 0).

10.2.8 Dynamics

- *"When we "add" causality" to kinematics we obtain* dynamics*.*
  - *We can do so, because primary entities are in time.*
  - *Kinematics imply that that a primary entity changes when it goes from being* at rest *to* be moving*.*
  - *Likewise when it goes from movement to rest.*
  - *And similarly, when it accelerates (decelerates).*
  - *So a primary entity has same* state of movement *if it has same velocity and moves in the same direction.*
  - *Primary entities change state of movement if they change velocity or direction.*

- *So, combining kinematics and the principle of causality,*
  - *we can deduce that*
    - *if a primary entity changes state of movement*
    - *then there must be a cause, and we call that cause a* force*".*

10.2.9 Newton's Laws

Newton's First Law:

- *"Combining* kinematics *and the* principle of causality*,*
  - *and the therefrom deduced concept of* force*,*
  - *we can deduce that any* change of movement
  - *is proportional*[60] *to the* force*.*
  - *This implies that a primary entity which*
    - *is not under the influence of an external force*
    - *will continue in the same state of movement.*
- *This is* Newton's First Law*".*

[60] Observe that we have "only" said: *proportional*, meaning also directly proportional, not whether it is logarithmically, or linearly, or polynomially, or exponentially, etc., so.

Newton's Second Law:

- *"That a certain, non-zero force implies change of movement,*
  - *imply that the primary entity*
  - *must excert a certain* resistance *to that change.*
  - *It must have what we shall call a certain* mass*.*[61]
  - *From this it follows that* the change in the state of movement of a primary entity
    - *not only is proportional to the excerted force,*
    - *but also inversely proportional*[62] *to the mass of that entity.*
- *This is* Newton's Second Law*".*

[61] *Mass* refers loosely to the amount of *matter* in an entity. This is in contrast to *weight* which refers to the *force* exerted on an entity by *gravity*.
[62] Cf. Footnote 60 [previous slide].

Newton's Third Law:

- *"In a possible world,*
  - *the forces that affects primary entities*
  - *must come from "other" primary entities.*
  - *Primary entities are located in different volumes of space.*
  - *Their location may interfere with one another in the sense*
  - *at least of "obstructing" their mutual movements –*
  - *leading to clashes.*
  - *In principle we must assume that even primary entities*
  - *"far away from one another" obstruct.*
  - *If they clash it must be with*
    oppositely directed and equal forces.
- *This is Newton's Third Law".*

10.3 Gravitation and Quantum Mechanics

Mutual Attraction:

- *"How can primary entities possibly be*
  the source of forces that influence one another?
- *How can primary entities at all have a mass*[63]
  such that it requires forces to change their state of movement?
- *The answer must be that primary entities excert a mutual influence on one another –*
- *that is there is a mutual attraction"*

[63] cf. Footnote 61 Slide 356

Gravitation:

- *"This must be the case for all primary entities.*
- *This must mean that all primary entities*
- *can be characterised by*
- *a universal mutual attraction:*
- *a universal gravitation "*

Finite Propagation – A Gravitational Constant:

- *"Thus mutual attraction must propagate*
  at a certain, finite, velocity.
- *If that velocity was infinite, then it is everywhere*
  and cannot therefore have its source in concretely existing primary entities.
- *But having a finite velocity implies that there must be*
  a propagational speed limit.
- *It must be a constant of nature."*[64]

[64] Let two entities have respective masses m_1 and m_2. Let the forces with which they attract each other be f_1, respectively f_2. Then the *law of gravitation – as it can be deduced by philosophical arguments* – can be expressed as $f_1 = f_2$. The specific force, expressed using Newton's constant G is $f = G \times m_1 \times m_2 \times r^{-2}$ where r is the distance between the two entities and $G = 6.674 \times 10^{-11} \times m^3 \times kg^{-1} \times s^{-2}$ [m:meter, kg:kilogam s:second] – *as derived by physicists.*

Gravitational "Pull":

- *"The nature of* **gravitational "pull"** *can be deduced, basically as follows:*
  - Primary entities must basically consist of elements
  - that attract one another, but which are *stable*,
  - and that is only possible if it is, in principle,
  - *impossible to describe these elementary particles precisely.*
  - If there is a fundamental limit to how these basic particles
  - can be described, then it is also precluded that they can undergo continuous change.
- Hence there is a basis for stability despite mutual attraction.
  - There must be a foundational limit for how precise these descriptions can be.
  - which implies that the elementary particle as a whole can be described statistically"

Quantum Mechanics:

- The rest is physics:
  - unification of quantum mechanics and Einstein's special relativity has been done;
  - unification of gravitation with Einstein's general theory of relativity is still to be done.

A Summary:

- *"Philosophy lends to physics its results a necessity*
- *that physics cannot give them.*
- *Experiments have shown that Einstein's results –*
- *with propagation limits –*
- *indeed hold for this world.*
- *Philosophy shows that every possible world is subject to a fixed propagation limit.*
- *Philosophy also shows that for a possible world to exist it must be built from elementary particles which cannot be individually described (with Newton's theory) "*

10.4 The Logical Conditions for Describing Living Species

10.4.1 Purpose, Life and Evolution

Causality of Purpose:

- *"If there is to be* **the possibility of language and meaning**
  - *then there must exist primary entities which are*
  - ***not entirely encapsulated within the physical conditions;***
  - *that they are stable and*
  - *can influence one another.*
- *This is only possible if such primary entities are*
  - *subject to a* **supplementary causality**
  - ***directed at the future:***
  - *a* **causality of purpose**"

Living Species:

