A Philosophy Basis for Domain Science & Engineering?
Incomplete Draft Sketch

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We investigate a possible philosophy basis for domain science & engineering. There are two bases for this paper: the philosophy of Kai Sørlander and my work on calculi for the analysis & description of manifest domains, their endurants and perdurants. That is, of parts: natural and artificial (including components and materials); of living species: plants and animals, including humans; and of the behaviours that can be transcendently deduced from endurants. The philosophy-question to be investigated is “what must inescapably be in any domain description?” that is: “which are the necessary characteristics of each and every possible world and our situation in it.”

ACM Reference Format:

1 INTRODUCTION

We investigate a possible philosophy basis for domain science & engineering. The departure point for this investigation is the paper: [14, A Domain Analysis & Description Method – Principles, Techniques and Modelling Languages] and Kai Sørlander’s books [59, 62, 66].

Characterisation 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”), as well as perdurants (“alive”). (By ‘rational descriptions’ we mean: “in terms of true propositions over primary entities”2.) Emphasis is placed on “human-assistedness”, that is, that the domain embodies at least one (man-made) artifact and thus that humans are a primary cause for change of endurant states as well as perdurant behaviours3 4.

Characterisation 2. Universe of Discourse: The term ‘domain’, in the context of this paper, is also referred to as ‘domain of discourse’, or ‘universe of discourse’. The term ‘universe of discourse’ generally refers to the collection of entities (objects) being discussed in a specific discourse. In model-theoretical semantics, a universe of discourse is the set of entities that a model is based on [https://en.wikipedia.org/wiki/Domain_of_discourse] 1.

The science and engineering of domain analysis & description is different from the science of physics and the core of its derived engineerings: building (civil), chemical, mechanical, electrical, electronics, 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.

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2 Margin change bars designate major text changes since a February 7, 2019, 17:16 version of this document. This boxed text and margin change bars will be removed when paper is no longer a draft.
3 The meaning of ‘true empirical propositions over primary entities’ will be explained in Sect. 3.1.3 [pp. 17].
4 We shall, throughout, use the term behaviour in the sense of their being characterisable as sets of sequences of actions, events and behaviours, and not from the point of view as propagated by behaviourism [58] and https://en.wikipedia.org/wiki/Behaviorism, i.e., not as a study within the realm of psychology. The two views may not necessarily “disagree”.

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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.

1.1 A Triptych of Software Development

Our focus on domain analysis & description stems from the following view of software development: (i) in order to design software we must know the expectations and requirements of users from and of that software; (ii) in order to prescribe requirements we must understand its usage domain of discourse; and hence, (iii) we must analyse & describe that domain – which then implies better expectation descriptions. From a formal point of view: \( D, \mathcal{R} \models \mathcal{S} \): Based on respective specifications, we can verify (prove, test) that \( \mathcal{S} \) software meets \( \mathcal{R} \) requirements and expectations in the context of \( D \) domain specifications. The essence here is that we must analyse & describe domain \( X \) if we are to have any hope of developing trustworthy software for domain \( X \).

1.2 The Thesis

The philosophical questions is: what must inescapably be in any description of a domain? With the philosophy of Kai Sørlander, [59, 66], we partially answer that question: (a) space, (b) time, (c) physical parts and (d) living species. With our investigation of analysis & description calculi, [14], we join to the above (partial) answer: the manifest notions of (e) endurant and (f) perdurant entities; (g) discrete and (h) continuous endurants; (i) artifactual parts and (j) artifactual materials; (k) action, (l) event and (m) behaviour perdurants; as well as the internal quality notions of (n) unique identifiers, (o) mereologies and (p) attributes – such as these, e–p, were defined in [14] and are summarised here.

1.3 Some Concepts of Philosophy

Characterisation 3. Philosophy: Philosophy (from Greek “love of wisdom”) is the study of general and fundamental problems concerning existence, knowledge, values, reason, mind, and language.

Characterisation 4. 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? 5

Topics of metaphysical investigation include entities (objects) and their properties, space and time, cause and effect, and possibility.

Characterisation 5. Epistemology: [from epistêmē, ’knowledge’, and logos, ’logical discourse’] is the branch of philosophy concerned with the theory of knowledge 6

The philosophy aspect of our study is primarily epistemological, i.e., not metaphysical.

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.

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?”. 6

5 https://en.wikipedia.org/wiki/Metaphysics, #Ontology (Being)
A central branch of epistemology is ontology, the investigation into the basic categories of being and how they relate to one another.\textsuperscript{7}

**Characterisation 6. Ontology:** By ontology we mean the philosophical study of being. More broadly, it studies concepts that directly relate to being, in particular becoming, existence, reality, as well as the basic categories of being and their relations.\textsuperscript{8}

An ontology encompasses a representation, formal naming, and definition of the categories, properties, and relations between the concepts, data, and entities that substantiate one, many, or all domains. Every field creates ontologies to limit complexity and organize information into data and knowledge. As new ontologies are made, their use hopefully improves problem solving within that domain. What ontologies in both information science and philosophy have in common is the attempt to represent entities, ideas, and events, with all their interdependent properties and relations, according to a system of categories. [en.wikipedia.org/wiki/Ontology_(information_science)]

**Characterisation 7. Upper Ontology:** An upper ontology is a model of the common relations and entities (objects) that are generally applicable across a wide range of domain ontologies. It usually employs a core glossary that contains the terms and associated entity descriptions as they are used in various relevant domain ontologies. [en.wikipedia.org/wiki/Ontology_(information_science)]

The study of this papers as well as of [14] is a study of upper ontologies. It seems, however, that most ontology studies of the literature focus on endurants (see below). We go well beyond that and also study perdurant components of upper ontology.

**Characterisation 8. Mereology:** By mereology we mean the study of parts, their relations and the wholes they form. Whereas set theory is founded on the membership relation between a set and its elements, mereology emphasizes the meronomic relation between entities, which – from a set-theoretic perspective – is closer to the concept of inclusion between sets.\textsuperscript{9}

In [16, To Every Manifest Domain a CSP Expression — A Role for Mereology in Computer Science] we study mereology in the context of [14]. Our upper ontology focuses on endurants and their mereological relations. Next we present an abstract example:

- The figure shows a mereology.
  - The Whole consists of three parts: A, B and C.
  - Part A is composed from parts D and E.
  - Part D is composite and consists of part F.
  - Parts B, C, E and F are atomic.


### 1.4 Structure of Paper

The paper consists of three main sections. The first two sections, Sect. 2 and Sect. 3, are independent of one another; can thus be read in any order. Sect. 2 brings a summary of the domain analysis & description calculi; Sect. 3 a summary of Kai Sr\"strander’s Philosophy [59, 60, 62, 66]. Section 4 interprets the former in terms of the latter. In Sect. 2 we show examples in footnotes while in Appendix A showing a larger, seven page detailed domain description (of a credit card system).
2 \THE DOMAIN ANALYSIS & DESCRIPTION CALCULI

The main sections, Sects. 2.2 and 2.5, of this section are separated by two important sections, Sects. 2.3 and 2.4.

Section 2.1 focuses on the broadest analysable & describable notion of entities; Sect. 2.2 focus on our notion of endurants; Sect. 2.3 then introduces the notion of transcendental deduction, a notion which “bridges” endurants with perdurants; Sect. 2.4, as another “aside”, covers the inevitable concepts of space and time; Sect. 2.5 focus on our notion of perdurants.

2.1 \Entities

Characterisation 9. 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 [41, Vol. I, pg. 665].

We shall, thus, only be concerned with entities. We take the above characterisation of what an entity is to be the same as a phenomenon that can be analysed & described. And we take that (analyzable & describable) as being the same as analysed & described using the analysis & description prompts outlined in this paper and detailed in [14, A Domain Analysis & Description Method – Principles, Techniques and Modelling Languages].

We have decided to use the term ‘entity’. Some use the term ‘object’, others the term ‘the thing’. Please note that entities are such phenomena which can be analysed & described using the analysis & description prompts introduced in [14] and summarised in this section, i.e., Sect. 2

Characterisation 10. 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” [41, Vol. I, pg. 656]. Were we to “freeze” time we would still be able to observe the full endurant.

Concrete endurants also known as continuants, or in some cases as “substance”, are manifest: You can touch them, see them, measure their location and extent as well as many other properties.

Characterisation 11. 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 [41, Vol. II, pg. 1552].

Perdurants also known as occurrences, accidents or happenings, are often what we know as processes, for example: “running”. If we freeze time then we only see a part of the running, without any previous knowledge one might not even be able to determine the actual process as being a process of running. Other examples include an activation, a kiss, or a procedure [en.wikipedia.org/wiki/Formal_ontology#Common_terms_in_formal_(upper-level)_ontologies]. The terms ‘process’, ‘activation’ and ‘procedure’ are here used in their most common sense, i.e., not in their computer science sense.

The terms ‘endurant’ and ‘perdurant’ are established in formal ontology [en.wikipedia.org/wiki/Formal_ontology].

2.2 \Endurants

We present a terse synopsis of an ontology of endurants, cf. Fig. 1 [next page].

2.2.1 Overview of Endurants: The observable endurants are either discrete or continuous, in which latter case we call them materials. Discrete endurants are either physical parts, or living species – plants or animals, incl. humans – or are structures (cf. [14, Sect. 3.2.3]).

Physical parts are either natural parts or are artifacts (man made parts). Artifacts are either sets of components – i.e., sets of parts of possibly different sorts10, or are of concrete type – i.e., sets of parts of the same sort [that is, type]11, or are

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10 Examples: letters (in a mailbox), goods (in a container), Lego blocks, …
11 Examples: automobiles (in a fleet of such), links (i.e., street segments of a road net), hubs (street intersections of a road net), …
atomic artifacts\textsuperscript{12} or composite artifacts\textsuperscript{13}. Materials may contain physical parts and/or living species (has_parts, \ldots). Physical parts may contain materials and/or components (has_materials, has_components).

With endurants we shall associate one or more of the qualities (also referred to as properties): unique identifiers, mereology, and attributes.

**Unique Identifiers:** We are mandated to uniquely identify discrete endurants: natural parts\textsuperscript{14}, man-made parts (artifacts)\textsuperscript{15}, and living species\textsuperscript{16}.

**Mereology:** Endurants that stand in some conceptual or spatial relation to other endurants have that relation captured by the mereology of those endurants. We endow most endurants – natural\textsuperscript{17} and man-made\textsuperscript{18} parts, and humans\textsuperscript{19} – with mereologies.

**Space and Time:** Space and Time are not attributes. They are concepts that, as we shall see, can be deduced transcendentally by rational reasoning. All endurants thus “occur” in both Space and Time.

**Attributes** characterise internal qualities. By attributes we shall mean measurable properties of endurants. Attributes, as we shall later see, are really what we refer to when expressing properties of endurants – or what we shall later refer to as primary objects\textsuperscript{20}.

