DOMAIN ANALYSIS & DESCRIPTION

AN EXAMPLE

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Method & Methodology

Method

- By a **method** we shall understand

  * a set of **principles** for selecting and applying
  * a set of **procedures** – also for selecting and applying
  * a set of **techniques** using
  * a set of **tools**,

  for people to adhere to in the **construction** of an **artefact**.

Methodology

* By **methodology** we shall understand the study of methods.

The Domain Modeling Method

- **Principles:**[1] abstraction.

- **Procedures:** the domain analysis & description ontology.

- **Techniques**[2]**:** Classical technique are that of establishing *invariants* and expressing *intentional pull*.

- **Tools**[3]**:** the analysis and description prompts and functions.

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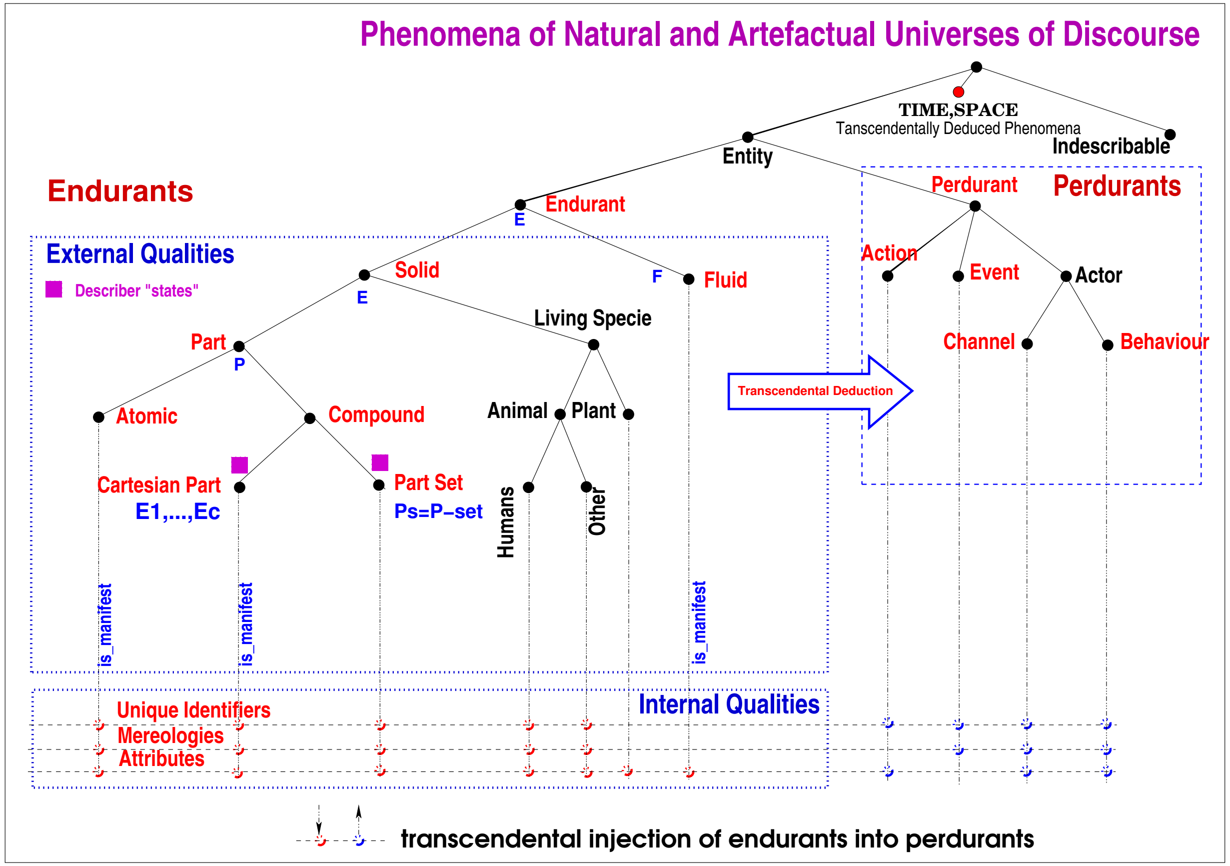
[1] **Principle:**
(i) elemental aspect of a craft or discipline,
(ii) foundation,
(iii) general law of nature, etc.

[2] **Technique:**
(i) formal practical details in artistic, etc., expression,
(ii) art, skill, craft in work".

[3] **Tool:**
(i) instrument, implement used by a craftsman or laborer, weapon,
(ii) that with which one prepares something.