- *"These primary entities are here called* living species.
- *What can be deduced about them ?*
  - *They must* have some form they can be developed to reach;
  - *and which* they must be causally determined to maintain.
  - *This* development *and* maintenance *must further in* an exchange of matter with an environment. *...*
  - *It must be possible that living species occur in one of two forms:*
    - *one form which is characterised by* development, form *and* exchange,
    - *and another form which, additionally, can be characterised by the ability to* purposeful movement.
- *The first we call* plants, *the second we call* animals*"*

Animate Entities:

- *"For an animal to purposefully move around*
  - *there must be "additional conditions" for such self-movements to be in accordance with the principle of causality:*
    - *they must have* sensory organs *sensing among others the immediate purpose of its movement;*
    - *they must have* means of motion *so that it can move; and*
    - *they must have* instincts, incentives *and* feelings *as causal conditions that what it senses can drive it to movements"*
  - *And all of this in accordance with the laws of physics.*

Animal Structure:

- *"Animals, to possess these three kinds of "additional conditions", must be built from special units which have an inner relation to their function as a whole:*
  - *their* purposefulness *must be built into their physical building units;*
  - *that is, as we can now say, their* genomes;
  - *that is, animals are built from genomes which give them the* inner determination *to such building blocks for* instincts, incentives *and* feelings.
- *Similar kinds of deduction can be carried out for to plants.*
- *Transcendentally one can deduce* basic principles of evolution *but not its details"*

10.4.2 Consciousness, Learning and Language

Consciousness and Learning:

- *"The existence of animals is a necessary condition for there being language and meaning in any world.*
  - *That there can be* language *means that animals are capable of* developing language.
  - *And this must presuppose that animals can* learn from their experience.
  - *To learn implies that animals*
    - *can* feel *pleasure and distaste*
    - *and can* learn. *...*
  - *One can therefore deduce that animals must possess such building blocks whose inner determination is a basis for learning and consciousness "*

Language:

- *"Animals with higher social interaction*
  - *uses* **signs***, eventually developing a* **language***.*
  - *These languages adhere to the same system of defined concepts*
  - *which are a prerequisite for any description of any world:*
    - *namely the system that philosophy lays bare from a basis*
    - *of transcendental deductions and*
    - *the* **principle of contradiction** *and*
    - *its* **implicit meaning theory***"*

10.5 Humans, Knowledge, Responsibility

Humans:

- *"A* **human** *is an animal which has a* **language***"*

Knowledge:

- *"Humans must be* **conscious**
  - *of having* **knowledge** *of its concrete situation,*
  - *and as such that humans can have knowledge about what they feel,*
  - *and eventually that humans can know whether what they feel is true or false.*
  - *Consequently* **humans can describe their situation correctly***"*

Responsibility:

- *"In this way one can deduce that humans*
  - *can thus have* **memory**
  - *and hence can have* **responsibility***,*
  - *be* **responsible***.*
  - *Further deductions lead us into* **ethics***"*

10.6 An Augmented Upper Ontology

- We now augment our upper-ontology, to include *living species*,
  - from that of Fig. 1 Slide 61
  - to that of Fig. 6 Slide 373.
- We leave it to the listener to "fill in the details!"

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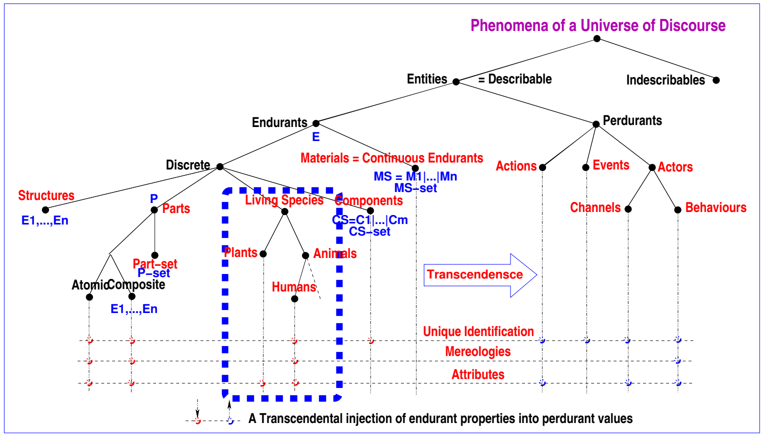

Figure 6: An Upper Ontology for Domains – with **Living Species**

10.7 Artifacts: Man-made Entities

Definition 27 Artifact:

- *By an **artifact** we shall understand*
  - *a **man-made entity**:*
    - *usually an **endurant** in **space**,*
    - *one that satisfies the laws of physics,*
    - *and sometimes one that,*
    - *by a **transcendental deduction**,*
    - *can take on the rôle of a **perdurant**;*
    - *but the artifact can also, for example,*
    - *by **intended** as a **piece of art**,*
    - *something for our enjoyment and reflection.*

- We then augment our upper-ontology, to include ***artifacts***,
  - from that of Fig. 6 Slide 373
  - to that of Fig. 7 Slide 376.
- We leave it to the listener to "fill in the details!"

.

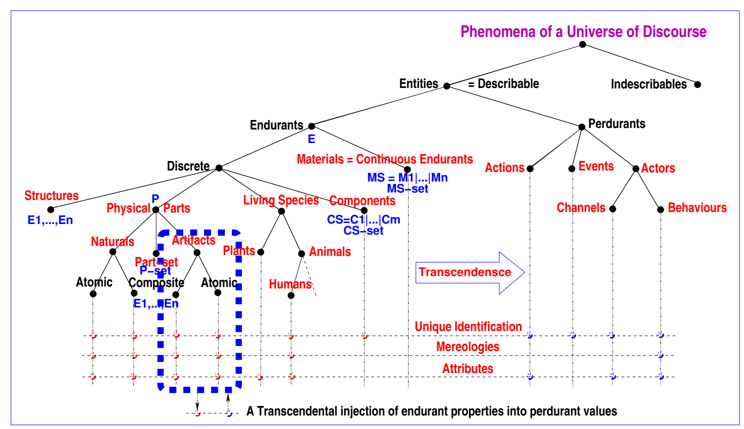

Figure 7: An Upper Ontology Extended with **Artifacts**

10.8 Intentionality

- We have ended our presentation of Sørlander's Philosophy.
  - Before going into justifications of our *domain analysis & description calculi* with respect to this philosophy
  - we shall briefly comment on the concept of *intentionality*.