\textsuperscript{12}Examples: an automobile, a link, a hub – where we have obviously chosen an abstraction level that “makes” them atomic.
\textsuperscript{13}Examples: a road net (of hubs, links, \ldots), a fleet of vehicles (that is, of automobiles, etc.), \ldots
\textsuperscript{14}Examples: the set of all plants and the set of all animals all have their members uniquely identified.
\textsuperscript{15}Examples: lakes, rivers and oceans are geographically related, so are the mountain ridges, valleys and flat-lands.
\textsuperscript{16}Examples: the set of all plants and the set of all animals all have their members uniquely identified.
\textsuperscript{17}Examples: humans are related genealogically (parents, siblings, etc.), etc.
\textsuperscript{20}Examples: Attributes of street segments, i.e., links, include length, number of traffic lanes, the history of automobile visits [i.e., as sequences of Time-stamped vehicle positions [Spatial location] along the link], etc.

2019-02-08 09:32. Page 5 of 1–35.
We reinterpret Michael A. Jackson’s [36] static and dynamic: inert, reactive and active: autonomous, biddable and programmable attributes into three categories: static, monitor-able (inert, reactive, autonomous) and controllable (biddable, programmable).

Artifact Attributes: Focusing on artifacts and their living species human creators – cf. Sect. 3.3.1 [pp. 20] – there arises the possibility, perhaps even the necessity to model attributes of artifacts, attributes that reflect the intents of humans when first conceiving these artifacts. Such attributes, in turn, reflect (a) causality of purpose (b) maintenance of their form, (c) exchange of matters with an environment, (d) purposeful movement, (e) sensory organs, and (f) instinct, incentives, feelings. The above enumeration mirrors essential elements of the contents of Sect. 3.3.1 [pp. 20]. The artifacts that humans build and operate thus possess properties that in turn reflect the above enumeration.

2.2.2 The Analysis and Description Calculi In [14, A Domain Analysis & Description Method – Principles, Techniques and Modelling Languages] we pedantically develop two calculi corresponding to the ontology of the previous section. Both are in the form of prompts. These prompts are for the informal use of the domain analyser cum describer.

An Analysis Calculus: “Applying” the prompts of the analysis calculus helps the analyser in deciding whether phenomena are describable or not, that is, in selecting entities for further analysis: is_entity. Subsequent prompts, is_endurant or is_perdurant helps decide whether an entity is one or the other. The full analysis calculus is:

```
• is_universe_of_discourse
• is_entity
• is_endurant
• is_perdurant
• is_discrete
• is_continuous
• is_physical_part
• is_living_species
• is_structure
• is_part
• is_atomic
• is_composite
• is_living_species
• has_components
• has_materials
• has_parts
• has_living_species
• is_artifact
• obs_endurant_sorts
• has_concrete_type
• has_mereology
```

A Description Calculus: “Applying” the prompts of the description calculus helps the analyser in deciding, based on the analysis, what descriptions to generate. The full description calculus is:

```
• obs_part_sorts
• obs_concrete_type
• obs_uniq_identifiers
• obs_mereology
• obs_attributes
• obs_component_sorts
• obs_material_sorts
```

We show some example description schemas below. If an endurant, p, is a composite part then obs_part_sorts results in:

```
<table>
<thead>
<tr>
<th>Description Schema 1: Composite Parts [Cf. App. A.1.1 [pp. 27]]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Narrative:</strong></td>
</tr>
<tr>
<td>• From composite parts p:P</td>
</tr>
<tr>
<td>• we can observe parts p1:P1, p2:P2, ..., pn:Pn.</td>
</tr>
<tr>
<td><strong>Formalisation:</strong></td>
</tr>
<tr>
<td>• type</td>
</tr>
<tr>
<td>• P1, P2, ..., Pn,</td>
</tr>
<tr>
<td>• value</td>
</tr>
<tr>
<td>• obs.Pi: P → Pi; ![for i: {1..n}]</td>
</tr>
</tbody>
</table>
```

If an endurant, p, has a concrete type, T, then obs_concrete_type yields:
### Description Schema 2: Concrete Parts [Cf. App. A.1.2 [pp. 27]]

**Narrative:**
- A concrete type, \( T \), is defined in terms of sorts \( S_1, S_2, \ldots, S_s \).

**Formalisation:**
- type:
  \( T = \mathcal{E}(S_1, S_2, \ldots, S_s) \)
- sorts:
  \( S_1, S_2, \ldots, S_s \)
- value:
  \( \text{obs}_T: P \rightarrow T\text{-set} \)

where \( \mathcal{E}(S_1, S_2, \ldots, S_s) \) is any type expression over sorts \( S_1, S_2, \ldots, S_s \).

Appendix A shows a description of the endurants of a simple domain.

Physical parts and living species have unique identifiers. Let \( p:P \) be a physical part, \( \ell:L \) be a living species.

### Description Schema 3: Unique Identifiers [Cf. App. A.2 [pp. 27]]

**Narrative:**
- The unique identifier of a part \( p:P \) is \( \pi:PI \) and of a living species \( \ell:L \) is \( \ell:LI \).
- Unique identifiers can be observed.

**Formalisation:**
- type:
  \( PI, LI \)
- value:
  \( \text{uid}_P: PI, \text{uid}_L: LI \)

Once all unique identifier types and observers have been defined one can state their uniqueness.

### Description Schema: Mereologies [Cf. App. A.3 [pp. 28]]

**Narrative:**
- Let \( p:P \) be the parts for which we analyse and describe the mereologies.

**Formalisation:**
- type:
  \( UL_a, UL_b, \ldots, UL_c \)
- value:
  \( \mathcal{M}(UL_a, UL_b, \ldots, UL_c) \)

- The mereology of parts \( p:P \) is then some set expression, \( \mathcal{M} \), over \( UL_a, UL_b, \ldots, UL_c \).

### Description Schema 5: Attributes [Cf. App. A.4 [pp. 29]]

**Narrative:**
- The attributes of parts \( p:P \) are \( A_1, A_2, \ldots, A_a \).
- They can be observed from parts \( p:P \).

**Formalisation:**
- type:
  \([t] A_1, A_2, \ldots, A_a \)
- value:
  \( \text{attr}_Ai: P \rightarrow Ai, [i: \{1..a\}] \)
2.2.3 States [App. A.1.3 [pp. 27]]. By a state we shall understand any collection of physical parts, materials, or living species.

2.2.4 Intentional “Pull”. Intentionality is a philosophical concept and is defined by the Stanford Encyclopedia of Philosophy as the power of minds (i.e., humans) to be about, to represent, or to stand for, things, properties and states of affairs.

Characterisation 12. Intentional “Pull”: Two or more artifactual parts of different sorts, but with overlapping sets of intents may exert 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, $\iota$. Manifestations of their common intent must be expressed as properties (i.e., attributes) of the parts and be subject to constraints, and these must be expressed predicatively.

Endowing a two or more parts with an intention reflects that their human creators have that intention with those parts. In order to fulfill an intention the intention-sharing parts must further reflect attributes that serve to “instrument”, i.e. “realise”, the intention.

Our notion of intentional “pull” is “inspired” by the physical phenomenon of gravitational pull: where the latter is a law of physics, “God-given”, and applies to physical parts (including artifacts), the former is a result of human intention(s), and applies to artifacts (only). We shall have more to say about intentional “pull” in Sects. 2.5.6 [pp. 13], 4.4.1 [pp. 23] and 4.4.3 [pp. 23]. Appendix A.4.5 [pp. 30] gives an informal example of the concept of intentional “pull”.

2.2.5 Calculi for Analysing & Describing Endurants. In this section, Sect. 2.2, we have studied endurants and “their calculi”. In Sect. 2.5 we shall study perdurants. We show how certain kinds of parts can be “morphed” into behaviours. And we show how to derive essential aspects of their structure and signature from the external and internal qualities of endurant parts.

2.3 Transcendental Deduction

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, especially ontology. In this section on a sub-field of epistemology, namely that of a number of issues of transcendental nature, we refer to [35, Oxford Companion to Philosophy, pp 878–880 1995], [1, The Cambridge Dictionary of Philosophy, pp 807–810, 1995], and [23, The Blackwell Dictionary of Philosophy, pp 54–55 (1998)].

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.

By a transcendental deduction we shall understand the philosophical notion: a transcendental ”conversion” of one kind of knowledge into a seemingly different kind of knowledge.

Example 1: Some Transcendental Deductions

We give some intuitive examples of transcendental deductions. They are from the “domain” of programming languages. (a) There is the syntax of a programming language, and there are the programs that supposedly adhere to this syntax (let us refer to the syntax as $F$). (b) The software tools, an automatic theorem prover and a model checker, for example SPIN [34], that takes a program and some theorem, respectively a Promela statement, and proves, respectively checks, the program correct with respect the theorem, or the statement. (c) A compiler and an interpreter for any programming language. (d) The software tool, a syntax checker, that takes a program and checks whether it satisfies the syntax, including the statically decidable context conditions, i.e., the statics semantics – that tool is one of several forms of transcendental deductions; (e) Yes, indeed, any abstract interpretation [21, 26] reflects a transcendental deduction.

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22 That may be a reason why humans often anthropomorphise, i.e., to ascribe human form or attributes to an entity.
First these examples show that there are many transcendental deductions. Secondly they show that there is no single-most preferred transcendental deduction.

A transcendental deduction, crudely speaking, is just any “concept” that can be “linked” to another, not by logical necessity, but by logical (and philosophical) possibility!

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

<table>
<thead>
<tr>
<th>Example 2: Transcendentality</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>(i)</strong> The bus as it is being &quot;maintained, serviced, refueled&quot;;</td>
</tr>
<tr>
<td><strong>(ii)</strong> the bus as it &quot;speeds&quot; down its route; and</td>
</tr>
<tr>
<td><strong>(iii)</strong> the bus as it &quot;appears&quot; (listed) in a bus time table.</td>
</tr>
</tbody>
</table>

The above example, we claim, reflects transcendentality as follows:

(i) We have knowledge of an endurant (i.e., a part) being an endurant.
(ii) 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.
(iii) 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.

In other words: two (i–ii) kinds of different knowledge; that they relate must indeed be based on a *priori* knowledge. Someone claims that they relate! The two statements (i–ii) are claimed to relate transcendentally.

### 2.4 Space and Time

This section is a necessary prelude to our treatment of perdurants.

Following Kai Sørlander’s Philosophy we must accept that space and time are rationally mandated in any domain description. It is, however not always necessary to model space and time. We can talk about space and time; and when we do, we must model them.

#### 2.4.1 Space. General

Mathematicians and physicists model space in, for example, the form of Hausdorff (or topological) space; or a metric space which 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; or Euclidean space, due to Euclid of Alexandria.

**Space Motivated Philosophically: Indefinite Space:** We motivate the concept of indefinite space as follows: [66, pp 154]

*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 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.

**Definite Space:** By a definite space we shall understand a space with a definite metric.

There is but just one space. It is all around us, from the inner earth to the farthest galaxy. It is not manifest. We can not observe it as we observe a road or a human.

**Space Types: The Spatial Value:**
1. There is an abstract notion of (definite) SPACE of further unanalysable points; and
2. there is a notion of POINT in SPACE.