. The Domain Analysis & Description Ontology

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An Example

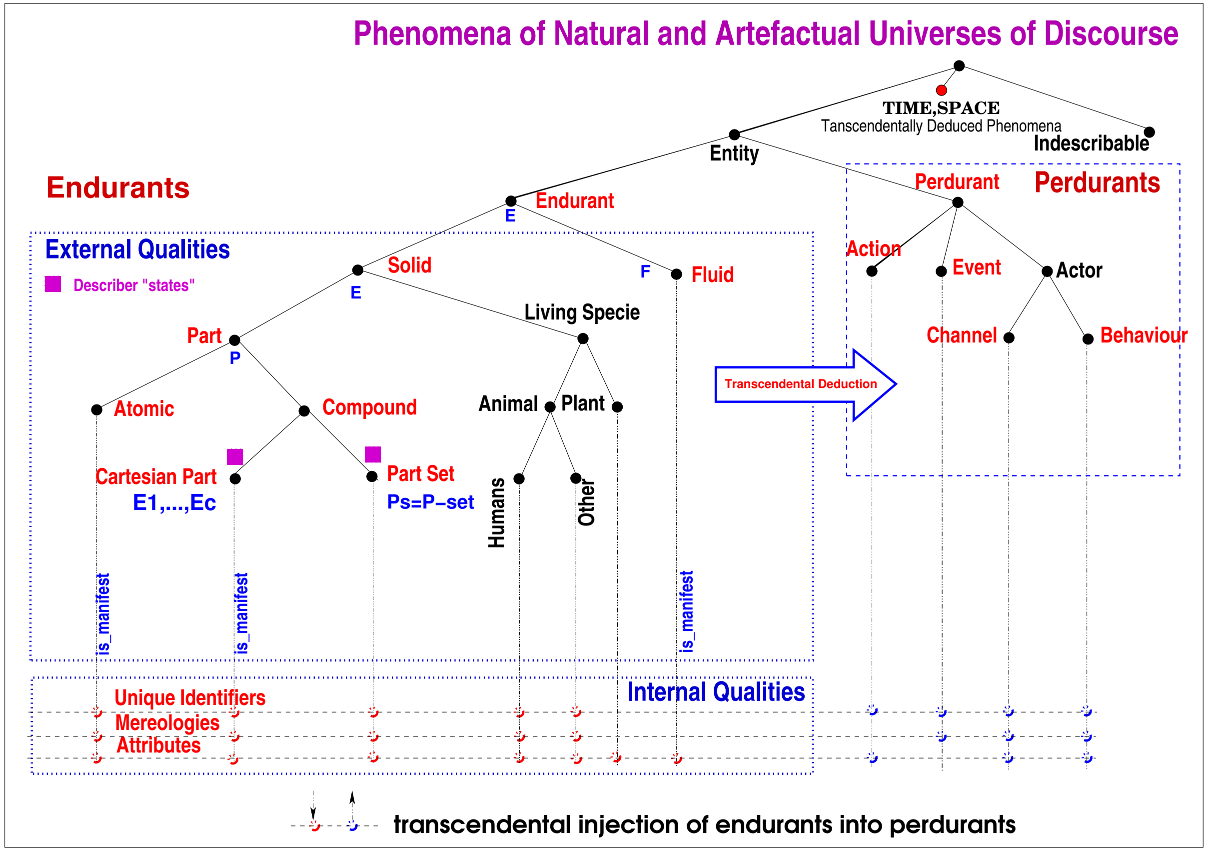
0. Universe of Discourse

Narration:

The domain is that of a road traffic system, **RT**
of passengers, **P**,
by automobiles, **A**, which **move** along a road net, **RN**.
Passengers **embark** and **disembark** merchandise at hubs, **H**,
and **travel** along links, **L** of the road net.
Etcetera, etcetera.

Formalization:

type
RT, P, A, RN, H, L, ...
value
move, embark, disembark, travel, ...
axiom
[The road net is connected, ...] ■

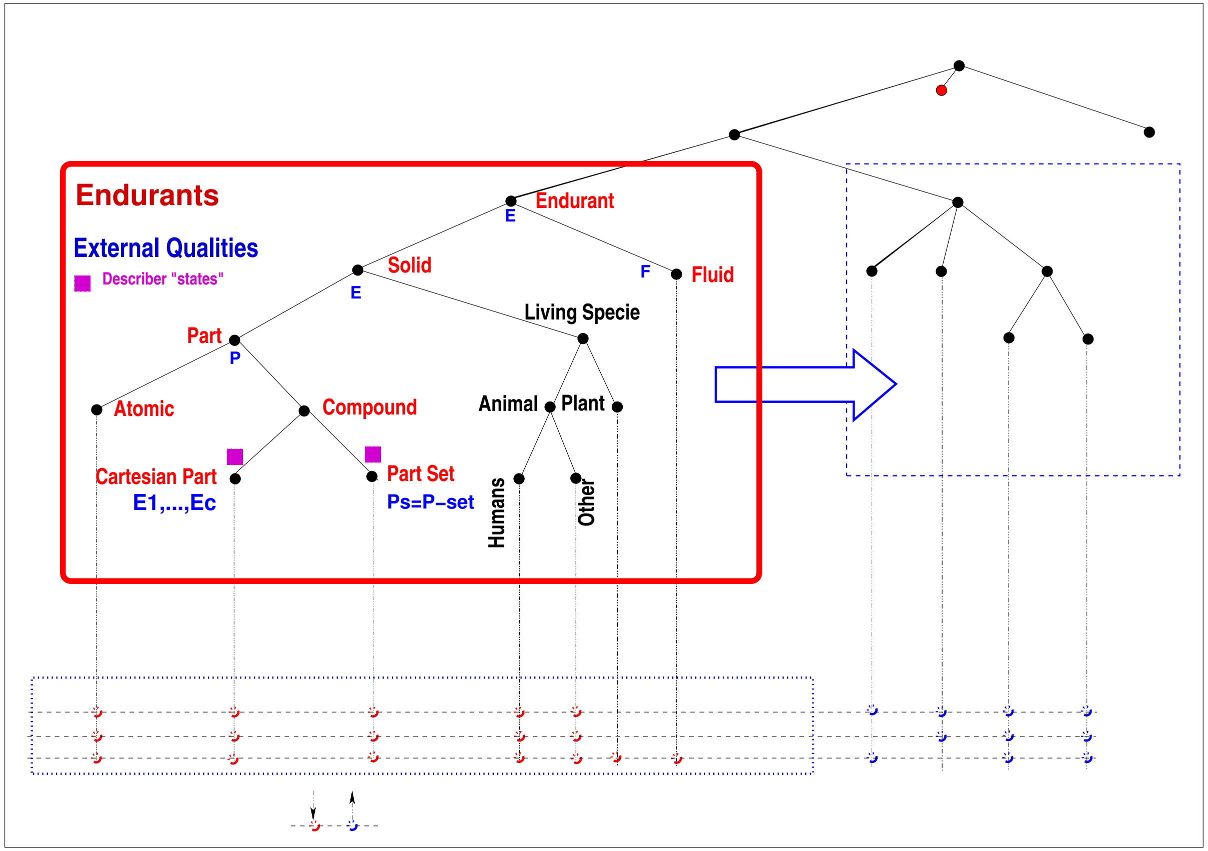


. The Domain Analysis & Description Ontology

1. Endurants

1.1. External Qualities

1.1.1 Parts



Part Analysis & Description

Narrative:

1. A road transport, rt:RT, is abstracted as a Cartesian of
2. a road net, RN and
3. an aggregate of automobiles, SA –
4. where the road net is a Cartesian of a set of hubs, AH,
5. and a set of links, AL.
6. An aggregate of automobiles is a set of automolbiles.
7. Automobiles are here considered atomic.