- *Intentionality is*
  - *a philosophical concept*
  - *and is defined by the* `Stanford Encyclopedia of Philosophy`[65] *as*
    - *"the power of minds to be about, to represent, or to stand for,*
    - *things, properties and states of affairs."*
  - *The puzzles of intentionality*
    - *lie at the interface between the philosophy of mind*
    - *and the philosophy of language.*

[65] Jacob, P. (Aug 31, 2010). *Intentionality*. Stanford Encyclopedia of Philosophy (https://-seop.illc.uva.nl/entries/intentionality/) October 15, 2014, retrieved April 3, 2018.

- *The word itself, which is of medieval Scholastic origin,*
  - *was rehabilitated by the philosopher Franz Brentano*
  - *towards the end of the nineteenth century.*
  - *and adopted by Edmund Husserl.*
- *'Intentionality' is a philosopher's word.*
  - *It derives from the Latin word* intentio,
  - *which in turn derives from the verb intendere,*
  - *which means being directed towards some goal or thing.*
- *The earliest theory of intentionality*
  - *is associated with St. Anselm's ontological argument for the existence of God,*
  - *and with his tenets distinguishing between objects that exist in the understanding and objects that exist in reality.*

- We shall here endow the concept of 'intentionality' with the following interpretation.
  - Man-made artifacts are made for specific purposes.
    - Often two or more artifacts are intended to serve a purpose,
    - that is, to represent an intent.
  - We speculate as follows:

Definition 28 On Intentional Pull:

- *Two or more artifactual parts*
  - *of different sorts, but with overlapping sets of intents*
  - *may excert an* intentional *"pull" on one another* ■

- This *intentional "pull"* may take many forms.
  - Let p_x:X and p_y:Y
  - be two parts of *different sorts* (X, Y),
  - and with *common intent*, ι.
  - *Manifestations* of these, their common intent
  - must somehow be *subject to constraints*,
  - and these must be *expressed predicatively*.
- We return, in Sect. **11.1.4** [Slide 407], with
  - an *example of* what we claim to be
  - an *intentional "pull"*,
  - that is, Example 34 [Slide 413].

Segment IV: Fusing Philosophy into Computer Science

11 Philosophical Issues of The Domain Calculi

- We now interpret
  - the *domain analysis & description analysis calculus* of Segment **I**
  - in the light of Sørlander's *Philosophy* of Sect. **10**.
- We re-examine all analysis calculus prompts with
  - references to their prompt number or the section –
  - and the page on which their definition is given.

11.1 The Analysis Calculus Prompts

11.1.1 External Qualities

- Item 1, pp. 41: `is_universe_of_discourse:`
  - After a rough sketch narrative of the contemplated domain,
  - the informal justification to be given for this query should be along these lines:
    - the chosen universe-of-discourse is one
    - that can be described in true propositions;
    - that is, one that is based in
      - *space* and *time*; subject to *Laws of Newton*; etc.,
    - and, indispensably so,
      - involves *persons*
      - with *language*, *responsibility* and *intents*.

- Item 2, pp. 46: `is_entity:` So entities are just that:
  - describable, based in
    - either space (as are endurants)
    - or in both space and time (as are perdurants),

    and
  - involving persons.
  - That is, entities are the "stuff"
    - that philosophy cares about
    - in its quest to understand the world.
  - What lies outside may be in the realm of
    - superstition, "mumbo-jumbo", et cetera;
    - "things" that are neither in space nor time;
    - figments of the mind.

- Item 3, pp. 49: `is_endurant:`
  - An endurant is an entity
    - which we characterise in propositions
    - without reference to (actual, i.e. "real") time.
    - There is no notion of state changes in describing entities.
  - Endurants are
    - either based in physics
    - or based in living species:
      - plants and animals
      - including persons,
    - or are artifacts which build on endurants.
  - Endurants are, in the words of Whitehead, [38], ***continuants***.

- Item 4, pp. 52: `is_perdurant:` And, consequently,
  - a perdurant is an entity
    - which we characterise in propositions
    - with more-or-less explicit reference to (actual, i.e. "real") time,
    - focusing on state-changes
    - and/or interaction between perdurants.
  - Perdurants are
    - either ***action***s
    - or ***event***s
    - or ***behaviour***s.
  - **Definition**: ***Behaviours*** are defined as sets of sequences of
    - actions,
    - events and
    - behaviours ■

- Philosophical treatments are given of the notions of
  - ***time*** in [39, 30, 32, 40],
  - [discrete] ***action***s in [41],
  - ***event***s in [42, 43, 44, 45, 46, 47, 48, 49, 50, 51], and
  - ***behaviour***s in, for example, the Internet based articles on
    - `plato.stanford.edu/entries/behaviorism/` and
    - `www.behavior.org/search.php?q=behavior+and+philosophy`.
    - Most of the literature on behaviours focus on psychological aspects which we consider outside the realm of our form of domain analysis & description,
- The interplay between endurants and perdurants is studied in [*Endurants and perdurants in directly depicting ontologies*; Bittner, Donnelly and Smith].

