2 Domains 41

By an observable phenomenon we shall here understand something that can be sensed by one or more of our five sense organs. By a domain we shall here informally understand an area of human activity characterised by observable phenomena: entities and their properties, and abstractions, i.e., concepts, thereof. In Sect. 2.4 we suggest a more formal way of characterising a domain. But first we give some rough sketch hints as to what domains are.

Inquiry: Rough-sketching and Rough Sketch

> *We shall be using the idea of 'rough-sketching' descriptions (prescriptions and specifications) as a means to give the reader a rough, but not yet sufficiently precise idea of what we are aiming at. Rough-sketching (as a verb) a domain description is a process which helps the 'rough-sketcher' in first discovering the parts, actions, events and behaviours of a domain. Rough sketch (as a noun) is the result of rough-sketching and serves to help the rough-sketcher to formulate (not the, but) an essence.* •

2.1 Informal Characterisation 42

There are several forms of observable phenomena. There are the entities: **endurant**[7] entities: **parts**, and **perdurant**[8] entities: **actions**, **events**, and **behaviours** of the domain. Then there are the properties of these entities: (i) their **unique identifications**, (ii) the **mereology** of parts, that is, how parts are "put together", parts within, or subparts of other parts, etcetera, and (iii) the **attributes** of parts: types and values, whether atomic
43 or composite, and of actions, events and behaviours: signatures and values. We will just examine one of the part properties.

2.2 Mereology

Mereology, to us, is the study and knowledge about how physical and conceptual parts relate and what it means for a part to be related to another part: being *adjacent* to, being
44 *contained* properly within, being *overlapped* (i.e., *sharing*) properly with, etcetera.

By physical parts we mean such spatial individuals which can be pointed to. **Examples:** *a road net (consisting of street segments and street intersections); a street segment (between two intersections); a street intersection; a vehicle; and a platoon (of sequentially*
45 *adjacent vehicles).*

By a conceptual part we mean an abstraction with no physical extent, which is either present or not. **Examples:** *a bus timetable (not as a piece or booklet of paper, or as an electronic device, but) as an image in the minds of potential bus passengers; and routes of a pipeline, that is, adjacent sequences of pipes, valves, pumps, forks and joins, for example*

[7] Endurants are those entities that can be observed-perceived as a complete concept, at no matter which given snapshot of time [Wikipedia].

[8] Perdurants are those entities for which only a part exists if we look at them at any given point in time. When we freeze time we can at most see a part of the perdurant. [Wikipedia].

referred to in discourse: take *"such-and-such" a route"*. The tricky thing here is that a route may be thought of as being both a concept or being a physical part — in which case one ought give them different names: a planned route and an actual route, for example. 46

The mereological notion of subpart, that is: *contained within* can be illustrated by **examples:** *the intersections and street segments are subparts of the road net; vehicles are subparts of a platoon; and pipes, valves, pumps, forks and joins are subparts of pipelines.* The mereological notion of adjacency can be illustrated by **examples:** *the pipes of a pipeline are adjacent (that is, connected) to other pipes or valves or pumps or forks or joins, etcetera; two immediately neighbouring vehicles of a platoon are adjacent. We shall mereologically model adjacency by the mereology notion of overlap.* The mereological 47 notion of proper overlap can be illustrated by **examples:** *two routes of a pipelines may overlap; and two conceptual bus timetables may overlap with some, but not all bus line entries being the same.*

2.3 Rough Sketch Hints of Domains 48

Example 5 (Domains) We present a number of examples:

- *Container Line:* A container line consists of a number of *container vessels* capable of holding (usually thousands of) *containers* being transported, by the vessels, between *container terminal ports* across the seven seas. A container vessel has its containers ordered in *bays*, *rows*, and *stacks* with *container terminal port cranes* depositing or removing ("lifting") *containers* onto or from port side *stack tops*. Container vessels sail specific *routes* with a route being designated by a sequence of *container terminal port visits* where a *container terminal port visit*, amongst others, has a *container terminal port name*, *estimated and actual arrival times*, etc. Etcetera. 49