Formalization:

type
1. RT
2. RN
3. SA
4. AH = H-**set**
5. AL = L-**set**
6. AS = A-**set**
7. A

value
2. **obs**_RN: RT → RN
3. **obs**_SA: RT → SA
4. **obs**_AH: RN → AH
5. **obs**_AL: RN → AL
6. **obs**_AS: SA → AS ■

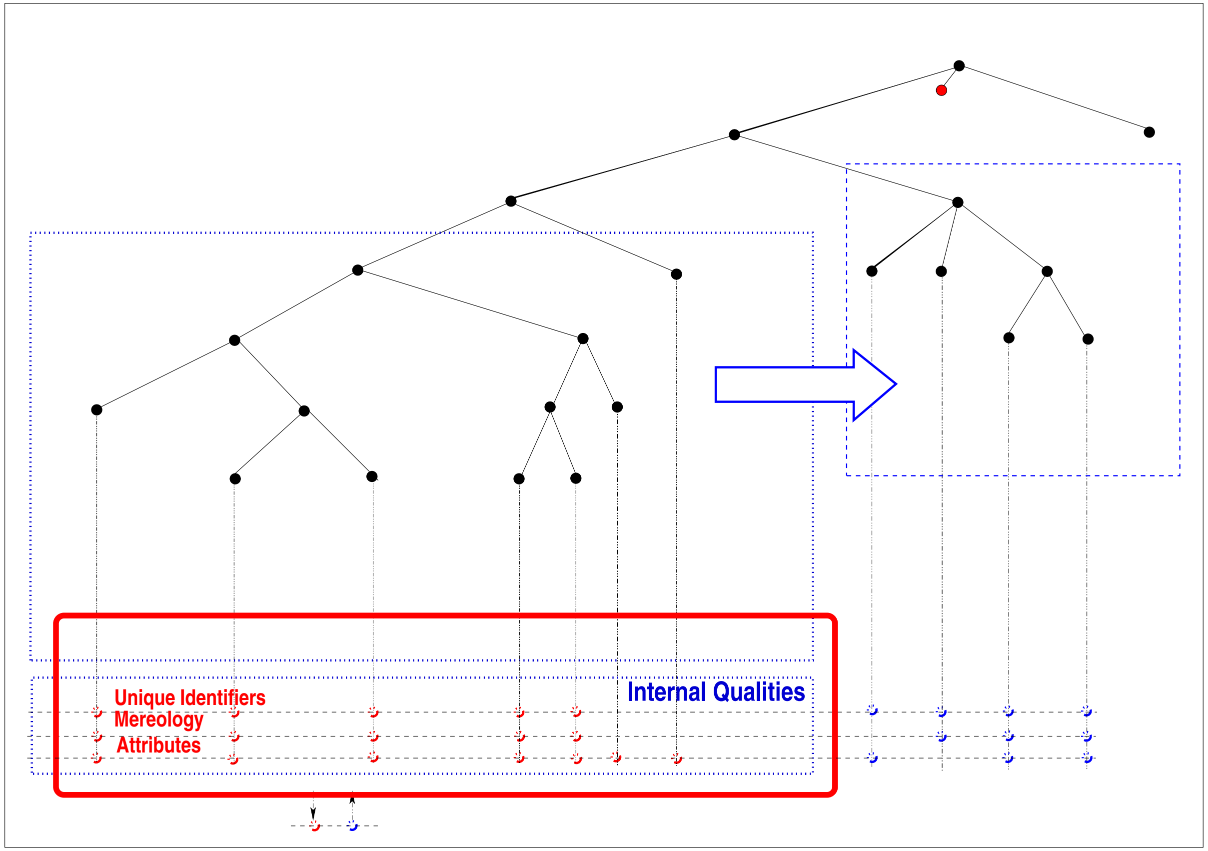
1.1.3 Part State

8. There is the set of all hubs,
9. and the set of all links,
10. and the set of all automobiles.
11. The union of these form a state.

variable

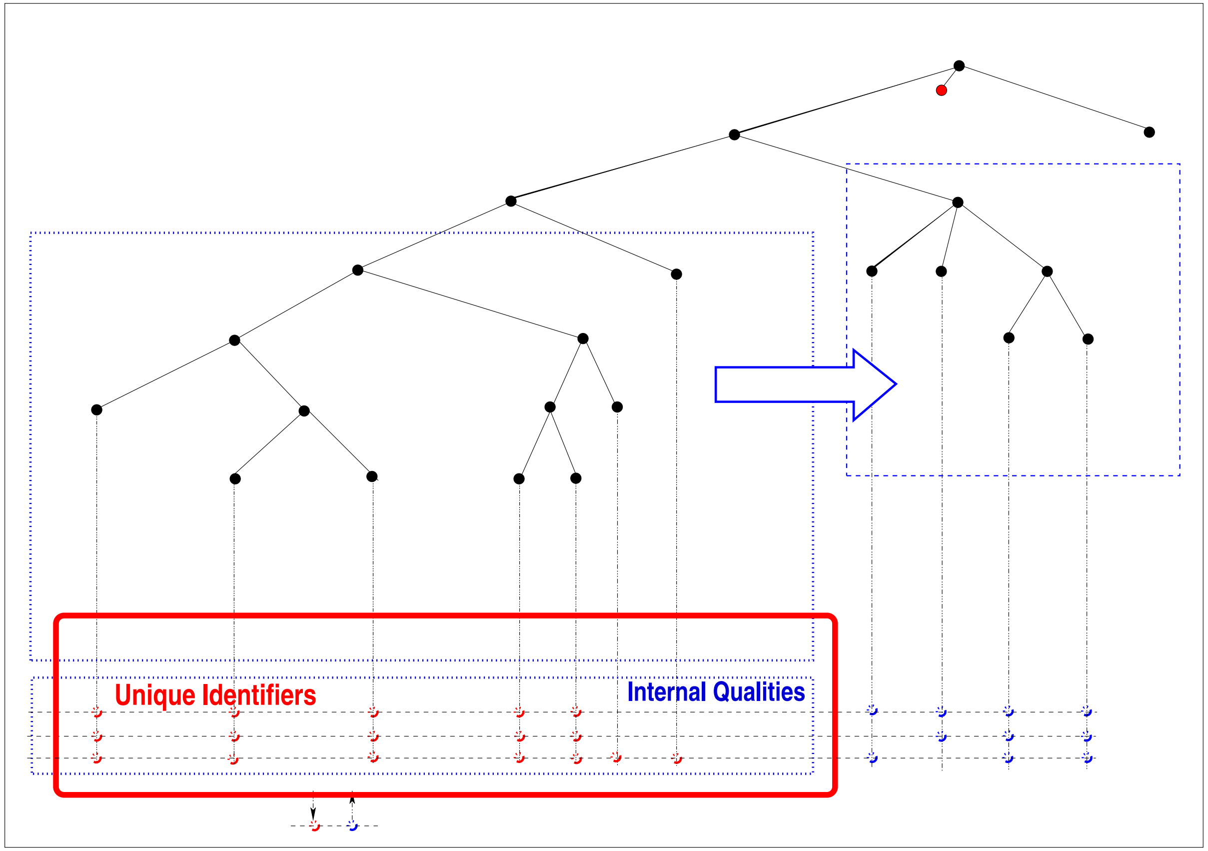
8. hs:AH := **obs**_AH(**obs**_RN(rt))
9. ls:AL := **obs**_AL(**obs**_RN(rt))
10. as:SA := **obs**_AS(**obs**_SA(rt))
11. σ:(H|L|A)-**set** := $hs \cup ls \cup as$ ■