**Spatial Observers.**
3. A point observer, observe_POINT, is a function which applies to physical parts, \( p \), and yield a point, \( \pi : \text{POINT} \).

Given a notion of POINTs one can then develop a notion of LOCATIONs.

### 2.4.2 Time. General:

Concepts of time continue to fascinate thinkers [27, 42, 46–52, 54, 67]. J.M.E. McTaggart (1908, [29, 42, 54]) discussed theories of time around the notions of “A-series”: with concepts like “past”, “present” and “future”, and “B-series”: has terms like “precede”, “simultaneous” and “follow”. Johan van Benthem [67] is the standard reference work on the study of time. Wayne D. Blizard [22, 1980] relates abstracted entities to spatial points and time. A recent computer programming-oriented treatment is given in [30, Mandrioli et al., 2013].

**Time Motivated Philosophically:** Indefinite Time: We motivate the abstract notion of time as follows. [66, pp 159] “Two 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.”

**Definite Time:** By a definite time we shall understand an abstract representation of time such as for example year, month, day, hour, minute, second, et cetera.

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**Example 3:** Temporal Notions of Endurants

By temporal notions of endurants we mean time properties of endurants, usually modelled as attributes. Examples are: (i) the time stamped link traffic and (ii) the time stamped hub traffic.

---

27 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 [1, (i) Plato, (ii) Aristotle, (iii) Plotinus, (iv) Augustine].

28 States are formally introduced in Sect. 2.2.3 [pp. 7].

---
Time Values / Time Points. We shall not be concerned with any representation of time points. A “standard” example would be February 8, 2019: 09:32 am, GMT. That is, we leave it to the domain analyser cum describer to choose an own representation [30]. Similarly we shall not be concerned with any representation of time intervals. 29

4 So there is an abstract type Time,
5 and an abstract type TI: Time|Interval.
6 There is no Time origin, but there is a “zero” TI
interval.
7 One can add (subtract) a time interval to (from) a time
and obtain a time.
8 One can add and subtract two time intervals and obtain
a time interval – with subtraction respecting that the
subtrahend is smaller than or equal to the minuend.
9 One can subtract a time from another time obtaining a
time interval respecting that the subtrahend is smaller
than or equal to the minuend.
10 One can multiply a time interval with a real and obtain
a time interval.
11 One can compare two times and two time intervals.

<table>
<thead>
<tr>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>type</td>
<td>value</td>
</tr>
<tr>
<td>T</td>
<td>TI</td>
</tr>
</tbody>
</table>

Models of Time: Modern models of time, by mathematicians and physicists evolve around spacetime. 30 We shall not be concerned with this notion of time. Models of time related to computing differs from those of mathematicians and physicists in focusing on divergence and convergence, zero (Zenon) time and interleaving time [72] are relevant in studies of real-time, typically distributed computing systems. We shall also not be concerned with this notion of time.

Spatial and Temporal Modelling: It is not always that we are compelled to endow our domain descriptions with those of spatial and/or temporal properties. In our experimental domain descriptions, for example, [5, 6, 8, 10–13, 20], we have either found no need to model space and/or time, or we model them explicitly, using slightly different types and observers than presented above.

2.4.3 Whither Attributes? Are space and time attributes of endurants? Of course not! Space and time surround us. Every endurant is in the one-and-only space we know of. Every endurant is “somewhere” in that space. We represent that ‘somewhere’ by a point in space. Every endurant point can be recorded. And every endurant point can be time-stamped.

2.5 Perdurants

In reading the early sections of this section, Sect. 2.5, it is important to keep in mind that to parts we shall, generally, and by a transcendental deduction, associate behaviours. So in a sense, behaviours is what we have uppermost in our mind, behaviours is what it is all about.

---

- 29 but point out that although a definite time interval may be referred to by number of years, number of days (less than 365), number of hours (less than 24), number of minutes (less than 60)number of seconds (less than 60), et cetera, this is not a time, but a time interval.
- 30 The concept of Spacetime was first "announced" by Hermann Minkowski, 1907–08 – based on work by Henri Poincaré, 1905–06, https://en.wikisource.org/wiki/Translation:_The_Fundamental_Equations_for_Electromagnetic_Processes_in_Moving_Bodies

2.5.1 **Proactive, Active and Passive Parts** We shall make a pragmatic distinction between proactive, active and passive parts.

**Characterisation 13. Proactive Parts:** By a proactive part we shall understand a part which when understood transcendentally, as a behaviour, of its own volition, is able to initiate actions usually interacting with other (either proactive or active) behaviours. These actions serve toward fulfillment of part intents ■

**Characterisation 14. Active Parts:** By an active part we shall understand a part which when understood transcendentally, as a behaviour, offers to interact with proactive behaviours. These actions serve toward fulfillment of part intents ■

**Characterisation 15. Passive Parts:** By a passive part we shall understand a part which is not transcendentally deduced into a behaviour ■

It is the domain analyser cum describer who decides whether a part has some (one or more) intents.

---

**Example 4: Proactive, Active and Passive Parts**

For a road transport system with links (street segments), hubs (street intersections) and automobiles, we may consider automobiles to be proactive (as they drive “hither and dither”), and links and hubs to be active, merely observing – as directed by automobiles – that automobiles are passing by! We can extend the road transport system with automobile clubs as composite parts from which we can observe sets of automobiles. We can then decide to consider these clubs as being passive parts!

---

2.5.2 **Discrete Behaviours.** By a discrete behaviour we shall understand a set of sequences of potentially interacting sets of discrete actions, events and behaviours ■

◊ We shall model domain behaviours in terms of RSL+ processes.

    We shall not deal with any notion of continuous behaviour.

        • • •

We shall also keep in mind that the domains we shall model mostly, as it turns out, focus on man-made parts. These parts have been designed and constructed to serve one or more intents. Usually two or more [separate] parts relate in their intents, for example: (a) roads [are intended to] accommodate automobiles; (b) banks and shops [are intended to] accommodate credit cards; and (c) canal locks [are intended] to raise and lower watercraft.

        • • •

Perdurants are thus analysed into actions, events, and behaviours. 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.

2.5.3 **Actors:** 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 analyser & describer. By what we learn from our study of Sørlander’s Philosophy some endurants (of a kind we shall introduce later31) can, by a transcendental deduction, “become” perdurants some of which thereby “acting” in rôles of actors.

◊ We shall model domain actors in terms of RSL+ process definitions.

2.5.4 **Discrete Actions:** By a discrete action [27, 70, 71] 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 ■

Actions, as we have already noted, serve to fulfill intentions.

31 humans and, although not a concept in [59, 66], their artifacts
We shall model domain actions in terms of \textit{RSL}+ clauses that “update”\footnote{Our \textit{RSL}+ descriptions avoid using \textit{RSL} variables and hence assignment. Thus updates are expressed in terms of “passing on” as changed values, controllable attribute parameters in tail-recursive behaviour invocations.} controllable attributes and in terms of \textit{RSL}+ (CSP) output/input.

We refer to \cite[Sect. 9.3 Behaviours, pp. 50–51]{14} for examples of behaviour designs.

We shall not deal with any notion of continuous action.

\subsection*{2.5.5 Discrete Events:}
There are many notions of events \cite{3, 24, 25, 27, 28, 31, 39, 43, 45, 53}. By a \textit{discrete event} we shall understand some \textit{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.

We shall model domain events in terms of \textit{RSL}+ CSP \textit{input} (from monitorable attributes).

Events, to illustrate, may occur, “to parts”, when actions involving these fail to operate properly. For example: (a) \textit{automobiles crash on a road}, (b) \textit{a credit card purchase exceeds credit}, and (c) \textit{a canal lock fails to open}.

We shall not deal with any notion of continuous event.

\subsection*{2.5.6 Behaviour Synchronisation and Communication.}
We refer to Sect. 2.2.4 \cite[pp. 8]{13}. We assume that the reader is familiar with CSP \cite{32, 33, 55, 56}. Behaviours derived from artifacts serve to fulfill intents. Since two or more artifacts may share an intent there derived behaviours may synchronise and communicate. And since any one artifact may share several intents its derived behaviour may alternate between distinct sub-behaviours. For proactive parts these sub-behaviours are typically “separated” by internal non-determinism, \footnote{We refer to the \textit{sketch behaviour definitions} below.}, whereas for just active parts these sub-behaviours are typically “separated” by external non-determinism, \footnote{We refer to the \textit{sketch behaviour definitions} below.}. We refer to the \textit{sketch behaviour definitions} below.

\subsection*{2.5.7 Translating Parts into Behaviours:}
The main \textit{transcendental deduction} of the domain analysis \& description method is that of \textit{associating} with each physical part a behaviour.

\textit{CSP}. The association has these main elements: with part mereologies we associate CSP channels; with part attributes we associate CSP process arguments; and with domain behaviour interaction we associate CSP input/output: \texttt{ch ?/! v}.

\textbf{Channels:} Let \texttt{p:P} be a physical part with which we have decided to associate a behaviour. Let \texttt{mero\_P(p)} be some set of unique identifiers \texttt{uids}. Then that induces a contribution to a CSP channel declaration:

\begin{verbatim}
channel \{ p.ch[i] | i:UID \* i \in uids \} : MSG_P
\end{verbatim}

where \texttt{MSG\_P} is the type of the messages communicated over channel \texttt{p.ch[...]}.

\textbf{Sketch Behaviour Signatures:} A schematic part, \texttt{p:P}, behaviour signature is \texttt{value}

\begin{verbatim}
p.behav: pi:PI \times mero\_P(p) \times static\_attrs(p) \rightarrow control\_attrs(p)
            \rightarrow \text{ in } monitor\_attrs(p)
            \rightarrow \text{ in.out } \{ p.ch[i] | i:UID \* i \in mero\_P(p) \} \text{ Unit}
\end{verbatim}

\texttt{p.behav} is our chosen name for the behaviour of \texttt{p}. \texttt{pi} is \texttt{uid\_P(p)}, \texttt{static\_attrs(p)} the static attributes, by value, of \texttt{p}, \texttt{control\_attrs(p)} the control attributes, by value, of \texttt{p}, and \texttt{monitor\_attrs(p)} typically of the form

\begin{itemize}
  \item \texttt{attr\_A_m(p).ch}, \texttt{attr\_A_m(p).ch}, \ldots, \texttt{attr\_A_m(p).ch},
\end{itemize}

where \texttt{m} is the number of monitor-able attributes, designate these. \texttt{Unit} indicates that the behaviour is never-ending.