- Item 5, pp. 55: `is_discrete:`
  - [We re-emphasize that
    - the notion of *discreteness* of *endurants*
    - such as we "need" it here, is not related
    - to the notion of *discreteness* in physics or mathematics.]
  - The terms *separate*, *individual* and *distinct*
  - characterise *discreteness*.
  - It is up to
    the *domain analysis & description scientist cum engineer*
    - to decide whether en entity should be characterised
    - as primarily distinguished by these 'qualities' – or not.

- Item 6, pp. 58: `is_continuous:`
  - [We re-emphasize that
    - the notion of *continuity* of *endurants*
    - such as we "need" it here, is not related
    - to the notion of *continuity* in physics or mathematics.]
  - The terms:
    - *prolonged,*
    - *without interruption*, and
    - *unbroken series or pattern*
  - characterise *continuity* of endurants.
  - It is up to
    the *domain analysis & description scientist cum engineer*
    - to decide whether en entity should be characterised as primarily distinguished by these 'qualities', or not.

- Item 7, pp. 64: `is_structure:`
  - Whether a discrete endurant is considered
    - a *structure*, or
    - a *part*, or
    - *a set of components*

    is a *pragmatic* decision.
  - So has no bearings in the Sørlander Philosophy
    - outside its possible bearings in language
    - where the notion of language can be motivated philosophically.

- Item 8, pp. 69: `is_part`,
  Item 14, pp. 86: `is_component` and
  Item 16, pp. 93: `is_material:`
  - All entities,
    - whether non-living species, including artifactual,
    - or living species (plants and animals, incl. humans)

    are subject to
    - *the inescapable meaning assignment*,
    - the *principle of contradiction* and
    - its *implicit meaning theory*.
  - They are also subject to the notions of *space* and *time*
    and to the *Laws of Newton*, etc.

- The living species entities are ***additionally*** subject to
  - ***causality of purpose***
- with humans having
  - ***language***,
  - ***memory*** and
  - ***responsibility***.
- These notions can be assumed,
  - but we do not, at present, i.e., in these lectures,
  - suggest any means of modelling language, memory and responsibility.

- Following Sørlander's Philosophy
  - there are the (atomic, see below) part p living species: **is**_LIVE_SPECIES(p), of which
    - there are plants, **is**_PLANT(p), and
    - there are animals, **is**_ANIMAL(p), of which (latter) some are
      - humans, **is**_HUMAN(p),
      - and some are not;
  - and there are the non-living-species parts, p, of which
    - some are made by man (or by other artifacts), **is**_ARTIFACT(p),
    - and some are not, we refer to them as ***physical part***s.
- We therefore now, as a consequence of Sørlander's Philosophy, suggest the domain analysis prompts:
  - **is**_LIVE_SPECIES,
  - **is**_PLANT,
  - **is**_ANIMAL,
  - **is**_HUMAN and
  - **is**_ARTIFACT.

- All this means that the Sørlander Philosophy, in a sense, mandates us to introduce the following ***new analysis prompts:***

Analysis Prompt 28 `is_physical:`

- *The domain analyser analyses discrete endurants (d) into physical parts:*
  - `is_physical` – *where* `is_physical(d)` *holds if d is a physical part* ■

Analysis Prompt 29 `is_living:`

- *The domain analyser analyses discrete endurants (d) into living species:*
  - `is_living` – *where* `is_living(d)` *holds if θ is a living species.* ■

Analysis Prompt 30 `is_natural:`

- *The domain analyser analyses physical parts (p) into natural:*
  - `is_natural` – *where* `is_natural(p)` *holds if p is a natural part* ■

Analysis Prompt 31 `is_artifactual:`

- *The domain analyser analyses physical parts (p) into artifactual physical parts:*
  - `is_artifactual` – *where* `is_artifactual(p)` *holds if p is a man-made part* ■

Analysis Prompt 32 *is_plant:*

- *The domain analyser analyses living species (ℓ) into plants:*
  - *is_plant – where* **is_plant(ℓ)** *holds if ℓ is a plant* ■

Analysis Prompt 33 *is_animal:*

- *The domain analyser analyses living species (ℓ) into animals:*
  - *is_animal – where* **is_animal(ℓ)** *holds if ℓ is an animal* ■

Analysis Prompt 34 *is_human:*

- *The domain analyser analyses animals (α) into humans:*
  - *is_human – where* **is_human(α)** *holds if α is a human* ■
- Analysis prompts, is_XXX,
  - similar to is_human,
  - can be devised for other animal species.

- Item 9, pp. 72: is_atomic: and Item 10, pp. 75: is_composite:
  - The notion of atomicity here has nothing to do with that of the the Greeks [Demokrit, pp. 275].
  - Here it is a rather pragmatic issue, void, it seems, of philosophical challenge.
    - It is a purely pragmatic issue with respect to any chose domain
    - whether the domain scientist cum engineer
    - decides to analyse & describe
    - a part into being atomic or composite.

Example 31 Automobile: Atomic or Composite: Thus, *for example*, you the listener

- may consider your automobile as atomic,
- whereas your mechanic undoubtedly considers it composite ■

11.1.2 Unique Identifiers

Sect. 2.6, pp. 97–101: unique identifiers:

- Uniqueness of entities follows from the basic logic of symmetry etc.
- Uniqueness or rather *identity*, is an thus important philosophical notion [cf. Sect. 10.2.1 [Slide 341]].
- Notice that we are not concerned with any representation of unique part and component identifiers.
- So please, dear listener, do not speculate on that!
- The uniqueness of part or component identifiers "follows"
  - the part and component, irrespective of the spatial location and time
  - of the possibly "movable" part or component, i.e.,
  - irrespective of its state!