- *Financial Service Industry:* A financial service industry consists of a number of *"high street" (i.e., deposit/demand) banks*, *savings & loan institutes*, *commercial banks*, other forms of banks, *insurance companies* (of differing specialisations), *stock/commodity exchanges* with their *brokers* and *traders*, one or more forms of *finance "watchdog" institutions* (SEC, FDIC, etc.), etc. A *bank* had *clients* and *clients* have one or more *accounts* having *account numbers* and *account balances* with *clients opening* and *closing accounts*, *depositing monies* into, and *withdrawing monies* from *accounts*, etc. Etcetera. 50

- *Health Care System:* A health care system consists of a number of *private physicians*, *hospitals*, *pharmacies*, *health insurance companies*, *a pharmaceutical industry*, *patients*, etc. A *hospital* consists of a number or *wards* (etc.) with each *ward* consisting of a number or *bedrooms* (etc.) with each *bedroom* consisting of a number of *beds* (etc.), etcetera. Etcetera. 51

- *Pipeline System:* A pipeline system consists of sequences of units: pumps, pipes, valves, forks and joins such that a fork connects to one pipe at the input and two at

the output and a join connects two pipes at the input and one at the output, such that the first unit is a pump and is connected at the input to a well and the last unit is a valve and is connected to a sink at the output. A pump, when active (i.e., pumping) should be moving a certain volume of gas or liquid from the input to the put per time unit. A valve when closed prevents flow of gas or liquid from the input
52 to the put, whereas when open unhindered permits such a flow. Etcetera.

- *Transportation System:* Transportation involves, say, three sub-domains: a transport net, a fleet of vehicles, and a community of vehicle drivers and vehicle passengers. A transport net consists of hubs and links such that a link is connected to exactly two distinct hubs and a hub is connected to zero, one or more links. Vehicles are positioned along the net: at hubs or on links and may be standing still or moving — while transporting freight, the driver and zero, one or more passengers. Etcetera.

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In the above, rather informal, "description" of facts about specific domains we primarily focused on enumerating some of the parts. Later examples will remedy this situation.

2.4 What are Domains ? 53

So what is a domain ? We can answer this in three ways: as above, by giving examples, or, as we now do, by an informal characterisation, or by a more formal characterisation.

2.4.1 An Informal Characterisation of Domains 54

A *domain* is a set of observable entities and abstractions of these, that is, of *parts* (some of which form states), *actions* (operation applications causing state changes), *events* ("spurious" state changes not [intentionally] caused by actions) and *behaviours* (seen as set of
55 sequences of sets of actions, events and behaviours). Whereas some entities are manifested spatio-physically, that is, we can point to them, others cannot, they are either abstractions of parts, or they are actions, events and behaviours. These latter can, however, be characterised by function definitions, event predicates and behaviour definitions which [when applied] denote actions, events and behaviours.

2.4.2 A Formal Characterisation of Domains 56

A domain is a behavioural algebra described as consisting of usually two or more type descriptions, usually two or more function and event descriptions, and usually one or more behaviour descriptions, which contain channel descriptions and behaviour process descriptions.

• • •

Inquiry: Domain

One person's domain is another person's sub-domain (where we have yet to characterise what a sub-domain is). And: the algebra "definition" of what a domain is maybe unsatisfactory.