\textbf{Sketch Behaviour Definitions:}
The proactive sketch behaviour definition schema:

\begin{align*}
\text{value} & \\
0. & \quad p\_behav(pi,m,s)(c) \equiv \\
1. & \quad \ldots \\
2. & \quad \text{let} \ \text{intent} = \text{select\_intents}(s,c) \ \text{in} \\
3. & \quad \text{case} \ \text{intent} \ \text{of} \\
4. & \quad \ldots \\
5. & \quad i \rightarrow \text{let} \ \text{vjs} = \text{act\_val\_beh}(s,c,i) \ \text{in} \\
6. & \quad \parallel \left\{ \ p\_ch[j]!v \mid (v,j) \in \text{vjs} \right\} \\
7. & \quad \text{let} \ \text{r} = [j \mapsto p\_ch[j] ? j \mapsto i] \ \text{in} \\
8. & \quad p\_behav(pi,m,s)(\text{upd\_sta}(c,r)) \ \text{end} \ \text{end} \\
9. & \quad \ldots \\
0. & \quad \text{end} \ \text{end}
\end{align*}

The proactive sketch behaviour definition: (2.) The arbitrary selection of an intent. (5.) The handling of intent \( i \): the determination of information needed to carry out intent \( i \); (6.) the parallel communication with active “intent-partners”; (7.) the accumulation of “feedback” results, \( r \), from those “partners”; (8.) and the resumption of the \( p\_behav \).

The active definition schema symbolically shows (2.) the possibly non-deterministic external accept of communication values from some indexed (other) behaviour; (4.) the possible offering of an output message to that \((i=j)\) or another behaviour \((i \neq j)\); (6.) the likely update of the controllable state; and (7.) the resumption of the \( p\_behav \).

As behaviours may be both proactive wrt. some intents, and [just] active wrt. other intents, actual behaviour definitions may be combinations of the above.

2.5.8 Translation Schemes: Here, then, follows a major set of transcendental deductions: of mereologies into CSP [33] channels, of attributes into CSP process, i.e., behaviour arguments, and of parts into CSP processes: their signatures and their definition ‘bodies’.

\begin{align*}
\text{Transcendental Schema 1.} & \quad \text{is\_composite}(e) \\
\text{value} & \quad \text{Translate}(p) \equiv \\
& \quad \text{let} \ \text{ui} = \text{uid\_P}(p), \ \text{me} = \text{mereo\_P}(p), \\
& \quad \text{sa} = \text{stat\_attr\_vals}(p), \ \text{ca} = \text{ctrl\_attr\_vals}(p) \\
& \quad \text{ST} = \text{stat\_attr\_typs}(p), \ \text{CT} = \text{ctrl\_attr\_typs}(p), \\
& \quad \text{IOR} = \text{calc\_i\_o\_chn\_refs}(p) \ \text{in} \\
& \quad \ll \text{value} \\
& \quad \mathcal{M}_p: P_{UI} \times MT \times ST \ \text{CT} \ \text{IOR} \ \text{Unit} \\
& \quad \mathcal{M}_p(\text{ui},\text{me},\text{sa})(\text{ca}) \equiv \mathcal{P}_p(\text{ui},\text{me},\text{sa})(\text{ca}) \ \triangleright \\
& \quad \text{Translate}(\text{obs\_endurant\_sorts\_P}_1(p)) \\
& \quad \ll \parallel \triangleright \text{Translate}(\text{obs\_endurant\_sorts\_P}_2(p)) \\
& \quad \ll \parallel \triangleright \ldots \\
& \quad \ll \parallel \triangleright \text{Translate}(\text{obs\_endurant\_sorts\_P}_n(p)) \ \text{end}
\end{align*}

\begin{align*}
\text{Transcendental Schema 2.} & \quad \text{Concrete is\_composite}(p): p:\text{Q-set} \\
\text{type} & \quad \text{Qs} = \text{Q-set}
\end{align*}
value
qs:Q-set = \texttt{obs}_Qs(p)
\texttt{Translate}(qs) \equiv \{ \texttt{Translate}(q) \mid q:Q \in qs \}

Transcendental Schema 3.

<table>
<thead>
<tr>
<th>is_atomic(p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>value</td>
</tr>
<tr>
<td>Translate(p) \equiv</td>
</tr>
<tr>
<td>let ui = \texttt{uid}_P(p), me = \texttt{mereo}_P(p),</td>
</tr>
<tr>
<td>sa = \texttt{stat}<em>\texttt{attr}</em>\texttt{vals}(p), ca = \texttt{ctrl}<em>\texttt{attr}</em>\texttt{vals}(p),</td>
</tr>
<tr>
<td>ST = \texttt{stat}<em>\texttt{attr}</em>\texttt{typs}(p), CT = \texttt{ctrl}<em>\texttt{attr}</em>\texttt{typs}(p),</td>
</tr>
<tr>
<td>IOR = \texttt{calc}<em>\texttt{i}</em>\texttt{o}<em>\texttt{chn}</em>\texttt{refs}(p) in</td>
</tr>
<tr>
<td>$\ll$ value</td>
</tr>
<tr>
<td>$\mathcal{M}<em>P: P</em>{UI} \times MT \times ST \times PT \times IOR \times Unit$</td>
</tr>
<tr>
<td>$\mathcal{M}_P(ui,me,sa)(ca) \equiv \mathcal{B}_P(ui,me,sa)(ca) \rhd \text{ end}$</td>
</tr>
</tbody>
</table>

Transcendental Schema 4.

<table>
<thead>
<tr>
<th>Core Behaviour</th>
</tr>
</thead>
<tbody>
<tr>
<td>The core processes can be understood as never ending, ‘tail recursively defined’ processes:</td>
</tr>
<tr>
<td>$\mathcal{B}<em>P: uid:P</em>{UI} \times Me:MT \times sa:SA \rightarrow ct:CT$</td>
</tr>
<tr>
<td>$\rightarrow \text {in} in_\text{chns}(me) \text {in} out_\text{chns}(me) \text {Unit}$</td>
</tr>
<tr>
<td>$\mathcal{B}_P(ui,me,sa)(ca) \equiv$</td>
</tr>
<tr>
<td>let $(me',ca') = \mathcal{F}_P(ui,me,sa)(ca) \in \mathcal{M}_P(ui,me',sa)(ca') \text { end}$</td>
</tr>
<tr>
<td>$\mathcal{F}<em>P: P</em>{UI} \times MT \times SA \rightarrow CT \rightarrow \text {in} in_\text{chns}(me) \text {in} out_\text{chns}(me) \rightarrow MT \times CT$</td>
</tr>
</tbody>
</table>

2.6 Closing Section 2

A capsule view of the domain analysis & description calculi has been presented. For details we refer to [14]. We have shown how to derive essential aspects of their structure and signature from the external and internal qualities of endurant parts. But we have not shown how to analyse the domain with respect to the composition of actions, events and behaviours cf. $\mathcal{F}_P(ui,me,sa)(ca)$ above!

3 KAI SØRLANDER’S PHILOSOPHY

We shall review an essence of [59, 62, 66]. Kai Sørlander’s objective [66, pp 131] “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.”

The next five and a half page requires very concentrated reading.

3.1 The Basis.

In this section we shall mostly quote from [59, 66] – as further supported by [62].
‘The world is all that is the case. All that can be described in true propositions’ [59] pp, 13, ℓ 2-3. ‘In science we investigate how the world is factually’ [59] pp, 13, ℓ 7-8. ‘Philosophy puts forward another question. We ask of what could not consistently be otherwise’ [59] pp, 13, ℓ 11-12. [59] pp 13, ℓ 2–3, 2 pp 13, ℓ 7–8, 3 pp 13, ℓ 11–12 1,2,3

3.1.1 The Inescapable Meaning Principle. ‘It is thus the task of philosophy to determine the inescapable characteristics of the world and our situation in it’ [59] pp, 13, ℓ 13-15. 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’ [59] pp, 13, ℓ 25-28. We shall refer to this assumption as:

The Inescapable Meaning Principle

- The Inescapable Meaning Principle [59, pg. 13 /13-pg.14 /1] is 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 principle we bring, albeit from the world of computing, that of the description of the stack data type (its values and operations).

The Meaning of Designations

Stacks, narrative

13 Stacks, s:S, have elements, e:E;
14 the empty_S operation takes no arguments and yields a result stack;
15 the is_empty_S operation takes an argument stack and yields a Boolean value result.
16 the stack operation takes two arguments: an element and a stack and yields a result stack.
17 the unstack operation takes an non-empty argument stack and yields a stack result.
18 the top operation takes an non-empty argument stack and yields an element result.

The consistency relations, narrative:

19 an empty_S stack is_empty, and a stack with at least one element is not;
20 unstacking an argument stack, stack(e,s), results in the stack s; and
21 inquiring as to the top of a non-empty argument stack, stack(e,s), yields e.

The meaning of designations, formalisation:

<table>
<thead>
<tr>
<th>type</th>
<th>value</th>
</tr>
</thead>
<tbody>
<tr>
<td>E, S</td>
<td>Unit → S</td>
</tr>
<tr>
<td>S</td>
<td>Bool</td>
</tr>
</tbody>
</table>

13. empty_S: S → Bool
16. stack: E × S → S
17. unstack: S → S
18. top: S → E

The consistency relations, formalisation:

- is_empty(empty_S()) = true
- unstack(stack(e,s)) = s
- is_empty(stack(e,s)) = false
- top(stack(e,s)) = e

3.1.2 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.’ ‘That the inescapable meaning principle 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.’ ‘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.’ [59] pp 13, ℓ 16–17; 2 pp 13, ℓ 17–18; 3 pp 13, ℓ 20–21; 4 pp 14, ℓ 26–30; 5 pp 13, ℓ 2–31,2,3,4,5 satisfies the inescapable meaning principle. ‘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’ [59] pp, 15, ℓ 6-12. The inescapable meaning principle satisfies this basis [59], pp 30, ℓ 16–28.

3.1.3 Primary Entities [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 entities that can be directly referred to in simple empirical propositions must necessarily be. Those things are referred to as primary entities. A deduction of the inevitable characteristics of a possible world is thus identical to a deduction of how primary entities must necessarily be’ [59] pp, 15, ℓ 23-30.

3.1.4 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; and it must not consistently be false’ [59] pp, 30, ℓ 6-12. The inescapable meaning principle satisfies this basis [59], pp 30, ℓ 16–28.

3.1.5 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 [66, pp 136] “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. [66, pp 136] “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. ”

3.1.6 The Logical Connectives. Kai Sørlander now defines the logical connectives: conjunction (‘and’, ∧), disjunction (‘or’, ∨), and implication. They are all, in a sense, “derived” from the principle of contradiction: a proposition and the negation of the same proposition cannot both be true. [62, Chapters I–II] provides a thorough analysis.

3.1.7 Necessity and Possibility. [66, pp 142] “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”.

3.1.8 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.

3.2 Logical Conditions for Describing Physical Worlds

Which are the logical conditions of descriptions of any world? In [59, 66] Kai Sørlander, through a series of transcendental deductions “unravel” the following logical conditions: (i) symmetry and asymmetry, and (ii) transitivity and intransitivity. From these Kai Sørlander transcendentally deduces: (iii) space: direction, distance, (iv) time: before, after, in-between, etc., (v) states and causality.

3.2.1 Symmetry and Asymmetry. [66, pp 152] “[In any world] 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.”

3.2.2 Transitivity and Intransitivity. [66, pp 148] “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 intransitive relation”.

3.2.3 Space. [66, pp 154] “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 thus be understood as spatial relations. From these relations are derived the relation in-between. Hence we must conclude, by a transcendental deduction, 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.