11.1.3 Mereology

Sect. **2.7**, pp. 102–108: `mereology:`
There are some new aspects

- of the concept of mereology –
- which, in light of the Sørlander Philosophy,
- were not considered in Sect. **2.7**,
- and which it is now high time to consider, and,
- for some of these aspects,
- *to include in the domain analysis & description method.*

- **Philosophy:** Mereology, such as we use it, derives from *Stanisław Leśniewski*, Polish mathematician, logician, philosopher (1886–1939) [52, 53, 54, 55, 56, 57].
  - Wikipedia presents an overview of aspects of mereology.[66]
  - Related to our "use" of the concept of mereology are:
    - Henry S. Leonard and Nelson Goodman [58, 59, 60, 1940–2008],
    - Bowman L. Clarke [61, 62, 1981–1985],
    - Douglass T. Ross [63, 1976],
    - Mario Bunge [64, 65, 1977–1979],
    - Peter Simons [66, 1987],
    - Barry Smith [67, 68, 69, 70, 71, 72, 1993–2004] and
    - Roberto Casati and Achille C. Varzi [73, 74, 24, 1993–1999].

[66] https://en.wikipedia.org/wiki/Mereology#Metaphysics

- **Topologies and Intents:** To us mereology,
  - in light of Sørlander's Philosophy,
  - now becomes either of two relations (or possibly both):
    - (i) spatial relations, as for *Stanisław Leśniewski* etc., and
    - (ii) *intensional* relations.
- We characterise the latter as follows:

Definition 29 Intentional Relations: *By an intensional relation we shall understand*

- *a relation between distinct endurants which manifests*
- *two (or more) designations and at least one meaning* ■

Example 32 Transport: Automobiles and roads

- have distinct sorts and designations,
- but share the *intent* (*meaning*)
- of technologically *supporting traffic* ■

We refer to [5, *Domain Facets: Analysis & Description*].

- **Part Mereologies:** Thus the mereology of parts shall be sought in
  - either their topological, i.e., spatial, arrangements,
  - or their intents –
    with parts of same intent being mereologically related,
  - or possibly some combination of both.

Example 33 Traffic: Hence, in reference to the example of Sect. 6, we have

- that the mereologies of each automobile include the set of unique identifiers of all hubs and links, and
- the mereologies of each hub and link include the set of unique identifiers of all automobiles ■

- **Further Studies:** It appears that the concept of mereology,
  - in light of Sørlander's Philosophy,
  - warrants further scrutiny,
    - philosophically
    - well as from the point of view of
      domain analysis & description method.
  - Should discrete endurants be further analysed into
    - structures, parts and components, as now, and
    - *natural discrete endurants* or
    - *artifact discrete endurants*
  - or should discrete endurants have attribute values of
    - *natural discrete endurant values* or
    - *artifact discrete endurant values*.

11.1.4 Attributes

Sect. 2.8, pp. 109–128: `attributes:`

- Attributes, their type and value, are the main means
  for *expressing propositions about primary entities.*[67]
- Let us first recall:
  - *parts* and *components* have **unique identifiers**,
  - *parts* have **mereologies** and
  - *parts* and *materials* have **attributes.**
- Let us also "remember" that these differences
  are purely pragmatic.

[67] *The world is all that is the case.*
All that can be described in true propositions. [15, pp.13, ℓ 2–3]

- All endurants are subject to
  - being in *space* and *time*, and
  - being subject to the *principle of causality*.
- Three sets of attributes follow from the Sørlander's Philosophy:
  - (i) attributes of non-life-specifies entities;
  - (ii) attributes of life-specifies entities,
    but additionally subject to
    - *purpose*,
    - *language*,
    - *responsibility*, and
    - *causality of principle*;

    and those
  - (iii) attributes that are additional and
    more individually determined by the kind of the part.
- We shall now summarise these.

11.1.4.1 Non-Species Parts

- These are the parts that were actually treated in Sect. 2.
  - To them, as a consequence of Sørlander's Philosophy, one can ascribe the following attribute observers:
    - **attr**_SPACE and **attr**_TIME.

    No explanation seems necessary here.
  - Attribute observers related to the above could be:
    - **attr**_LOCATION where the *location* to be yielded is some spatial point within the space yielded by the SPACE observer.
    - **attr**_VOLUME where the *volume* is the volume (in some units) of the space yielded by the SPACE observer.
    - **attr**_MASS(p) where the *mass* is the mass (in some units) of the part p.
    - Et cetera.
  - We leave it to the listener to "think up" Boolean and other algebraic operators over time, space, location, mass, etc.

11.1.4.2 Artifacts

- To remind, ***artifacts*** are parts made by man and/or other artifacts.
  - They have all the same attributes (i.e. attribute observers) as has non-species parts.
  - In addition they may have such attribute observes as
    - **attr_Intent**,
    - **attr**_Maker,
    - **attr**_Brand_Name,
    - **attr**_Production_Year,
    - **attr**_Owner,
    - **attr**_Purchase_Price,
    - **attr**_Current_Value and
    - **attr**_Condition.
  - The idea of the **attr_Intent** attribute observer is to yield a token that somehow identifies the *purpose* of the artifact: `transport`, `"measurement-of-this"`, `"measurement-of-that"`, `"food-stuff"`, etc.
  - We leave it to the listener to figure out the idea of the other attributes.

11.1.4.3 Artifactual Intents

- In the world of physics, since Isaac Newton,
  - the mutual attraction of bodies (with mass)
  - and in the context of gravitation
  - leads to the **gravitational pull**,
  - cf. Sect. 10.3 pp. 361.
- Now, in the context of artifactual parts with intents
  - we may speak of **intentional "pull"**.

Definition 30 Intentional Pull:

- *Two or more artifactual parts*
  - *of different sorts, but with overlapping sets of intents*
  - *may excert an intentional "pull" on one another* ■

- This *intentional "pull"* may take many forms.
  - Let $p_x : X$ and $p_y : Y$
  - be two parts of ***different sorts*** (X, Y),
  - and with ***common intent***, ι.
  - ***Manifestations*** of these, their common intent
  - must somehow be ***subject to constraints***,
  - and these must be ***expressed predicatively***.