1.2 Internal Qualities



. Internal Qualities Analysis & Description

1.2.1 Unique Identification



Unique Identification

12. Each hub has a unique identifier,
13. each link has a unique identifier, and
14. each automobile has a unique identifier.

type
12. HI
13. LI
14. AI

value
12. **uid**_H: H $\rightarrow$ HI
13. **uid**_H: L $\rightarrow$ LI
14. **uid**_H: A $\rightarrow$ AI ■

1.2.1.1 Unique Identifier State

There are

15. the set of all hub identifiers,
16. the set of all link identifiers,
17. the set of all automobile identifiers.
18. Together they form a unique identifier state.
19. There are as many hubs, links and automobiles as there are hub, link and automobile identifiers.

variable

15. hs_{uids}:HI-**set** := { **uid**_H(h) | h:H·u $\in \sigma$ }
16. ls_{uids}:LI-**set** := { **uid**_L(l) | l:L·u $\in \sigma$ }
17. as_{uids}:AI-**set** := { **uid**_A(a) | a:A·u $\in \sigma$ }
18. σ_{uids}:(HI|LI|AI)-**set** := $hs_{uids} \cup ls_{uids} \cup as_{uids}$

axiom

19. $\Box$ **card** σ = **card** σ_{uids} ■

1.2.1.2 Part Uniqueness

The unique identifiers of a road transport, rt:RT, consists of the unique identifiers of

20. the set of all hub identifiers,
21. the set of all link identifiers,
22. the set of all automobile identifiers.
23. Together they form a unique identifier state.

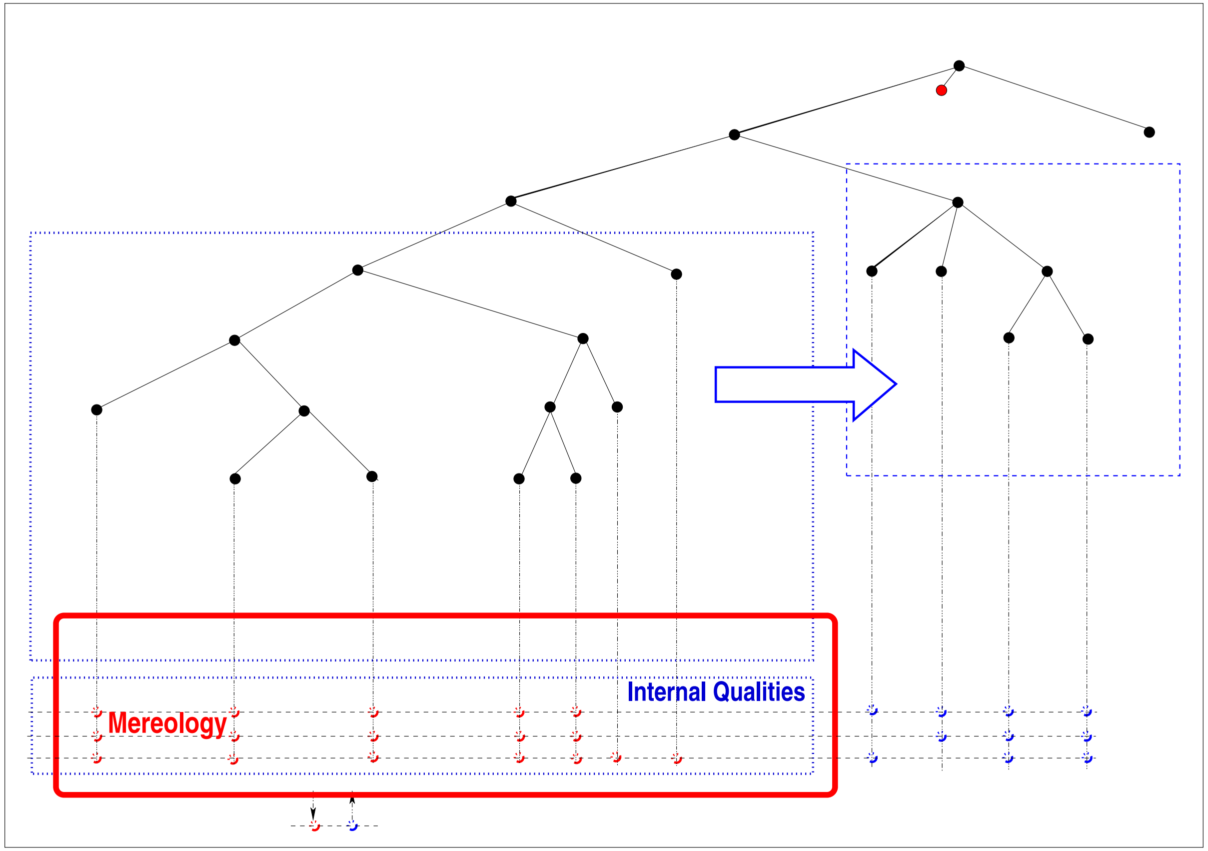
24. There are as many hubs, links and automobiles as there are hub, link and automobile identifiers.