MORE TO COME

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2.5 Six Examples 57

2.5.1 Air Traffic

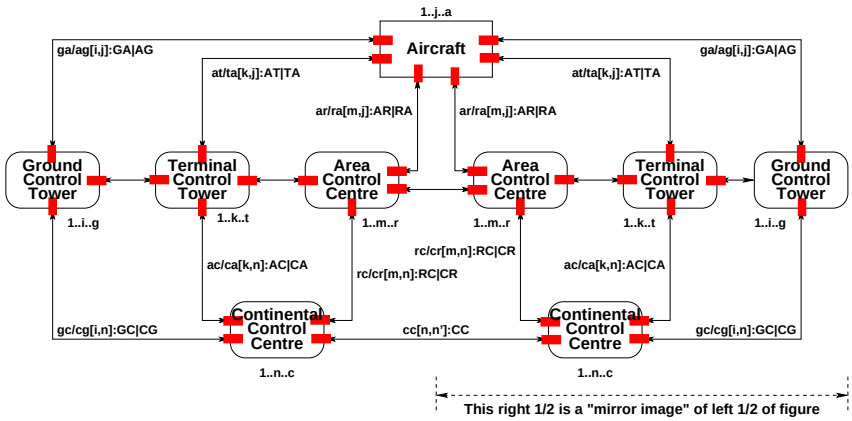

Figure 1: An air traffic system

Figure 1 shows nine (9) round edge or rectangular boxes and eighteen (18) lines. Together they form a composite part. Individually boxes and lines represent subparts. The rounded corner boxes denote buildings. The sharp corner box denote an aircraft. Lines denote radio telecommunication. Only where lines touch boxes do we have connections. These are shown as red horisontal or vertical boxes at both ends of the double-headed arrows, overlapping both the arrows and the boxes. The index ranges shown attached to, i.e., labelling each unit, shall indicate that there are a multiple of the "single" (thus representative) unit shown. Notice that the 'box' parts are fixed installations and that the double-headed arrows designate the ether where radio waves may propagate. We could, for example, assume that each such line is characterised by a combination of location and (possibly encrypted) radio communication frequency. That would allow us to consider all lines for not overlapping. And if they were overlapping, then that must have been a decision of the air traffic system.

2.5.2 Buildings 58

Figure 2 on the next page shows a building plan — as a composite part of two neighbouring, common wall-sharing buildings, A and H, probably built at different times; with room

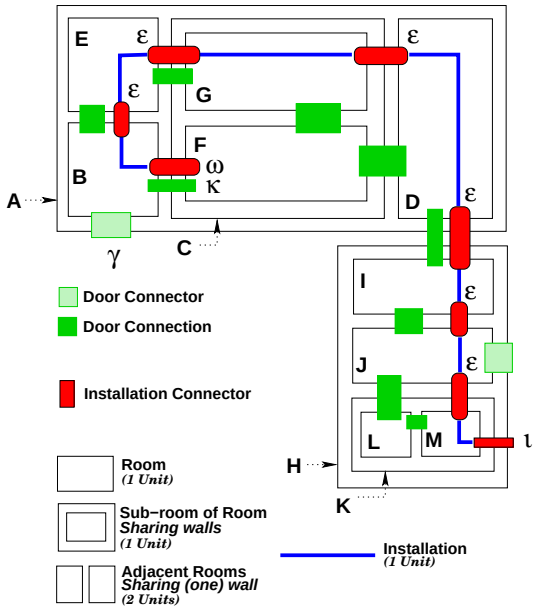

Figure 2: A building plan with installation

sections B, C, D and E contained within A, and room sections I, J and K within H; with room sections L and M within K, and F and G within C.

Connector γ provides means of a connection between A and B. Connection κ provides "access" between B and F. Connectors ι and ω enable input, respectively output adaptors (receptor, resp. outlet) for electricity (or water, or oil), connection ϵ allow electricity (or water, or oil) to be conducted through a wall. Etcetera.

2.5.3 Financial Service Industry 59

Figure 3 on the facing page shows seven (7) larger boxes [6 of which are shown by dashed lines] and twelve (12) double-arrowed lines. Where double-arrowed lines touch upon (dashed) boxes we have connections (also to inner boxes). Six (6) of the boxes, the dashed line boxes, are composite parts, five (5) of them consisting of a variable number of atomic parts; five (5) are here shown as having three atomic parts each with bullets "between" them to designate "variability". People, not shown, access the outermost (and hence the "innermost" boxes, but the latter is not shown) through connectors, shown by bullets, •.