Example 34 Automobile and Road Transport:

- For the main example, Sect. **6**,

90 *automobiles* shall now include the intent of `'transport'`,

91 and so shall *hubs* and *links*.

90 **attr**_Intent: A → (`'transport'`|...)-**set**
91 **attr**_Intent: H → (`'transport'`|...)-**set**
91 **attr**_Intent: L → (`'transport'`|...)-**set**

- *Manifestations* of `'transport'` is reflected in
  - *automobiles* having the automobile position attribute, APos, Item 55 Slide 196,
  - *hubs* having the *hub traffic* attribute, H_Traffic, Item 48 Slide 191, and in
  - *links* having the *link traffic* attribute, L_Traffic, Item 52 Slide 194.

92 Seen from the point of view of an automobile there is its own traffic history, A_Hist Item 55c. Slide 196, which is a (time ordered) sequence of timed automobile's positions;

93 seen from the point of view of a hub there is its own traffic history, H_Traffic Item 48 Slide 191, which is a (time ordered) sequence of timed maps from automobile identities into automobile positions; and

94 seen from the point of view of a link there is its own traffic history, L_Traffic Item 52 Slide 194, which is a (time ordered) sequence of timed maps from automobile identities into automobile positions.

- The *intentional "pull"* of these manifestations is this:

95 The union, i.e. proper merge of all automobile traffic histories, AllATH, must now be identical to the same proper merge of all hub, AllHTH, and all link traffic histories, AllLTH.

type
55c., pp.196 A_Hist $= (\mathcal{T} \times \text{APos})^*$
48, pp.191 H_Traffic $=$ A_UI $\overrightarrow{m}$ $(\mathcal{T} \times \text{APos})^*$
52, pp.194 L_Traffic $=$ A_UI $\overrightarrow{m}$ $(\mathcal{T} \times \text{APos})^*$
95 AllATH $= \mathcal{T}$ $\overrightarrow{m}$ (AUI $\overrightarrow{m}$ APos)
95 AllHTH $= \mathcal{T}$ $\overrightarrow{m}$ (AUI $\overrightarrow{m}$ APos)
95 AllLTH $= \mathcal{T}$ $\overrightarrow{m}$ (AUI $\overrightarrow{m}$ APos)
axiom
95 **let** allA = proper_merge_into_AllATH({(a,attr_A_Hist(a))|a:A•a $\in as$}),
95 allH = proper_merge_into_AllHTH({attr_H_Traffic(h)|h:H•h $\in hs$}),
95 allL = proper_merge_into_AllLTH({attr_L_Traffic(l)|l:L•h $\in ls$}) **in**
95 allA = H_and_L_Traffic_merge(allH,allL) **end**

- We leave the definition of the merge functions to the listener!

- We now discuss the concept of *intentional "pull"*.
  - We endow
    - each automobile with its history of timed positions and
    - each hub and link with their histories of timed automobile positions.
  - These histories are facts!
  - They are not something that is laboriously recorded, where such recordings may be imprecise or cumbersome[68].
  - The facts are there, so we can (but may not necessarily) talk about these histories as facts.
  - It is in that sense that the purpose (`'transport'`)
    - for which man let automobiles, hubs and link be made
    - with their `'transport'` intent
    - are subject to an *intentional "pull"*.
- It can be no other way: if automobiles "record" their history, then hubs and links must together "record" identically the same history! ■

[68] or thought technologically in-feasible – at least some decades ago!

- We have tentatively proposed a concept of *intentional "pull"*.
  - That proposal is in the form, I think, of
  - a transcendental deduction;
  - it has to be further studied.

11.1.4.4 Humans[70]

- *Humans* have
  - *sensory organs* and
  - *means of motion*;
  - *inner determination* for
  - *instincts*,
  - *incentives* and
  - *feelings*;
  - *purpose*; and
  - *language*; and can
  - *learn*[71].
- We leave it, to the listener, as a *research topic*:
  - to suggest means for expressing analysis prompts
  - that cover these kinds of attributes.

[70] We focus on humans, but the discussion can be "repeated", in modified form, for plants and animals in general.

[71] cf. Sect. **10.4.2** [Slide 368]

- For these lectures we have little to say
  - on the issue of *humans*.
  - Rather much more work has to be done for any meaningful writing.
  - So, here is a challenge to the listeners!

11.1.5 A Summary of Domain Analysis Prompts

11.2 The Description Calculus Prompts

MORE TO COME

- Item 1, pp. 43: `observe_universe_of_discourse:`
- Item 2, pp. 77: `observe_endurant_sorts:`
- Item 3, pp. 81: `observe_part_type:`
- Item 4, pp. 87: `observe_component_sorts:`
- Item 5, pp. 94: `observe_material_sorts:`
- Item 6, pp. 99: `observe_unique_identifier:`
- Item 7, pp. 106: `observe_mereology:`
- Item 8, pp. 116: `observe_attributes:`

MORE TO COME

11.2.1 A Summary of Domain Description Prompts

MORE TO COME

MORE TO COME

11.3 The Behaviour Schemata

TO BE WRITTEN

11.4 Wrapping Up

- We summarise the above in a revision
  - of the *ontology diagram* first given in Fig. 1 Slide 61
  - and used, in more-or-less that form, in several publications:
  - [1, 4, 7, 75].
- The revision is shown in Fig. 8:

.