variable

20. hs_{uids}:HI-**set** := { **uid**_H(h) | h:H · h $\in \sigma$}
21. ls_{uids}:LI-**set** := { **uid**_L(l) | l:L · l $\in \sigma$}
22. as_{uids}:AI-**set** := { **uid**_A(a) | a:A · a $\in \sigma$}
23. σ_{uids}:(HI|LI|AI)-**set** := $hs_{uids} \cup hs_{uids} \cup hs_{uids}$

24. $\mathbf{card}\sigma = \mathbf{card}\sigma_{uids}$

1.2.2 Mereology



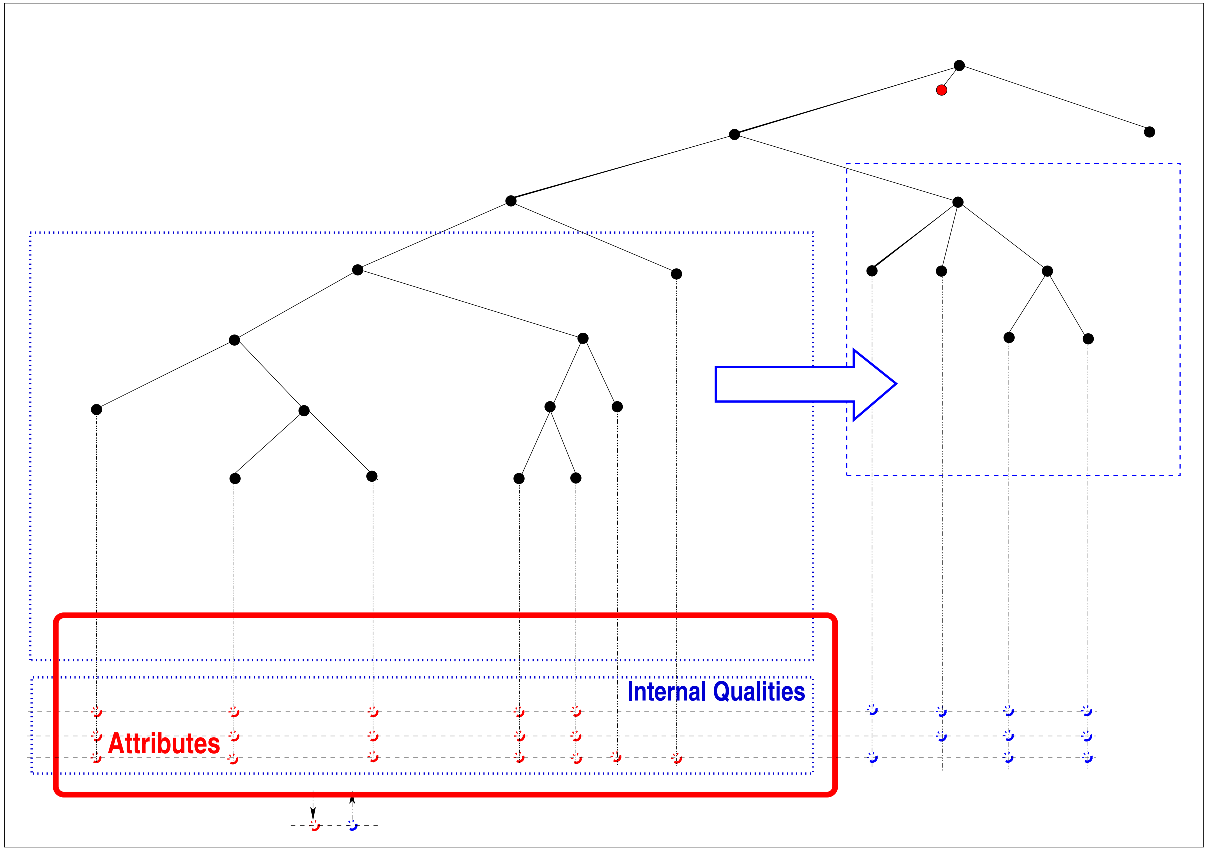
. Mereology

We shall be concerned only with the mereology of some manifest parts.

25. The mereology of links is a 2 element set of hub identifiers.
26. The mereology of a hub is a possibly empty set of hub identifiers.
27. The mereology of an automobile is a set of hub and link identifiers

type
25. ML = LI-**set** **axiom** $\forall$ ml:MK $\cdot$ **card** ml = 2 $\wedge$ ml $\subseteq ls_{uis}$
26. MH = HI-**set** **axiom** $\forall$ mh:MH $\cdot$ mh $\subseteq hs_{uis}$
27. MA = (HI|LI)-**set** **axiom** $\forall$ ma:MA $\cdot$ ma $\subseteq as_{uis}$
value
25. **mereo**_L: L $\rightarrow$ ML
26. **mereo**_H: H $\rightarrow$ MH
27. **mereo**_A: A $\rightarrow$ MA ■

1.2.3 Attributes



. Attributes

Example attributes are:

28. Hubs have states, hσ:HΣ: the set of pairs of link identifiers, ($f$li,$t$li), of the links $f$rom and to which automobiles may enter, respectively leave the hub.
29. Hubs have state spaces, hω:HΩ: the set of hub states "signaling" which states are open/closed, i.e., **green/red**.
30. Links that have lengths, LEN; and
31. Automobiles have road net positions, APos,
32. either ***at a hub***, atH,
33. or ***on a link***, onL, some fraction, f:**Real**, down a link, identified by li, from a hub, identified by fhi, towards a hub, identified by thi.
34. Links have states, lσ:LΣ: the set of pairs of link identifiers, ($f$li,$t$li), of the links $f$rom and to which automobiles may enter, respectively leave the hub.
35. Links have state spaces, lω:LΩ: the set of link states "signaling" which states are open/closed, i.e., **green/red**.
36. Hubs, links and automobiles have *histories:* time-stamped, chronologically ordered sequences of automobiles entering and leaving links and hubs, with automobile histories similarly recording hubs and links entered and left.
37. Link positions have well-defined identifiers and fractions.

type

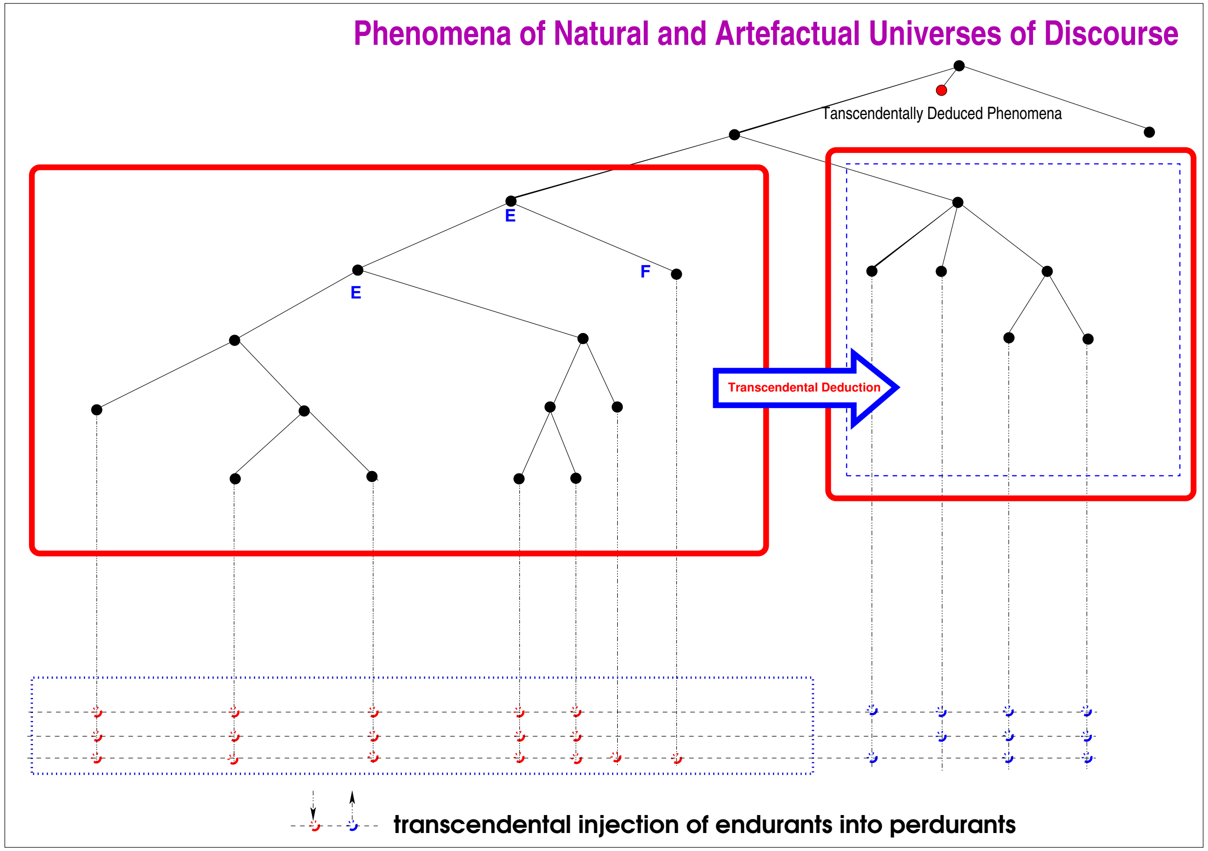
28. $\mathsf{H}\Sigma$ = (LI×LI)-**set**
29. $\mathsf{H}\Omega$ = $\mathsf{H}\Sigma$-**set**
30. LEN = **Nat**
31. APos = atH | onL
32. atH :: HI
33. onL :: LI × (fhi:HI × f:**Real** × thi:HI)
34. $\mathsf{L}\Sigma$ = (HI×HI)-**set**
35. $\mathsf{L}\Omega$ = $\mathsf{L}\Sigma$-**set**
36. HHis,LHis = $(\mathbb{TIME}\times\mathsf{AI})^*$
36. AHis = $(\mathbb{TIME}\times(\mathsf{HI}|\mathsf{LI}))^*$

value

28. attr_$\mathsf{H}\Sigma$: H → $\mathsf{H}\Sigma$
29. attr_$\mathsf{H}\Omega$: H → $\mathsf{H}\Omega$
30. attr_LEN: L → LEN
31. attr_APos: A → APos
34. attr_$\mathsf{L}\Sigma$: L → $\mathsf{L}\Sigma$
35. attr_$\mathsf{L}\Omega$: L → $\mathsf{L}\Omega$
36. attr_HHis: H → HHis
36. attr_LHis: L → LHis
36. attr_AHis: A → AHis

axiom

37. ∀ mk_onL(li,(fhi,f,thi)):onL • 0<f<1 ∧ li∈ls_{uids} ∧ {fhi,thi}⊆hs_{uids} ∧ ... ■