See http://www.imm.dtu.dk/~db/todai/tse-1.pdf

2.5.4 Machine Assemblies 60

Figure 4 on the next page shows a machine assembly. Square boxes show composite and atomic parts. Bullets, •, show connectors. Strands of two or three bullets on a thin line,

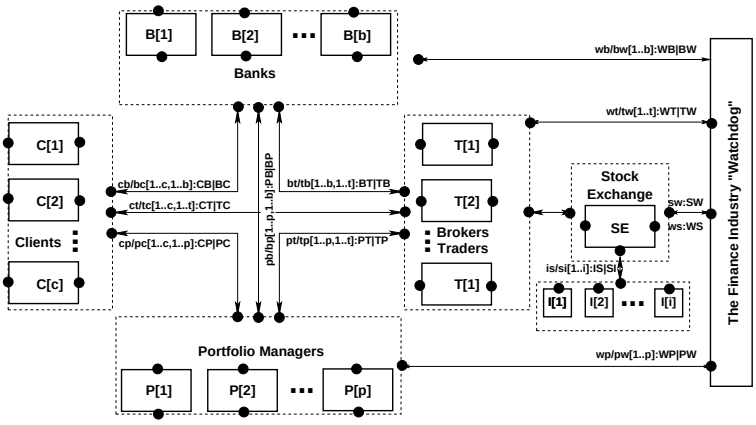

Figure 3: A financial service industry

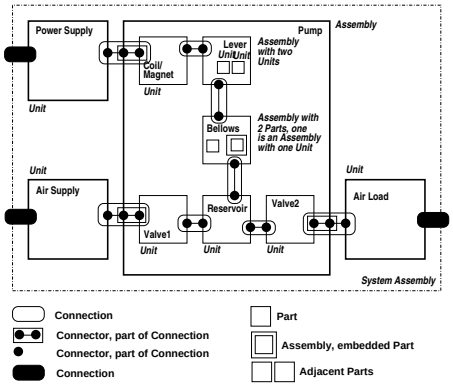

Figure 4: An air pump, i.e., a physical mechanical system

encircled by a rounded box, show connections. The full, i.e., the level 0, assembly (a composite part) consists of four parts and three internal and three external connections. The Pump is an assembly of six (6) parts, five (5) internal connections and three (3) external connectors. Etcetera. One connector and some connections afford "transmission" of electrical power. Other connections convey torque. Two connectors convey input air, respectively output air.

2.5.5 Oil Industry 61

"The" Overall Assembly Figure 5 on the following page shows a composite part consisting of fourteen (14) composite parts, left-to-right: one oil field, a crude oil pipeline system, two refineries and one, say, gasoline distribution network, two seaports, an ocean (with oil and ethanol tankers and their sea lanes), three (more) seaports, and three, say gasoline and ethanol distribution networks.

Between all of the composite parts there are connections, and from some of these

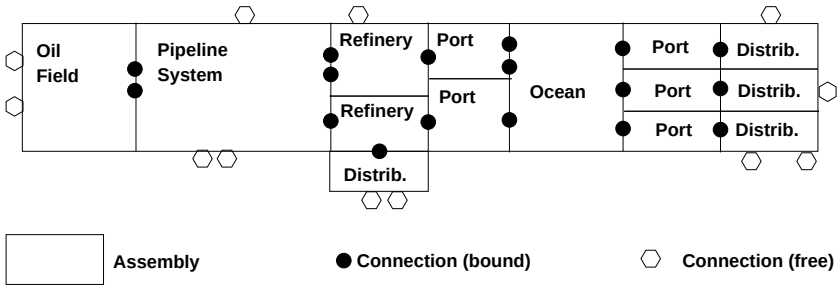

Figure 5: A Schematic of an Oil Industry

composite parts there are connectors (to an external environment). The crude oil pipeline system composite part will be concretised next.