3.2.4 States. [66, pp 158-159] “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”.

3.2.5 Time. [66, pp 159] “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”.

3.2.6 Multiple Entities. On the basis of the above Kai Sørlander can then deduce [62, Chap. II] that any world must exhibit multiple entities.

3.2.7 Causality. [66, pp 162-163] “States are related by the time relations “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 must 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 one 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! Transcendently, therefore, there must be a non-logical implicative between propositions about properties of a primary entity at different times. Such a non-logical implicative must depend on empirical circumstances subject to which the primary entity exists. There are no other circumstances. If the state of 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 possibility of self-awareness. Kai 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 Kai 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.

3.2.8 Kinematics. [66, pp 164–165] “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. A primary entity which does not change location is said to be at rest. The velocity\textsuperscript{34} 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.

3.2.9 Dynamics. [66, pp 165-165] “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 \textit{[transcendentally] deduce that if a primary entity changes state of movement then there must be a cause, and we call that cause a force”}.

3.2.10 Newton’s Laws. Newton’s First Law: [66, pp 165-166] “Combining kinematics and the principle of causality, and the theorems deduced concept of force, we can deduce that any change of movement is proportional\textsuperscript{35} 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 – that is, be at rest or conduction a linear movement at constant velocity. \textit{This is Newton’s First Law”}. Newton’s Second Law: [66, pp 166] “That a certain, non-zero force implies change of movement, imply that the primary entity must exert a certain resistance to that change. It must have what we shall call a certain mass.\textsuperscript{36} From this it follows that \textit{the change in the state of movement of a primary entity not only is proportional to the exerted force, but also inversely proportional\textsuperscript{37} to the mass of that entity.\textit{This is Newton’s Second Law.”} Newton’s Third Law: [66, pp 166-167] “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 \textit{oppositely directed and equal forces.\textit{This is Newton’s Third Law.”}”

3.2.11 Gravitation and Quantum Mechanics. Mutual Attraction: [66, pp 167-168] “How can primary entities possibly be the source of forces that influence one another? How can primary entities at all have a mass\textsuperscript{38} such that it requires forces to change their state of movement? The answer must be that primary entities exert a mutual influence on one another – that is \textit{there is a mutual attraction.” Gravitation: [66, pp 168] “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: [66, pp 168] “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.”\textsuperscript{39} Gravitational “Pull”: [66, pp 169-170] “The nature of gravitational “pull” can be \textit{[transcendentally] 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

\textsuperscript{34}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 ≤ z ≤ 90, where, if z = 90 we have that both x and y are 0).

\textsuperscript{35}Observe that we have “only” said: proportional, meaning also directly proportional, not whether it is logarithmically, or linearly, or polynomially, or exponentially, etc., so.

\textsuperscript{36}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.

\textsuperscript{37}Cf. Footnote 35.

\textsuperscript{38}cf. Footnote 36 Pg. 19

\textsuperscript{39}Let two entities have respective masses m\textsubscript{1} and m\textsubscript{2}. Let the forces with which they attract each other be f\textsubscript{1}, respectively f\textsubscript{2}. Then the law of gravitation – as it can be deduced by philosophical arguments – can be expressed as f\textsubscript{1} = f\textsubscript{2}. The specific force, expressed using Newton’s constant G is f = G\textsubscript{m\textsubscript{1}}\textsubscript{m\textsubscript{2}}\textsubscript{r\textsuperscript{-2}} where r is the distance between the two entities and G = 6.674×10\textsuperscript{-11} \text{m\textsuperscript{3}}\text{kg\textsuperscript{-1}}\text{s\textsuperscript{-2}} [m: meter, kg: kilogram s:second] – as derived by physicists.

Experiments have shown that Einstein’s results — with propagation limits — indeed hold for this world. Philosophy shows that edge:

A Summary: [66, pp 170-173] “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).”

3.3 The Logical Conditions for Describing Living Species

3.3.1 Purpose, Life and Evolution. Causality of Purpose: [66, pp 174] “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 and that these primary entities must be 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: [66, pp 174-175] “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 be in an exchange of matter with an environment. . . . It must be possible that living species occur in one of two forms: one form [1] which is characterised by development, form and exchange, and another form [2] which, additionally, can be characterised by the ability of purposeful movements. The first [1] we call plants, the second [2] we call animals.” Animate Entities: [66, pp 176] “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: [66, pp 177-178] “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 with respect to plants. Transcendentally one can deduce basic principles of evolution but not its details”

3.3.2 Consciousness, Learning and Language. Consciousness and Learning: [66, pp 180-181] “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 [transcendentally] deduce that animals must possess such building blocks whose inner determination is a basis for learning and consciousness.” Language: [66, pp 181-182] “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”.

3.3.3 Humans, Knowledge, Responsibility. Humans: [66, pp 184] “A human is an animal which has a language.” Knowledge: [66, pp 184] “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: [66, pp 184] “In this way one can
[transcendently] deduce that humans can thus have memory and hence can have responsibility, be responsible. Further deductions lead us into ethics.”

3.4 Closing Section 3

A capsule view of Kai Sørlander’s Philosophy has been presented. The first book in which Kai Sørlander develops his philosophy is [59], [62] reaffirms that philosophy along a different line. [66] is the most recent of Kai Sørlander’s books, treating the same subject, but now along a third and different line. We have mostly, and extensively, quoted from [59, 66].

4 AN INTERPRETATION

We refer to the thesis of this paper, Sect. 1.2 [pp. 2]. In this section we shall mark by a □ those statements where we conclude that specific description categories are indispensable.

4.1 What versus How to Describe?

Kai Sørlander’s Philosophy does not tell us what to describe, but it tells us, so is our interpretation, some fundamentals about how to analyse & describe. The domain analyser cum describer determines what; the domain analysis & description method mandates principles, techniques and some tools.

4.2 Entities

The calculi of Sect. 2 are a consequence of the universal fact that there must be more than one entity, in fact, an indefinite number of entities, in any universe, cf. Sect. 3.2.6 [pp. 18]. Thus the existence of the calculi is motivated on philosophical grounds.

Phenomena which can be analysed & described using the calculi of Sect. 2 are entities. So description of entities are the very core elements of any domain description.
□ Entities are inescapable elements of any world, i.e., any domain.

4.2.1 Endurants and Perdurants.

Entities are either endurants or perdurants. This distinction is ours. It is not made in Kai Sørlander’s Philosophy.

We are not quite happy with the two characterisations of ‘endurants’ respectively ‘perdurants’. They are taken from [35, Oxford Companion to Philosophy, pp 878–880 1995], [1, The Cambridge Dictionary of Philosophy, pp 807–810, 1995], and [23, The Blackwell Dictionary of Philosophy, pp 54–55 (1998)]. We shall stick to them for want of better. One reason is, crudely speaking, that endurants, when “represented” in software “occur” as data, while the counterpart of endurant parts (i.e., perdurants) “occur” a ‘procedures/processes’. Another reason for making the distinction is that we can then, as a transcendental deduction, relate endurants to perdurants

4.3 Endurants

Discussion 1. Discrete and Continuous Endurants: Our distinction between ‘discrete’ and ‘continuous’ endurants may be problematic. Why just those two “alternatives” ? As an example: water is deemed ‘continuous’, so is ‘vapour’. One might claim that some vapour is water at one temperature, but that the “same” entity is vapour at another temperature. So should one not have several distinctions instead of one for ‘continuous’ ? Generally: at one temperature an endurant is judged discrete, while at another, a usually higher, temperature, it is judged continuous. We focus on artifacts and their cause

In this paper we do not discuss natural endurants (parts or materials)

Kai Sørlander’s Philosophy does not introduce the notions of atomic and composite entities, i.e., parts.

The distinction between atomic and composite parts is important to “our whole story”!

The further analysis into ‘components’ and ‘concrete [set-oriented] parts’ is pragmatic and need not, and cannot (?) be justified on philosophical grounds.
4.3.1 Artifactual Endurants. Kai Sørlander’s Philosophy does not specifically make a distinction between natural (as pre-given in the physical world) and artifactual endurants. But his thinking applies to both natural and artifactual endurants.

Discussion 2. The Cause of Artifactual Endurants: We shall take it as a fact that humans are the cause of artifacts. Humans conceive, for example, of automobiles and roads, and humans endow these with intents: automobiles to drive on roads and roads to accept automobiles.

Hence the intentional “pull”: if we can talk of automobiles on roads, then we can describe that as a traffic attribute of any automobile; and if we can talk of roads accommodating automobiles, then we can describe that as a traffic attribute of any road, and hence we can postulate the intentional pull: The sum total of automobile traffics is commensurate with the sum total of road traffics. If we do talk, then we must describe:

- Intents and Intentional “Pull” are aspects of descriptions of artifactual entities in the same way that gravitational pull is of natural world descriptions.

4.3.2 Unique Identifiers [cf. pp. 5]. We recall that domains consist of indefinite numbers of endurants, cf. Sect. 4.2 [previous page]. Since they are spatial and cannot overlap we can speak of their unique identification.


Characterisation 16. Identity of Indiscernibles: The identity of indiscernibles is an ontological principle that states that there cannot be separate entities that have all their properties in common. That is, entities x and y are identical if every predicate possessed by x is also possessed by y and vice versa; to suppose two things indiscernible is to suppose the same thing under two names. It states that no two distinct things (such as snowflakes) can be exactly alike, but this is intended as a metaphysical principle rather than one of natural science. For any x and y, if x and y have all the same properties, then x is identical to y.

- \( \forall x \forall y [\forall P (P_x \leftrightarrow P_y) \rightarrow x = y] \)

Characterisation 17. Indiscernibility of Identicals: If two entities are in fact one and the same, they have all the same properties. For any x and y, if x is identical to y, then x and y have all the same properties.

- \( \forall x \forall y [x = y \rightarrow \forall P (P_x \leftrightarrow P_y)] \)

We shall adopt both characterisations – disregarding any controversies concerning these two principles. We do so since we restrict ourselves to manifest substances.40

Discussion 3. Representation of Unique Identifiers: We do not prescribe any representation of unique identifiers. It is enough to say that discrete endurants can be uniquely identified – for example by their LOCATION in SPACE (at a given TIME).

- We therefore argue that unique identification of discrete endurants are an indispensable aspect of any domain description.

4.3.3 Mereology [cf. pp. 5]. The English term ‘part’ has many possible meanings and is highly ambiguous. The introductory paragraphs of https://plato.stanford.edu/entries/mereology/ discusses quite a variety (fifteen) of these. Consonant with our upper level ontology parts are discrete physical endurants. It is only for such entities (save structures) that we define mereologies.

- Mereologies, and hence their description, are an indispensable element in any domain description.

4.3.4 Attributes [cf. pp. 5]. Endurants are characterised by one or more attributes. That is a universal fact. It is true for any domain.41 Attributes are what makes it possible to describe endurants Hence, we conclude that attributes of entities are an inevitable element in any description of the world!

- Attributes, and hence their description, are an indispensable element in any domain description.