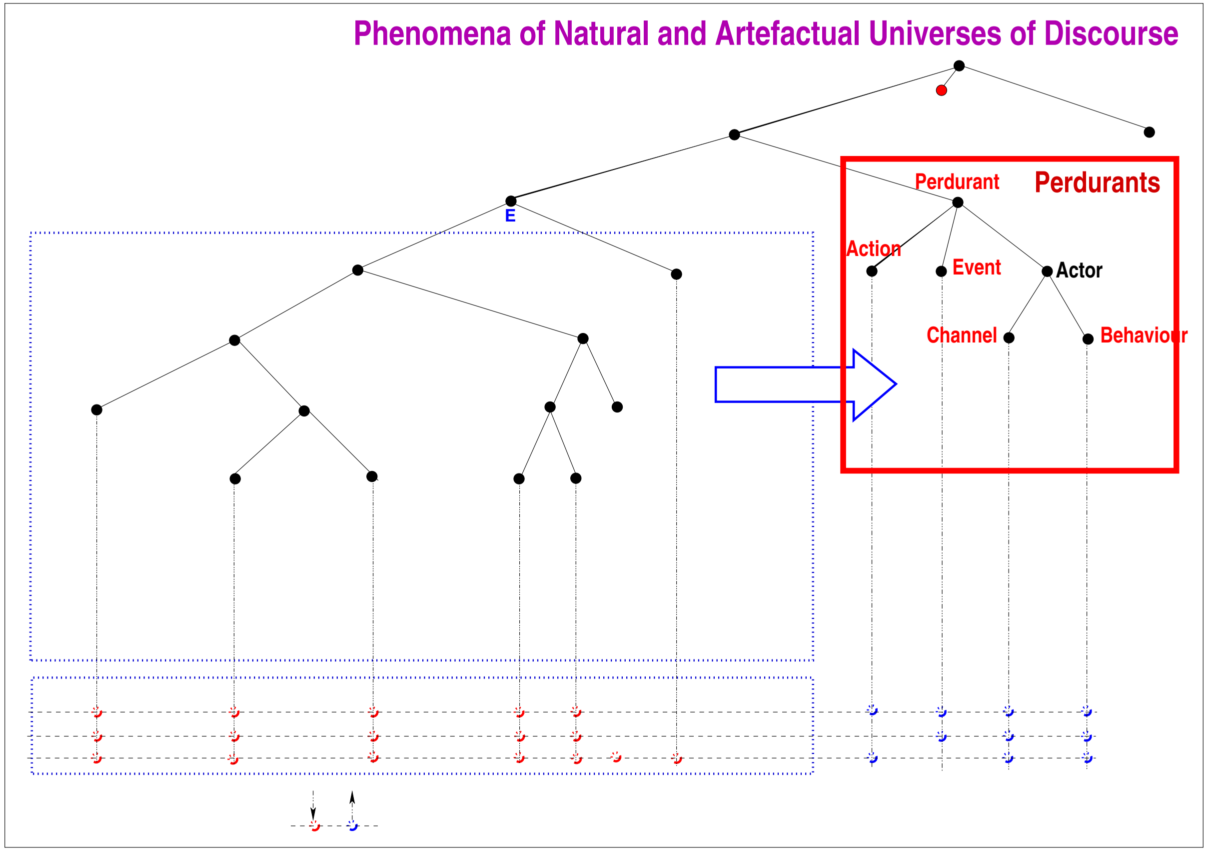


.2. Transcendental Deduction

Transcendental Deductions:

- We decide to transcendental deduce the following manifest parts:
  - stations,
  - lines,
  - junctions and
  - passengers,
- into behaviours.

3. Perdurants


Phenomena of Natural and Artefactual Universes of Discourse
Perdurant
Perdurants
E
Action
Event
Actor
Channel
Behaviour

. **Perdurants**

•

3.1 Channels

Channel

38. There is a set of channels between
hubs, links and automobiles.
39. These channels communicate messages, `M`.
`M` will "transpire" frm the behaviour definitions.

channel
38. $\{$ ch$[\{$ui,uj$\}]$ $|$ $\{$ui,ij$\}$:(HI|LI|AI)-**set** $\cdot$ ui$\neq$uj$\wedge\{$ui,uj$\}\subseteq\sigma_{uids}$ $\}$ M
type
38. M ■

3.2 Behaviour Signatures

- The signature of behaviours follow the "Schönfinkel'ed pattern" of

names of behaviour: unique identifier
→ *mereology*
→ *static attributes*
[→ *inert and monitorable attributes*]
→ *programmable attributes*
→ *channel arrays* and **Unit**.

value

. hub: HI
→ MereoH
→ (HΩ×...)
→ (HΣ × HHist × ...)
→ {ch[{**uid**_H(p),ai}]|ai:AI•ai∈as_{uid}} **Unit**

??. link: LI
→ MereoL→
→ (LΩ×LEN × ...)→
→ (LΣ × LHist × ...)
→ {ch[{**uid**_L(p),ai}]|ai:AI•ai∈as_{uid}} **Unit**

??. automobile: AI
→ MereoA
→ (...)
→ (AVel × HAcc × ... × APos × AHist)
→ {ch[{**uid**_H(p),ri}]|ri:(HI|LI)•ri∈hs_{uid}∪ls_{uid}} **Unit**

3.3 Behaviour Definitions

Automobile at Hub

40. We abstract automobile behaviour at a Hub (hi).
    (a) Either the automobile **remain**s at the hub,
    (b) or, **internally non-deterministically**,
    (c) **leaves** the hub entering a link,
    (d) or, **internally non-deterministically**,
    (e) **stops**.

```
40   automobile(ai)(ris)(...)(atH(hi),ahis,_) ≡
40a       automobile_remain_at_hub(ai)(ris)(...)(atH(hi),ahis,_)
40b       ⌈⌉
40c       automobile_leaving_hub(ai)(ris)(...)(atH(hi),ahis,_)
40d       ⌈⌉
40e       automobile_stop(ai)(ris)(...)(atH(hi),ahis,_)
```

Automobile at Hub – Contd.

41. [40a] The automobile **remains** at a hub:
   (a) time is recorded,
   (b) informing the hub behaviour, whereupon
   (c) the automobile remains at that hub, “idling”,

41 automobile_**remain**_at_hub(ai)(ris)(...)(atH(hi),ahis,_) $\equiv$
41a **let** τ = **record**_$\mathbb{TIME}$ **in**
41b ch[{ai,hi}] ! τ ;
41c automobile(ai)(ris)(...)(atH(hi),$\langle$(τ,hi)$\rangle$$^\frown$ahis,_) **end**

Automobile at Hub – Contd.