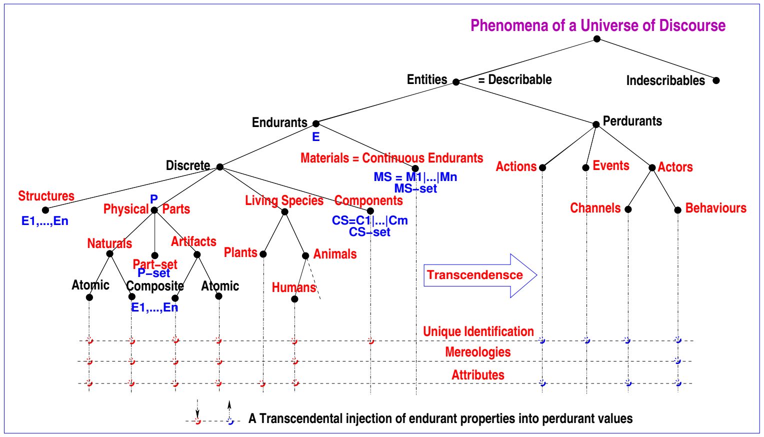

Figure 8: A Revised Upper Ontology for Domains

- Figure 8 emphasies the analytic, "upper" structure of domains and emphasises endurants:
  - **Black** names attached to diagram nodes designate "upper" categories of entities.
  - **Red** names similarly attached designate manifest categories of entities.
  - **Blue** names also so attached are the sort names of values of manifest endurants.
  - Both naturals and artifacts have atomic and composite values.
  - We only hint (· · .) at other (than human) animal species.
  - The lower dashed horizontal lines with pairs of -**o**- - -**o**- hint at the internal endurant qualities that are "transferred"

11.5 Discussion
11.5.1 Review of Revisions

- We have related a number of
  - the domain analysis & description method's analysis prompts to Sørlander's Philosophy –
  - and have found that a number of corrections has to be made to the understanding of these:
    - the basis for ***unique identifiers*** and
    - the categories of endurants and attributes.

- With [1]
  - endurants came in three forms:
    - *structures*,
    - *parts* (atomic and composite), and
    - *materials*.
  - Now we must ***refine*** the notion of parts into:
    - *physical parts* (as assumed in [1]),
    - *artifactual parts* and
    - *living species parts*.

- We must further articulate the notion of attributes:
  - as before, for *physical parts*, to
    - necessarily include the in-avoidable classical physics attributes[72]
    - and be subject to the *principle of causality* and *gravitational pull*;

    but now additionally also
  - to *artifactual parts*,
    still subject to the attributes of physical parts
    but now additionally subject to
    additional in-avoidable attributes such as *intent*
    and to both *gravitational pull* and *intentional "pull"*;

[72] *space*, *time*, *mass*, *velocity*, etc.

- and to *living species parts*,
  - notably, in these lectures, *humans*
  - with their attributes.

11.5.2 General

- It is only of interest to study
  the domain analysis & description method *analysis calculus*
  with respect to Sørlander's Philosophy.
  - The corresponding *description calculus* and schemata are not analytic.
  - They represent our "response" to the domain analysis.
  - So our "quest" has ended.
  - It is time to "sum up".

Segment V: Summing Up

- Although there is obviously a lot more to study
  - we stop here, for a while,
  - to wrap up these lectures.
- With what we have presented
  - we can, however, make several conclusions –
  - and that will now be done!

12 Conclusion

12.1 General Remarks

- When I have informed my colleagues of this work
  their reactions have been mixed.
  - *Oh yes, philosophy, yes,*
    I referred to Plato in one of my papers, ages ago!, or
  - *– does it relate to the recent Facebook scandal?*,
  - and other such deeply committing and understanding uttering.

- Philosophy is actually hard.
- Anyone can claim to reflect philosophically, and many do,
  - and some even refer, in their newspaper columns, to being philosophers,
  - but it does take some practice
  - to actually do philosophy.

- Good schooling, up to senior high, is required.
  - Having learned to reason,
  - in classical disciplines like mathematics and physics;
  - being able to read in two or more foreign languages;
  - having learned history, real history, for us, in the Western world, from before the ancient Greeks, and on-wards;
  - these seems to be prerequisites for a serious study of philosophy.

- In grammar school I passed the little test in Greek and the "large" test in Latin at the age of 14–15.
  - I had wonderful teachers.
  - I learned about the ***history of ideas*** from Johs. Sløk [21].
  - My university did not offer courses in philosophy.
  - Over the years I acquired many [and browsed some additional] philosophy books:
    - Karl Jaspers [76],
    - Bertrand Russell [77, 78, 79],
    - [Alfred North Whitehead [80, 38, 81],]
    - Willard van Orme Quine [82, 83, 84],
    - [Martin Heidegger [39],]
    - Ludwig Johan Josef Wittgenstein [85, 37],
    - Karl Popper [86, 87, 88, 89, 90, 91],
    - Imre Lakatos [92],
    - David Favrholdt [93, 94],
    - John Sowa [95],
  - as well as some dictionaries: [28, 96, 97, 98, Cambridge, Oxford, Blackwell] and [99].

- In this century I started looking at a number of epistemological essays:
  - [100, Logic and Ontology],
  - [64, 65, 69, 101, 102, Objects],
  - [66, 67, 68, 103, 72, Ontology],
  - [104, 41, 45, Actions],
  - [42, 43, 47, 105, 49, 51, 50, 46, 45, Events],
  - [53, 54, 61, 62, 58, 73, 74, 70, 50, 24, Mereology],
  - [106, 107, 108, 109, Qualities, Properties] and
  - [44, SpaceTime].

- But although wonderful "reads", it was not until
  - Sørlander's [15, 16, 2, 17, 110, 111, 3, 18]
  - that philosophy really started meaning something.
- *'Philosophy is useless'* it is said.
- *' "Results" of philosophy are not meant to solve problems '*, it is said.