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40 Substantive: anything that has mass and takes up space.
41 Although we may not always in any specific domain description, ascribe LOCATION attributes to parts, they nevertheless do possess such attributes, and they are all different. Similarly for attributes concerning the substance of discrete parts (wood, cement, clay bricks, steel and other metals, plastic, etc.).
4.4 Perdurants

We motivate that perdurants are an inevitable element of any domain and hence also their description, by referring to how Kai Sørlander arrives at kinematics and dynamics, cf. Sects. 3.2.8 [pp. 18]– 3.2.9 [pp. 19]. Kai Sørlander’s argument evolves from the transcendental reasoning that leads to the inevitability of space and time in any world, via the reasoning for causality to kinematics and dynamics. Purely logical reasoning and transcendental implications. Since kinematics and dynamics apply to natural parts they also apply to artifacts, and it is in this way we argue for the inevitability of actions, events and behaviours. There is an added dimension, though. Whereas Kai Sørlander’s argument for kinematics and dynamics, evolved purely without reference to living species, we shall have to include reasoning that does include living species in that artifacts can only be understood as having been conceived and created/constructed by humans and with some intent.

We therefore argue that **perdurants over discrete endurants are an indispensible aspect of any domain description.**

We do observe perdurants in the manifest, artifactual domains that we describe. But we “arrive” at perdurants, not by empirically observing these in the form of actions. events and behaviours. We “arrive”, instead, at behaviours by a transcendental deduction, i.e., by “morphing” pro-active and active parts into behaviours, and only then do we describe the composition of part behaviours in terms of observable sets of sequences of actions and events as they interact with other part behaviours. We have not, neither in this paper nor in [14], studied possible analysis calculi for perdurants: specifically how behaviours are composed from actions, events and (other) behaviours.

The reader must keep in mind that we are analysing & describing actions, events and behaviours in manifest, artifactual domains. We are not describing computable actions, events and processes of computers. But we are describing these domain perdurants in the specification language RSL$^+$ – in what may appear as actions, events and processes – and that may explain any possible confusion.

We shall argue for the distinction between actions, events and behaviours.

4.4.1 Actions [cf. Sect. 2.5.4 [pp. 12]]. Actions have been studied from a philosophy-point of view, as done in [70, 71, Wilson & Shpall https://plato.stanford.edu/entries/action/ 2012] and in [2, 27]. We refer to Sects. 2.2.4 [pp. 8], 2.5.6 [pp. 13] and 4.4.3.

4.4.2 Events [cf. Sect. 2.5.5 [pp. 13]]. Events have likewise been studied from a philosophy-point of view, as done in [3, 24, 25, 27, 28, 31, 39, 43, 45, 53, Casati & Varzi: https://plato.stanford.edu/entries/events/ 2014].

4.4.3 Behaviours [cf. Sect. 2.5.2 [pp. 12]]. We have used the term ‘behaviour’$^{43}$ in the loose sense$^{44}$ of their being sets of sequences of actions, events and behaviours and not from the point of view as propagated by behaviorism [58]. We have also noted that the two views may not necessarily “disagree”. The point being repeated here is that – by behaviours – we are referring to those associated with proactive and active domain parts, cf. Sect. 2.5.1, Defns. 13– 14 [pp. 12]. We refer to Sects. 2.2.4 [pp. 8], 2.5.6 [pp. 13] and 4.4.1. 5.2.4 [next page] [68, 69]

4.5 Further Issues.
5 CONCLUSION

Physicists analyse & describe the natural world as subject to the laws of Newton etc. Primary tools of description are the differential and integral calculi, statistics, probability theory and the like. In life sciences we analyse & describe living species: plants (botanists) and animals (zoologists, medical scientists, etc.). A primary tool of study is that of biology. In domain science & engineering we primarily analyse & describe the artificial world and, to some extent, humans as they monitor & control artifacts. In [14] and in this paper we have outlined a primary tool of domain study, the domain analysis & description principles, techniques and languages.

5.1 Have We Achieved A Clarification?
The claim is here being made that before [7, 9, 14, 17] there was no analysis & description method for studying artifactual domains. In that sense we claim to have achieved a clarification of the what the second half of the title of this paper refers to. As to the first half and the tailing question mark, does domain science & engineering have a basis in philosophy? we now claim that there is a basis, and that we have at least made some contribution towards such a basis. It is all very much a first such study. We expect refutations and further clarifications so that the suggested field of study may progress.

5.2 Open Problems / Future Work
We invite the reader to reflect upon the issues of this paper and on those listed here.

5.2.1 Intents and Intentional “Pull”. In this paper as well as in [14], we have only very briefly touched upon the issue of ‘intents’ as “laid down” in artifactual parts by human designers, as well as the derived notion of intentional “pull”. It should be clear that [14] and this paper has only “scratched a surface”, that is, that more dedicated studies of intents and intentional “pull” are needed.

5.2.2 Artifact Attributes. We refer to Sect. 2.2.1 [pp. 6].

5.2.3 Transcendental Deduction. It is the first time we have applied a principle of transcendental deduction. We expect to receive critique (positive and, better, negative) on our use of this principle. We also expect to be able better to delineate the scope for use of this principle.

5.2.4 Process Philosophy. If you discerned some hesitancy in my ascribing, in the examples of Sect. 2.3, perdurants to [some] endurants, there is, perhaps, a reason. The issue of transcendental deduction of behaviours from parts is really not that simple. The reader may rightfully say that my claim is a bit too “bold”. Some philosophers have thought more deeply on this than I do here. Alfred North Whitehead, in [68, 69], for example, proposes a different way of considering endurancy and perdurancy of entities. We refer to [40, Ivor Leclerc].

5.2.5 Ethics. In [59, 62, 66] and especially in [60] Kai Sørlander also explores issues of ethics as they can be transcendentally deduced. We shall, ourselves, reflect on Kai Sørlander’s study in this area as it may relate to issues of ethics in computer science.

5.3 Is Philosophy Useless?
It is often said that “philosophy is useless”. In this paper we have “made use of philosophy”. Hopefully I have not defiled Kai Sørlander’s Philosophy.

With philosophy we are dealing with a human endeavour in which it does not make sense to speak of refutable theories. One philosophers claims, although they can be disputed, can not be refuted in the science sense of that concept.
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My most serious thanks goes, naturally, to Kai Sørlander, the Danish philosopher whose books [59–66] inspired and keep inspiring me.

REFERENCES

A. A DOMAIN ANALYSIS & DESCRIPTION EXAMPLE

The domain is that of a simplified credit card system. It is simplified for example in the following aspects. We model credit card holders in terms of their credit cards. We model the goods (i.e., goods), traded by enterprises, and hence either owned by these or by credit card holders, as (a “pool”) separate from both enterprises and credit card holders, i.e., not as elements of composite credit cards or composite enterprises. That is: credit cards, banks, enterprises and goods are considered atomic. From unique goods identifiers we postulate that one can obtain the detailed type of the goods (detailed kind, manufacturer, production date, etc.), but so that all instances of any specific type [still] have unique identification.

A.1 Parts

A.1.1 Abstract Sorts: Composite Parts, Page 6

1. A simple credit card system, SCS, consists of
2. a conglomerate, CCs, of credit cards,
3. a conglomerate, CBs, of credit card banks,
4. a conglomerate, CEs, of credit card accepting enterprises, and
5. a conglomerate, CGs, of goods.

value

6. obs_CCs: SCS \rightarrow CCs
7. obs_CBs: SCS \rightarrow CBs
8. obs_CEs: SCS \rightarrow CEs
9. obs_CGs: SCS \rightarrow CGs

A.1.2 Concrete Types: Atomic Parts, Page 7

6. From a conglomerate, CCs, of credit cards we can observe a set, Cs, of credit cards, C.
7. From a conglomerate, CBs, of credit card banks we can observe a non-empty set, Bs, of banks, B.
8. From a conglomerate, CEs, of credit card accepting enterprises we can observe a non-empty set, Es, of enterprises, E.
9. From a conglomerate, CGs, of goods we can observe a non-empty set, Gs, of goods, G.

value

6. obs_Cs: CCs \rightarrow Cs
7. obs_Bs: CBs \rightarrow Bs
8. obs_Es: CEs \rightarrow Es
9. obs_Gs: CGs \rightarrow Gs

A.1.3 States [Sect. 2.2.3 [pp. 7]]:

10. Any value of an entire credit card system is a state.

value

10. ccs: CCS
11. cs:Cs = obs_Cs(obs_CCs(ccs))
12. bs:Bs = obs_Bs(obs_CBs(ccs))
13. es:Es = obs_Es(obs_CEs(ccs))

A.2 Unique Identifiers, Page 7

We shall omit consideration of identification of conglomerates and sets and focus only on consideration of atomic parts.

A.2.1 Sorts

MORE TO COME

A.2.2 Auxiliary Functions: From a credit card system we can extract the sets of

\[ \text{card, bank, enterprise, and goods identifiers.} \]

\[ \text{value} \]

\[ \text{xtr.Cls: CCS} \rightarrow \text{Cl-set} \]

A.2.3 Auxiliary Values: From the universal ccs we can extract the unique identifier constants.

\[ \text{value} \]

\[ \text{cis.Cl-set} = \text{xtr.Cls(ccs)} \]
\[ \text{bis.Bl-set} = \text{xtr.Blss(ccs)} \]
\[ \text{eis.El-set} = \text{xtr.ELss(cis)} \]
\[ \text{gis.Gl-set} = \text{xtr.Glss(cis)} \]

A.2.4 Part Retrieval Functions

Given any credit card identifier we can retrieve the credit card with that identifier.

\[ \text{value} \]

\[ \text{retr.C.C} \rightarrow \text{C-set} \rightarrow \text{C} \]

A.2.5 Constraints

All credit card, bank, enterprise and goods (item) identifiers are unique.

A.3 Mereologies, Page 7

Every credit card (of the system) is conceptually connected to a single bank (of the system), to a subset of the enterprises (of the system) and to potentially all goods (of the system).

\[ \text{type} \]

\[ \text{CM} = \text{Bl} \times \text{El-set} \times \text{Gl-set} \]
\[ \text{BM} = \text{Cl-set} \times \text{El-set} \]
\[ \text{EM} = \text{Cl-set} \times \text{Bl-set} \times \text{Gl-set} \times \text{Bl} \]
\[ \text{GM} = \text{El-set} \times \text{Cl-set} \]

A.3.1 (…) Constraints [cf. Sects. A.1.3 and A.2.3]

\[ \text{axiom} \]

\[ \forall \ c: \text{C} \in \text{ccs} \Rightarrow \]
\[ \text{let} \ (\text{bi}, \text{meis}, \text{mpis}) = \text{mereo.C}(c) \]
\[ \Rightarrow \ b: \text{bi} \in \text{meis} \land \text{bi} \in \text{mpis} \land \text{mpis} \in \text{pis end} \land \]
\[ \forall \ b: \text{bi} \in \text{meis} \Rightarrow \]
\[ \text{let} \ (\text{mcis}, \text{meis}) = \text{mereo.B}(b) \]
A.4 Attributes, Page 7

A.4.1 Credit Cards

33 To every card we associate a possibly empty wish list of desired goods,
their supplying enterprise, time when “whished for” and cost – where
these supplying enterprises have indeed at that time had that goods (item)
for sale and at that price.