42. [40c] The automobile **leaves** the hub entering link li:
    (a) time is recorded;
    (b) hub is informed of automobile leaving and link that it is entering;
    (c) "whereupon" the vehicle resumes (i.e., "while at the same time" resuming) the vehicle behaviour positioned at the very beginning (0) of that link.

42 automobile_**leaving**_b(ai)({li}∪ris)(...)(atH(hi),ahis,_) $\equiv$
42a   **let** τ = **record**_$\mathbb{TIME}$ **in**
42b   (ch[{ai,hi}] ! τ ∥ ch[{ai,li}] ! τ) ;
42c   automobile(ai)(ris)(...)(onL(li,(hi,0,_)),⟨(τ,li)⟩⌢ahis,_) **end**
42   **pre**: [hub is not isolated]

Automobile at Hub – Contd.

43. [40e] Or the automobile **stop**s, "disappears — off the radar" !

43 automobile_**stop**(ai)(ris),(...)(atH(hi),ahis,_) $\equiv$ **stop** ■

3.4 Behaviour Initialization

Initialization

44. Let us refer to the system initialization as a behaviour:
   (a) all hubs are initialized concurrently,
   (b) and, concurrently,
   (c) all links are initialized concurrently,
   (d) and, concurrently,
   (e) all automobiles are initialized concurrently.

value

44. rts_initialisation: $\mathbf{Unit} \rightarrow \mathbf{Unit}$
44. rts_initialisation() $\equiv$
44a. $\|$ { hub(**uid**_H(l))(**mereo**_H(l))(**attr**_HΩ(l),...)(**attr**_HΣ(l),...)| h:H • h $\in$ hs }
44b. $\|$
44c. $\|$ { link(**uid**_L(l))(**mereo**_L(l))(**attr**_LEN(l),...)(**attr**_LΣ(l),...)| l:L • l $\in$ ls }
44d. $\|$
44e. $\|$ { automobile(**uid**_A(a))(**mereo**_A(a))(**attr**_APos(a)**attr**_AHis(a),...) | a:A • a $\in$ as }

Summing Up

- **This is NEITHER Computer NOR Computing Science:**
  - **This is Domain Science & Engineering**
    - $*$ It is, for example,
      - · a prerequisite for software requirements
      - · and hence software design & coding!
    - $*$ We must abandon the "old" approach: just
      - · first software requirements.
      - · then software design & coding!
  - **Now:**
    - $*$ First domain modeling $\mathbb{D}$.
    - $*$ Then "derive" requirements $\mathbb{R}$ from $\mathbb{D}$.
    - $*$ Then "derive" software $\mathbb{S}$ from $\mathbb{R}$.
    - $*$ Finally verify $\mathbb{D}, \mathbb{S} \models \mathbb{R}$

- **Four uses of Domain Models:**
  - **Understanding**
    - Theorems of Societal Infrastructures
  - **“Business Process Re-engineering”**
    - Redesigning Societal Infrastructures
  - **Software Development:** $\mathbb{D}$omains → $\mathbb{R}$equirements → $\mathbb{S}$oftware
  - **Basis for School Textbooks !**
    - Today we teach & learn about mathematics, physics, zoology, wt.
    - Tomorrow we could/should teach & learn about our own infrastructures:
      - utilities,
      - health care,
      - banking,
      - transport logistics,
      - judiciary system,
      - manufacturing,
      - retailing,
      - et cetera.

- **Exploratory Models – 1995–2025:**
  * *A Retailer Market*,
  * *Documents*,
  * *Canals*,
  * *Container Terminals*,
  * *Credit Cards*,
  * *Double-entry Bookkeeping*,
  * *Graphs*,
  * *Rivers & Canals*,
  * *Railways*,
  * *Road Transport*,
  * *Shipping*,
  * *Stock Exchanges*,
  * *Swarms of Drones*,
  * *The "7 Seas"*,
  * *The "Blue Skies"*,
  * *Transport Logistics*,
  * *Urban Planning*,
  * *Weather Information*,
  * *Web Transactions*,
  * *Worldwide Banking*.

Review & Outlook – Continued:

- **How to Do:**

  * **Study the Domain:**
    - ∗ visit/work in the domain
    - ∗ talk to domain stakeholders
    - ∗ read about the domain
    - ∗ etc., etc.

  * **Exploratory Model:** one person[4] 2 months ! – then

  * **Establish & Mantain Vocabulary:** throughout the project

  * **Form a Team:** one or two per manifest endurant + perdurant[5]

  * **Follow the Method:** Strictly, “no wavering !”

  * **Daily Work:**
    - ∗ **Early am:** [Rotating/Shift] **Review** colleague's work 8:30–10:00
    - ∗ **Mid am:** Team white board meeting: **Discuss** issues 10:00-10:45
    - ∗ **Late am + all pm:** **Modeling** 10:45–12:00, 13:00–16:30

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[4] – as for this example – or two for “larger” domain
[5] – that is: 5 for this example !

Review & Outlook – Continued:

- **How Much – How Little ? :**
  - **For Understanding:**
    Any amount of a domain !
  - **For "Business Process Re-Engineering" :**
    Those aspects that appears to be re-oriented plus a little more !
  - **For Software Development:**
    A little more than what appears to be "computerized" !
  - **For School Textbooks:**
    That of a domain that he textbook would like to teach students.

Review & Outlook – Continued:

- **Commensurate Models:**

  *** "Families" of Domain Models:**

  - $*$ We assume that there are, or will be, two or more domain X models.
  - $*$ Then X_i, X_j, ..., X_k, should/must satisfy some "$\mathcal{C}$ommensurateness" relations:
  - $*$ $\mathcal{C}_{ij}(X_i, X_j)$, $\mathcal{C}_{ik}(X_i, X_k)$, ..., $\mathcal{C}_{jk}(X_j, X_k)$.
  - $*$ $\mathcal{C}$ "being": *extension, retraction, refinement, enlargement, ...*

That's it, Folks !

THANKS