See abstract model: http://www.imm.dtu.dk/~db/pipeline.pdf

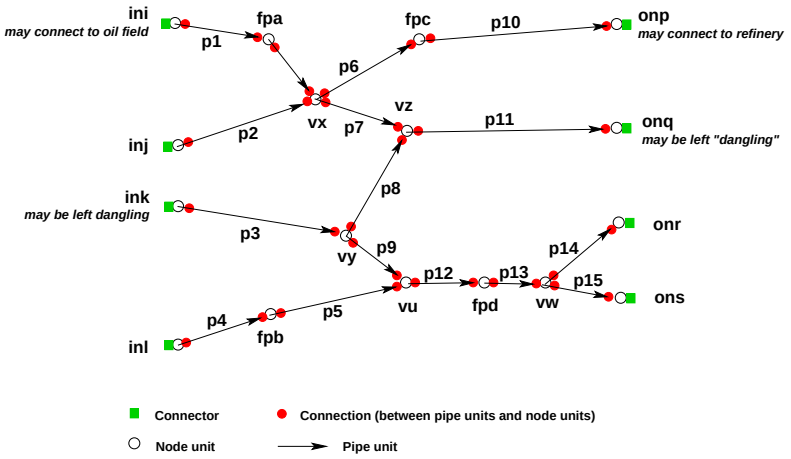

Figure 6: A Pipeline System

62 **A Concretised Composite parts:** Figure 6 shows a pipeline system. It consists of 32 atomic parts: fifteen (15) pipe units (shown as directed arrows and labelled p1–p15), four (4) input node units (shown as small circles, ○, and labelled in$i$–inℓ), four (4) flow pump units (shown as small circles, ○, and labelled fp$a$–fp$d$), five (5) valve units (shown as small circles, ○, and labelled vx–vw), and four (4) output node units (shown as small circles, ○, and labelled on$p$–on$s$). In this example the routes through the pipeline system start with node units and end with node units, alternates between node units and pipe units, and are connected as shown by fully filled-out **red**[9] disc connections. Input and output nodes have input, respectively output connectors, one each, and shown with **green**[10]

[9]This paper is most likely not published with colours, so **red** will be shown as **darker colour**.
[10]Shown as **lighter coloured** connections.

2.5.6 Railway Nets 63

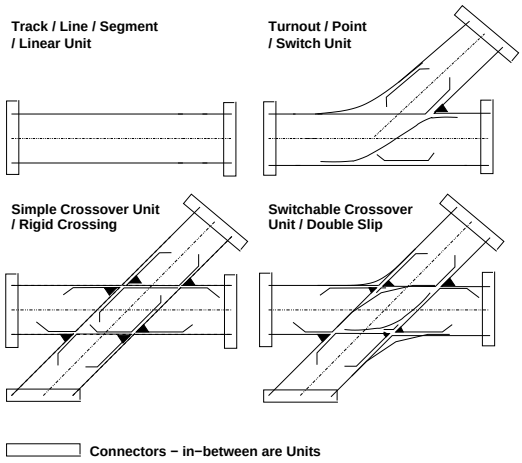

Figure 7: Four example rail units

Figure 7 diagrams four rail units, each with their two, three or four connectors. Multiple instances of these rail units can be assembled (i.e., composed) as shown on Fig. 8 into proper rail nets. 64

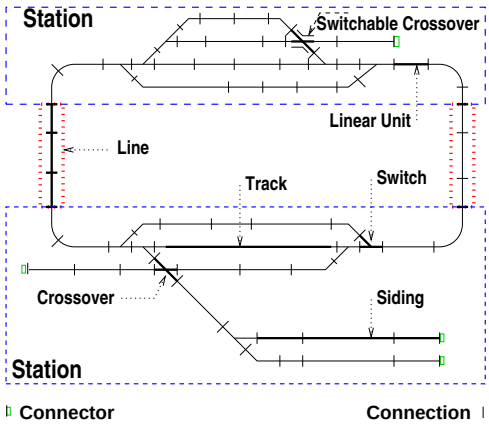

Figure 8: A "model" railway net. An Assembly of four Assemblies:
Two stations and two lines; Lines here consist of linear rail units;
stations of all the kinds of units shown in Fig. 7.
There are 66 connections and four "dangling" connectors

See http://www.railwaydomain.org/

Figure 8 diagrams an example of a proper rail net. It is assembled from the kind of units shown in Fig. 7. In Fig. 8 consider just the four dashed boxes: The dashed boxes are assembly units. Two designate stations, two designate lines (tracks) between stations. We

refer to to the caption four line text of Fig. 7 on the previous page for more "statistics". We could have chosen to show, instead, for each of the four "dangling' connectors, a composition of a connection, a special "end block" rail unit and a connector.