34 To every card we associate a possibly empty set of goods – represented
by their unique identifiers – “mapped” into a triplet: identity of enter-
prise, time when acquired and

35 acquisition cost – where these supplying enterprises have indeed at that
time had that goods (item) for sale and at that price.

\[ \text{WISH} = \text{GI}_{\text{acq}}(\text{EI} \times \text{T} \times \text{COST}) \]

A.4.2 Banks

Banks are characterised by

36 a ledger which records, for every customer – whether a credit card
(owner) or an enterprise (owner) – its credit balance; and

37 a cash register which reflects the sum total of all customers’ credit
balances.

\[ \text{LDGR} = (\text{CI} | \text{EI}) \rightarrow \text{m} \rightarrow \text{BAL} \]

\[ \text{CASH} = \text{Intg} \]

A.4.3 Enterprises

38 An enterprise records a set of goods as a map from goods (item) identi-
fiers to their price (cost), as well as

39 a record of all most recent sales in the form of a map from goods (item)
identifiers to customer (by credit card identifier), sales date (i.e., time)
and price (cost),

40 a record of all most recent refunds in the form of a map from goods
(item) identifiers to customer (by credit card identifier), return date (i.e.,
time) and refund, and

41 a history of all transactions in the form a list of enterprise transactions,
most recent first.

42 An enterprise transaction is ...

Some constraints:

a goods (for sale) includes returns,

b sold goods (i.e. sales) are not among the goods for sale, and

c browsings, sales and returns are recorded (whether successful or not)
in the transaction history which is a time stamped sequence of
browses, sales and refund transactions.

d Occurrences of credit card identifications in goods, sales and history
attributes must be those of credit card system credit card identifiers.

A.4.4 Goods

44 To every goods (item) we can associate a goods history which, in this
case is a sequence of time-stamped (alternative) identifiers of enterprises
and credit card (holder)s.

\[ \text{GS} = \text{GI}_{\text{acq}}(\text{T} \times \text{CI} \times \text{COST}) \]

\[ \text{SS} = \text{GI}_{\text{acq}}(\text{T} \times \text{CI} \times \text{COST}) \]

\[ \text{RS} = \text{GI}_{\text{acq}}(\text{T} \times \text{CI} \times \text{COST}) \]

\[ \text{TH} = \text{ET}^+ \]

\[ \text{value} \]

\[ \text{let} (\text{gs,ss,rs,th}) = (\text{xtr_GS,attr_SS,attr_RS,attr_PH}(e) \in \text{gs}) \]

\[ \text{dom rs} \subseteq \text{dom gs} \]

\[ \text{dom ss} \cap \text{dom gs} = \{\} \]

\[ \text{type} \]

\[ \text{value} \]

\[ \text{let} (\text{gs,ss,rs,th}) = (\text{xtr_GS,attr_SS,attr_RS,attr_PH}(e) \in \text{gs}) \]

\[ \text{dom rs} \subseteq \text{dom gs} \]

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\[ \text{let} (\text{gs,ss,rs,th}) = (\text{xtr_GS,attr_SS,attr_RS,attr_PH}(e) \in \text{gs}) \]

\[ \text{dom rs} \subseteq \text{dom gs} \]

\[ \text{dom ss} \cap \text{dom gs} = \{\} \]

\[ \text{type} \]

\[ \text{value} \]

\[ \text{let} (\text{gs,ss,rs,th}) = (\text{xtr_GS,attr_SS,attr_RS,attr_PH}(e) \in \text{gs}) \]

\[ \text{dom rs} \subseteq \text{dom gs} \]

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\[ \text{type} \]

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\[ \text{let} (\text{gs,ss,rs,th}) = (\text{xtr_GS,attr_SS,attr_RS,attr_PH}(e) \in \text{gs}) \]

\[ \text{dom rs} \subseteq \text{dom gs} \]

\[ \text{dom ss} \cap \text{dom gs} = \{\} \]

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\[ \text{value} \]

\[ \text{let} (\text{gs,ss,rs,th}) = (\text{xtr_GS,attr_SS,attr_RS,attr_PH}(e) \in \text{gs}) \]

\[ \text{dom rs} \subseteq \text{dom gs} \]

\[ \text{dom ss} \cap \text{dom gs} = \{\} \]
A.4.5 Intentional “Pull” [cf. Sect. 2.2.4 [pp. 8]]

48 If a goods (item) is recorded in an enterprise’s goods (item) inventory, then somehow it must be recorded as such in that goods history, and vice versa; similarly if recorded in a credit card as acquired.

A.5 Channels [Cf. pp. 13]

We shall be using all four transcendental schemes.

55 Using Transcendental Schema 1 we shall omit (i.e., skip) of the Translate(p) clause – hence the first 9 lines of the Translate clause – which expands into the composition, using Transcendental Schema 2, of sets of

56 Translate(c),
57 Translate(b),
58 Translate(e), and
59 Translate(p).

A.6.1 Credit Card Behaviour Signature:

60 The translation of credit card parts yields some RSL+-text:

61 the credit_card behaviour signature followed by
62 the credit_card behaviour definition which we, for the moment, omit!

A.6.2 Bank Behaviour Signature:

63 The translation of bank parts yields some RSL+-text:

64 the bank behaviour signature followed by
65 the bank behaviour definition which we, for the moment, omit!
A.6.3 Enterprise Behaviour Signature:

66 The translation of enterprise parts yields some RSL+\text{-text}:
67 the enterprise behaviour signature followed by
68 the enterprise behaviour definition which we, for the moment, omit!

A.6.4 Goods Behaviour Signature:

69 The translation of bank parts yields some RSL+\text{-text}:
70 the bank behaviour signature followed by
71 the bank behaviour definition which we, for the moment, omit!

A.6.5 System Initialisation:

72 The credit card system behaviour is
73 parallel composition of the set of credit card behaviours in parallel with

74 parallel composition of the set of bank behaviours in parallel with
75 parallel composition of the set of enterprise behaviours in parallel with
76 parallel composition of the set of goods behaviours.

A.7 Individual Behaviours

A.7.1 The Intentional Credit Card System Behaviours The overall intention of the credit card system that we are modelling is that of endowing existing citizens, banks and enterprises with credit cards. Citizens are modelled as credit card holders. A citizen purchasing a product (incl. a service) from an enterprise is modelled by the actions of the credit card – which is here seen as having a proactive behaviour. We model the following behaviours:

- **Credit card holders** proactively:
  - browse (enterprises) for price of products (goods) of specific kinds;
  - purchase such goods (from enterprises); and
  - return bought goods (to enterprises) for refund.

- **Banks** actively responding to:
  - inquiries checking account balances (from credit cards);
  - deposit requests (from enterprises); and
  - withdrawal requests (from enterprises).

- **Enterprises** actively responding to (credit card holders):
  - browsing queries;
  - purchase requests; and
  - refund requests.

- **Goods [Products]** actively responding to move directives (from enterprises).

A.7.2 Credit Card Behaviour. We consider only the proactive facets of credit card[ holder]\s, not their possible active facets.

77 Cards proactively either
78 (window shopping) browses as to desirable products: item, provider and
cost.
79 acquires such a product – provided sufficient credit, or
80 returns the product for a refund.
In “window-shopping” the credit card [holder]

81 selects an arbitrary enterprise, and an arbitrary kind of product; then
82 communicates, ch[(ci,ei)]!mkWiWh(ci,ki,ti), its desire to browse and,
in return, receives a suggestion, i.e. a choice, let (ei,piest)=ch[(ci,ei)];
83 if the enterprise has not found an offer
84 then it resumes being an unchanged credit card,
85 else
86 the credit card [holder] updates its wish list; and
87 resumes being a credit card with the updated wish list.

In acquiring a product

88 the credit card [holder] selects a wished-for such, where to buy it and its
cost;
89 then it checks with the bank that there are sufficient funds;
90 if there is not sufficient credit the credit card resumes being so with no
changes;
91 if there is sufficient credit then a purchase is requested from the enter-
prise;
92 if the enterprise has the requested item then
a the following is noted: the purchase time, that the credit card no
longer wishes that item, and that the item has now been acquired,
b whereupon the credit card resumes being so with updated wish and
acquisition states,
93 otherwise the resumes being so with no updated states.

value
79 acquisition((ci,(bi,eis,gis),...),(wish,acq)) ∈
80 let pi:pi∈dom wish in
88 let (ei,ti,pri) = wish(pi) in
89,101 let rb = ch[(ci,bi)]! mkChkBali(pi,bi) ;ch[(ci,bi)]? in
90,103 if rb = (“nok”,””) then
91,124 else if there is sufficient credit then a purchase is requested from the enter-
prise;
92 if the enterprise has the requested item then
a the following is noted: the purchase time, that the credit card no
longer wishes that item, and that the item has now been acquired,
b whereupon the credit card resumes being so with updated wish and
acquisition states,
93 otherwise the resumes being so with no updated states.

value
78 window_shopping((ci,(bi,eis,gis),per),(wish,acq)) ∈
81 let ei:Ei∈eis, ki:KI in
82,115 if re = ch[(ci,ei)]! mkWiSh(ci,ki) ;ch[(ci,ei)]? in
83,136 else if re = “nok” then
84,144 then credit_card((ci,(bi,eis,gis),per),(wish,acq)
85,119 else let (ei,(pi,ti,pr)) = re in
86,144 let wish’ = wish ? [pi→(ei,ti,pr)] in
87,144 credit_card((ci,(bi,eis,gis),per),(wish’,acq)
78 end end end end

In refunding
94 the credit card [holder] selects an acquired product;
95 informs the designated enterprise of the product, its time of acquisition
and cost;
96 then the credit card [holder] awaits a response from the enterprise;
97 if that response is “ok” then
a the credit card [holder] removes the refunded product
b and resumes being a credit card (with an updated acquisition state);
98 else resumes being a credit card (with no changed state).

value
80 refund((ci,(bi,eis,gis),per),(wish,acq)) ∈
94 let pi:pi∈dom acq in
94 let (ei,ti,pr) = acq(pi) in
95,140 ch[(ci,ei)]! mkRfnd(pi,ti,bi) ;
96,144 let (re,ch[(ci,ei)]) = re in
97 if r = “ok” then
97a if there is not sufficient credit the credit card resumes being so with no
changes;
98,144 else credit_card((ci,(bi,eis,gis),per),(wish,acq)
80 end end end

A.7.3 Bank Behaviour. We here consider only the active facets of a bank, not its possible proactive facets.

