Dines Bjørner's MAP-i Lecture # 6

A Domain Description

Tuesday, 26 May 2015: 12:00–13:00

6. A Domain Description

6.1. Endurants

6.1.1. Domain, Net, Fleet and Monitor

- The root domain, $\Delta_{\mathcal{D}}$,
- the step-wise unfolding of whose description is to be exemplified, is that of a composite traffic system
  - with a road net,
  - with a fleet of vehicles and
  - of whose individual position on the road net we can speak, that is, monitor.

112 We analyse the composite traffic system into

a. a composite road net,

b. a composite fleet (of vehicles), and

c. an atomic monitor.

113 The road net consists of two composite parts,

a. an aggregation of hubs and

b. an aggregation of links.

type
112. Δ_Δ
112a.. N_Δ
112b.. F_Δ
112c.. M_Δ
value
112a.. **obs_part**_N_Δ: $\Delta_\Delta \rightarrow \mathsf{N}_\Delta$
112b.. **obs_part**_F_Δ: $\Delta_\Delta \rightarrow \mathsf{F}_\Delta$
112c.. **obs_part**_M_Δ: $\Delta_\Delta \rightarrow \mathsf{M}_\Delta$
type
113a.. HA_Δ
113b.. LA_Δ
value
113a.. **obs_part**_HA_Δ: $\mathsf{N}_\Delta \rightarrow \mathsf{HA}_\Delta$
113b.. **obs_part**_LA_Δ: $\mathsf{N}_\Delta \rightarrow \mathsf{LA}_\Delta$

6.1.2. Hubs and Links

114 Hub aggregates are sets of hubs.

115 Link aggregates are sets of links.

116 Fleets are set of vehicles.

117 We introduce some auxiliary functions.

  a. links extracts the links of a network.

  b. hubs extracts the hubs of a network.

type

114. H_Δ, $\mathsf{HS}_\Delta = \mathsf{H}_\Delta$-**set**

115. L_Δ, $\mathsf{LS}_\Delta = \mathsf{L}_\Delta$-**set**

116. V_Δ, $\mathsf{VS}_\Delta = \mathsf{V}_\Delta$-**set**

value

114. **obs_part**_HS_Δ: $\mathsf{HA}_\Delta \to \mathsf{HS}_\Delta$

115. **obs_part**_LS_Δ: $\mathsf{LA}_\Delta \to \mathsf{LS}_\Delta$

116. **obs_part**_VS_Δ: $\mathsf{F}_\Delta \to \mathsf{VS}_\Delta$

117a.. links_Δ: $\Delta_\Delta \to$ L-**set**

117a.. $\mathsf{links}_\Delta(\delta_\Delta) \equiv$ **obs_part**_LS(**obs_part**_LA(δ_Δ))

117b.. hubs_Δ: $\Delta_\Delta \to$ H-**set**

117b.. $\mathsf{hubs}_\Delta(\delta_\Delta) \equiv$ **obs_part**_HS(**obs_part**_HA(δ_Δ))

6.1.3. Unique Identfiers

We cover the unique identifiers of all parts, whether needed or not.

118 Nets, hub and link aggregates, hubs and links, fleets, vehicles and the monitor all

a. have unique identifiers

b. such that all such are distinct, and

c. with corresponding observers.

119 We introduce some auxiliary functions:

a. xtr_lis extracts all link identifiers of a traffic system.

b. xtr_his extracts all hub identifiers of a traffic system.

c. given an appropriate link identifier and a net get_link 'retrieves' the designated link.

d. given an appropriate hub identifier and a net get_hub 'retrieves' the designated hub.

type

118a.. NI, HAI, LAI, HI, LI, FI, VI, MI

value

118c.. **uid**_NI: $N_\Delta \to$ NI

118c.. **uid**_HAI: $HA_\Delta \to$ HAI

118c.. **uid**_LAI: $LA_\Delta \to$ LAI

118c.. **uid**_HI: $H_\Delta \to$ HI

118c.. **uid**_LI: $L_\Delta \to$ LI

118c.. **uid**_FI: $F_\Delta \to$ FI

118c.. **uid**_VI: $V_\Delta \to$ VI

118c.. **uid**_MI: $M_\Delta \to$ MI

axiom

118b.. $NI \bigcap HAI = \emptyset$, $NI \bigcap LAI = \emptyset$, $NI \bigcap HI = \emptyset$, etc.

where axiom 118b.. is expressed semi-formally, in mathematics.