- But Sørlander's Philosophy, [15, 18], have definitely helped shape the ***domain analysis & description analysis calculus*** into a form that makes it rather definitive!
- Before my study of Kai Sørlander's Philosophy
  - the upper ontology – like shown in Fig. 1 Slide 61 –
  - was based on empirical observations.
- After my study
  - the upper ontology – now shown in Fig. 7 Slide 376 –
  - is based on philosophical reasoning and is definite, is unavoidable!

12.2 Revisions to the Calculi and Further Studies

- Yes, our study of Sørlander's Philosophy, [15, 18], has led to the following modifications of the *domain analysis & description analysis calculus*:
  - (i) a more refined view of *discrete endurants*;
  - (ii) "refinements" of ***attributes*** need be studied further;
  - (iii) the *intentional "pull"* between *artifactual parts* need be studied further; and
  - (iv) the *transcendental deduction* that "translates" *endurants* into *behaviours* need be studied further

  see, however, below.

(i) Refined View of Discrete Endurants:

- Where *discrete endurants* before were
  - (i.1) *parts* and
  - (i.2) *components*,

  they are now
  - (i.1a) *physical*,
  - (i.3) *live species parts* and
  - (i.2) *components*,
  - (i.1b) *artifacts*.

  of which the *live species parts* are
  - (i.3a) *plants* and
  - (i.3b) *animals*,
  - (i.3c) for which latter we focus on ***humans***,

(iv) Which Endurants are Candidates for Perdurancy ?

- (iv.1) **Naturals:**
  - It seems that if we only focus on transcendentally deducing
  - *natural endurants* into behaviours
  - then we are really studying or doing **physics:**
    - *mechanics*,
    - *electricity*,
    - *chemistry*,
    - et cetera.

- (iv.2) **Living Species:**
  - It seems that if we only focus on transcendentally deducing
  - (iv.2.1) *living species* into behaviours
    - then we are really studying or doing **life sciences:**
      - *botanics*,
      - *biology*,
      - *zoology*,
      - et cetera.
- (iv.2.2) or if we just focus on *humans*,
  - then we are really studying or doing **behavioral sciences**.

- (iv.3) **Artifacts:**
  - (iv.3.1) We have seen that it makes sense to "transmogrify" many artifacts into behaviours.
    - But how characterise those for which that deduction makes, or does not make sense?
  - (iv.3.2) It seems that if we only focus on transcendentally deducing *artifacts* into behaviours
    - then we are really studying or doing **engineering:**
      - *mechanical*,
      - *electrical*,
      - *chemical*,
      - *electronics*,

    et cetera, engineering.

12.3 Remarks on Classes of Artifactual Perdurants

- We can rather immediately identify the following "classes" of *artifactual perdurants*:
- **Computerised Command & Control Systems:**
  - Here we have several, i.e. more than just a few distinct artifacts,
    - interacting with human operators
    - for the purpose of command, monitoring and controlling some of these artifacts and humans.
  - Examples are
    - *pipelines* [112] and
    - *swarms of drones* [113].

- **Logistics: Planning & Monitoring:**
  - Here again we have several, i.e. more than just a few distinct artifacts,
    - but the emphasis is on operational planning
    - and the monitoring of plan fulfillment.
  - Examples are
    - *container lines* [114] and
    - *railways* [115, 116, 117, 118, 119].

- **Monitoring:**
  - Usually the systems here are just monitoring a single endurant.
  - Examples are
    - *weather forecast* [120] and
    - *health care*.

- **Mechanics:**
  - Here we are dealing with the operation of just one artifact:
    - a *lathe* a *machine saw*, etc.,
    - an *automobile*,
    - et cetera.

- **The "End" Result:**
  - Here we are dealing with computers being the artifacts
  - – "final" instruments in achieving some purpose!
  - Examples are
    - *urban planning* [121]
    - *stock exchange* [122]
    - *credit card system* [123]
    - *documents* [124]
    - *Web systems* [125]
    - *E-market* [126]

- We refer to [14] for a discussion of domain models as a basis for
  - software demos,
  - software simulators,
  - software monitoring and
  - software monitoring and control.

12.4 Acknowledgements

- First and foremost I acknowledge the deep inspiration drawn from the study of Sørlander's Philosophy, notably [2] and [3].
- Several people have commented,
  in various more-or-less spurious ways,
  not knowing really, what I was up to,
  when I informed them of my current study and writing on
  "applying" Sørlander's Philosophy, notably [2] and [3] to my work
  on domain analysis & description.
- Several of these comments, however uncommitted, have, however
  – strangely enough, upon reflection, helped me
  to even better grasp what it was I was trying to unravel.
- Let my acknowledgments to them remain anonymous.

13 Bibliography

13.1 Bibliographical Notes

- We list a number of reports all of which document descriptions of domains.
  - These descriptions were carried out in order to research and develop the domain analysis and description concepts now summarised in the present paper.
  - These reports ought now be revised, some slightly, others less so, so as to follow all of the prescriptions of the current paper.
  - Except where a URL is given in full, please prefix the web reference with: `http://www2.compute.dtu.dk/~dibj/`.

1 *A Railway Systems Domain:* `racosy/domains.ps` (2003)

2 *Models of IT Security:* `it-security.pdf` (2006)

3 *A Container Line Industry Domain:* `container-paper.pdf` (2007)

4 *The "Market": Buyers, Sellers, Traders:* `themarket.pdf` (2007)

5 *What is Logistics ?:* `logistics.pdf` (2009)

6 *A Domain Model of Oil Pipelines:* `pipeline.pdf` (2009)

7 *Transport Systems:* `comet/comet1.pdf` (2010)

8 *The Tokyo Stock Exchange:* `todai/tse-1.pdf` and `todai/tse-2.pdf` (2010)

9 *On Development of Web-based Software:* `wfdftp.pdf` (2010)

10 *A Credit Card System:* `/2016/uppsala/accs.pdf` (2016)

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