Footnote: The first of the double references in formalisations refer to a narrative description; the second to the narrative+formalisation that “matches”, as here, the CSP output clause see Page 33.
A Philosophy Basis for Domain Science & Engineering?
Incomplete Draft Sketch

In depositing an amount of monies into an enterprise account the bank external non-deterministically 
99 either credit card holder(s) (for checking credit balance) actions;
99 or with enterprises for their deposit actions;
98 [0x0]balance(bi,bm,sa)(ldgr,cash)
98 KI(pi)
97 T
96
A.7.4 Enterprise Behaviour. We consider only the active facets of enterprises, not their possible proactive facets.
93 In browsing the enterprise
91 offers external non-deterministically, from any credit card holder, to
91 accept a window shopping inquiry for a product of a designated kind;
91 then, if some (one or more) are for sale,
92 selects an arbitrary product of that kind,
92 retrieves its price, records browsing time,
92 and communicates this to the inquiring credit card holder;
92 whereupon it resumes being the enterprise with an updated enterprise transaction history.
91 Otherwise
91 the inquiring credit card holder is informed that there is no such product available
90
In withdrawing an amount of monies from an enterprise holder’s account the bank external non-deterministically 
106 offers to accept such withdraw communications from its enterprise customers;
107 updates that enterprise holder’s (ledger) account
108 let
107 mkWithdraw(cei,amnt,ti)=ch(bi,ei) \in in
106 let
105ch(bi,bm,sa)(ldgr,cash)
104 else a “nok” to the inquiring credit card –
103 a either responds to window browsing,
102 or to purchasing,
101 c or to refunds.
100 else
100 whereupon it resumes being a bank (with no state change).

In checking a credit card balance towards some amount (cost) the bank external non-deterministically
101 offers to accept such checking queries from any credit card holder;
102 retrieves the balance on the designated account;
103 if that balance is less than the designated amount, i.e., cost, then the bank communicates an “ok”;
104 else a “nok” to the inquiring credit card –
105 whereupon it resumes being a bank (with no state change).

In depositing an amount of monies into an enterprise account the bank external non-deterministically 
111 offers to accept such deposit communications from its enterprise customers;
112 updates that customers’ account with the amount;
113 whereupon it resumes being a bank (with the ledger state change).

In withdrawing an amount of monies from an enterprise holder’s account the bank external non-deterministically
106 offers non-deterministically
107 offers to accept such withdraw communications from its enterprise customers;
108 updates that enterprise holder’s (ledger) account
109 whereupon it resumes being a bank (with the ledger state change).

A.7.4 Enterprise Behaviour. We consider only the active facets of enterprises, not their possible proactive facets.

In depositing an amount of monies into an enterprise account the bank 
110 external non-deterministically
111 offers to accept such deposit communications from its enterprise customers;
112 updates that customers’ account with the amount;
113 whereupon it resumes being a bank (with the appropriate state changes).

A bank c or with enterprises for their withdraw actions.
99
98
97
96
95
94
93
92
91
90

<table>
<thead>
<tr>
<th>A bank</th>
<th>c or with enterprises for their withdraw actions.</th>
</tr>
</thead>
<tbody>
<tr>
<td>99</td>
<td>bank(bi,bm,sa)(ldgr,cash) ≡</td>
</tr>
<tr>
<td>99a</td>
<td>check_balance(bi,bm,sa)(ldgr,cash) ≡</td>
</tr>
<tr>
<td>99b</td>
<td>deposit(bi,bm,sa)(ldgr,cash) ≡</td>
</tr>
<tr>
<td>99c</td>
<td>withdraw(bi,bm,sa)(ldgr,cash) ≡</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>In checking a credit card balance towards some amount (cost) the bank</th>
<th>99a check_balance(bi,bm,sa)(ldgr,cash) ≡</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>101.89 ( { \text{let } mkChkBal(pr,ei,bi,ei)=ch(bi,ei) \text{ if } \in } )</td>
</tr>
<tr>
<td>external non-deterministically</td>
<td>102 let bal = ldgr(cei) in</td>
</tr>
<tr>
<td>offers to accept such checking queries from any credit card holder;</td>
<td>103.90 if pri\geq bal then ch(bi,ei) \equiv &quot;nok&quot;</td>
</tr>
<tr>
<td>retrieves the balance on the designated account;</td>
<td>104.92 else ch[bis,ei] \equiv &quot;ok&quot; end</td>
</tr>
<tr>
<td>103</td>
<td>105 bank(bi,bm,sa)(ldgr,cash) end end</td>
</tr>
<tr>
<td>if that balance is less than the designated amount, i.e., cost, then</td>
<td>106</td>
</tr>
<tr>
<td>the bank communicates an “ok”;</td>
<td>107</td>
</tr>
<tr>
<td>else a “nok” to the inquiring credit card –</td>
<td>108</td>
</tr>
<tr>
<td>105</td>
<td>109</td>
</tr>
<tr>
<td>whereupon it resumes being a bank (with no state change).</td>
<td>106</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>In depositing an amount of monies into an enterprise account the bank</th>
<th>99b deposit(bi,bm,sa)(ldgr,cash) ≡</th>
</tr>
</thead>
<tbody>
<tr>
<td>110</td>
<td>111.147 ( { \text{let } mkDeposit(cei,amnt,ti)=ch(bi,ei) \text{ if } \in } )</td>
</tr>
<tr>
<td>external non-deterministically</td>
<td>112 let ldgr'=ldgr(cei+amnt) in</td>
</tr>
<tr>
<td>offers to accept such deposit communications from its enterprise customers;</td>
<td>113 bank(bi,bm,sa)(ldgr',cash+amnt) end end</td>
</tr>
<tr>
<td>updates that enterprise holder’s (ledger) account</td>
<td>110 { ei:EI }</td>
</tr>
<tr>
<td>whereupon it resumes being a bank (with the ledger state change).</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>A.7.4 Enterprise Behaviour. We consider only the active facets of enterprises, not their possible proactive facets.</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>114 An enterprise externally non-deterministically ([])</td>
<td>114 An enterprise externally non-deterministically ([])</td>
</tr>
<tr>
<td>a either responds to window browsing,</td>
<td>a either responds to window browsing,</td>
</tr>
<tr>
<td>b or to purchasing,</td>
<td>b or to purchasing,</td>
</tr>
<tr>
<td>c or to refunds.</td>
<td>c or to refunds.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>In browsing the enterprise</th>
<th>123 whereupon the enterprise resumes being the enterprise with an updated enterprise transaction history.</th>
</tr>
</thead>
<tbody>
<tr>
<td>115 offers external non-deterministically, from any credit card holder, to</td>
<td>114a browse(ei,em,...)(ps,ss,rb,ph) \equiv</td>
</tr>
<tr>
<td>accept a window shopping inquiry for a product of a designated kind;</td>
<td>114b purchase(ei,em,...)(ps,ss,rb,ph) \equiv</td>
</tr>
<tr>
<td>then, if some (one or more) are for sale,</td>
<td>114c refund(ei,em,...)(ps,ss,rb,ph) \equiv</td>
</tr>
<tr>
<td>116 selects an arbitrary product of that kind,</td>
<td>117 { let mkWiSh(pi,ei)=ch(bi,ei) \equiv in</td>
</tr>
<tr>
<td>117 retrieves its price, records browsing time,</td>
<td>117 if ( \exists \text{pi:PI }\in \text{dom ps} \land \text{xtr(K(pi))=ki} )</td>
</tr>
<tr>
<td>118 and communicates this to the inquiring credit card holder;</td>
<td>117 then let ( \text{pi:PI }\in \text{dom ps} \land \text{xtr(K(pi))=ki} )</td>
</tr>
<tr>
<td>119 whereupon it resumes being the enterprise with an updated enterprise</td>
<td>118 let pri = ps(pi), t = record_mkWiSh(pi,t,pr) \equiv</td>
</tr>
<tr>
<td>transaction history.</td>
<td>119,85 ch[bis,ei] \equiv mkWiSh(pi,ei) \equiv</td>
</tr>
<tr>
<td>120 Otherwise</td>
<td>120 enterprise(ei,em,...)(ps,ss,rb,((bi,ei))) \equiv</td>
</tr>
<tr>
<td>121 the inquiring credit card holder is informed that there is no such product available</td>
<td>121 end</td>
</tr>
<tr>
<td>122 whereupon the enterprise resumes being the enterprise with an updated enterprise transaction history.</td>
<td>122,83 ch[bis,ei] \equiv &quot;nok&quot;</td>
</tr>
</tbody>
</table>

In refunding the enterprise
113 externally non-deterministically offers to consider a buy order from
114 appropriate credit card holders;
115 the time of purchase is recorded;
116 if the product and buyer-stated price of the order is available at the
117 enterprise and matches its price then five concurrent actions then take
118 place:
119 the buyer is informed of a successful purchase,
120 the buyer’s bank is requested to withdraw the amount of the price from
121 the credit card holder’s balance,
122 the enterprise’s bank is requested to deposit that amount in the enter-
123 prise’s account;
124 the product is “relocated”, from the enterprise to the buying credit card
125 holder, and
126 the enterprise then resumes being an enterprise now with
127 product removed from being available,
128 updated product sales record,
129 unchanged refund history, and
130 updated transaction history.
131 Otherwise the buying credit card holder is informed of a failed purchase,
132 product is “relocated”, from the enterprise to the buying credit card
133 holder, and
134 the enterprise resumes being an enterprise now with
135 no change in products for sale, sales and refund history,
136 but with an updated transaction history.

In purchasing the enterprise
123 externally non-deterministically offers to consider a buy order from
124 appropriate credit card holders;
125 the time of purchase is recorded;
126 if the product and buyer-stated price of the order is available at the
127 enterprise and matches its price then five concurrent actions then take
128 place:
129 the buyer is informed of a successful purchase,
130 the buyer’s bank is requested to withdraw the amount of the price from
131 the credit card holder’s balance,
132 the enterprise’s bank is requested to deposit that amount in the enter-
133 prise’s account;
134 the product is “relocated”, from the enterprise to the buying credit card
135 holder, and
136 the enterprise then resumes being an enterprise now with
137 product removed from being available,
138 updated product sales record,
139 unchanged refund history, and
140 updated transaction history.
141 Otherwise the buying credit card holder is informed of a failed purchase,
142 product is “relocated”, from the enterprise to the buying credit card
143 holder, and
144 the enterprise resumes being an enterprise
145 with no change in products for sale, sales and refund history,
146 but with an updated transaction history.

A.7.5 Product Behaviour. We consider only the active facets of products, not their possible proactive facets.
The product externally non-deterministically offers to accept messages from enterprises informing that product as to its changed ownership:

a. either to henceforth belong to some credit card [holder], where before it belong to an enterprise,

b. or to henceforth belong to some enterprise where before it belong to a credit card [holder]

whereupon the product resumes being a product with updated history.

```plaintext
let mkOwner(i,t) = ch[g],e, ? in

assert: i:CI ⇒ ∃ ei:EI • ei ∈ eis ∧ hd ph = ⟨ mkOwner(ei) ⟩
∧ i:EI ⇒ ∃ ci:CI • ci ∈ cis ∧ hd ph = ⟨ mkOwner(ci) ⟩
goods(gi,(eis,cis),...)(⟨ mkOwner(i,t) ⟩) end
```

150 | ei:EI ∈ eis |
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