value

119a.. xtr_lis: $\Delta_\Delta \rightarrow$ LI-**set**
119a.. xtr_lis(δ_Δ) $\equiv$
119a.. **let** ls = links(δ_Δ) **in** {**uid**_LI(l)|l:L•l $\in$ ls} **end**
119b.. xtr_his: $\Delta_\Delta \rightarrow$ HI-**set**
119b.. xtr_his(δ_Δ) $\equiv$
119b.. **let** hs = hubs(δ_Δ) **in** {**uid**_HI(h)|h:H•k $\in$ hs} **end**
119c.. get_link: LI $\rightarrow \Delta_\Delta \stackrel{\sim}{\rightarrow}$ L
119c.. get_link(li)(δ_Δ) $\equiv$
119c.. **let** ls = links(δ_Δ) **in**
119c.. **let** l:L · l $\in$ ls $\wedge$ li=**uid**_LI(l) **in** l **end end**
119c.. **pre**: li $\in$ xtr_lis(δ_Δ)
119d.. get_hub: HI $\rightarrow \Delta_\Delta \stackrel{\sim}{\rightarrow}$ H
119d.. get_hub(hi)(δ_Δ) $\equiv$
119d.. **let** hs = hubs(δ_Δ) **in**
119d.. **let** h:H · h $\in$ hs $\wedge$ hi=**uid**_HI(h) **in** h **end end**
119d.. **pre**: hi $\in$ xtr_his(δ_Δ)

6.1.4. Mereology

We cover the mereologies of all part sorts introduced so far. We decide that nets, hub aggregates, link aggregates and fleets have no mereologies of interest.

120 Hub mereologies reflect that they are connected to zero, one or more links.

121 Link mereologies reflect that they are connected to exactly two distinct hubs.

122 Vehicle mereologies reflect that they are connected to the monitor.

123 The monitor mereology reflects that it is connected to all vehicles.

124 For all hubs of any net it must be the case that their mereology designates links of that net.

125 For all links of any net it must be the case that their mereologies designates hubs of that net.

126 For all transport domains it must be the case that

a. the mereology of vehicles of that system designates the monitor of that system, and that

b. the mereology of the monitor of that system designates vehicles of that system.

value

120. **obs_mereo**_H_Δ: $H_\Delta \rightarrow$ LI-**set**

121. **obs_mereo**_L: L $\rightarrow$ HI-**set axiom** $\forall$ l:L$\cdot$**card obs_mereo**_L(l)=2

122. **obs_mereo**_V: V $\rightarrow$ MI

123. **obs_mereo**_M: M $\rightarrow$ VI-**set**

axiom

124. $\forall$ δ:Δ, hs:$HS_\Delta$$\cdot$hs=hubs($\delta$), ls:$LS_\Delta$$\cdot$ls=links($\delta$) $\cdot$

124. $\forall$ h:$H_\Delta$$\cdot$h $\in$ hs$\cdot$**obs_mereo**_H(h)$\subseteq$xtr_his(δ) $\wedge$

125. $\forall$ l:$L_\Delta$$\cdot$l $\in$ ls$\cdot$**obs_mereo**_L(l)$\subseteq$xtr_lis(δ) $\wedge$

126a.. **let** f:$F_\Delta$$\cdot$f=**obs_part**_F($\delta$) $\Rightarrow$

126a.. **let** m:$M_\Delta$$\cdot$m=**obs_part**_M($\delta$),

126a.. vs:VS$\cdot$vs=**obs_part**_VS(f) **in**

126a.. $\forall$ v:$V_\Delta$$\cdot$v $\in$ vs$\Rightarrow$**uid**_V(v) $\in$ **obs_mereo**_M(m)

126b.. $\wedge$ **obs_mereo**_M(m) = {**uid**_V(v)|v:V$\cdot$v $\in$ vs}

126b.. **end end**

6.1.5. Attributes, I

We may not have shown all of the attributes mentioned below — so consider them informally introduced !

- **Hubs:**
  - *location*s are considered static,
  - *wear and tear* (condition of road surface) is considered inert,
  - *hub states* and *hub state space*s are considered programmable;
- **Links:**
  - *length*s and *location*s are considered static,
  - *wear and tear* (condition of road surface) is considered inert,
  - *link states* and *link state space*s are considered programmable;

- **Vehicles:**
  - *manufacturer name*, *engine type* (whether diesel, gasoline or electric) and *engine power* (kW/horse power) are considered static;
  - *velocity* and *acceleration* may be considered reactive (i.e., a function of gas pedal position, etc.),
  - *global position* (informed via a `GNSS: Global Navigation Satellite System`) and *local position* (calculated from a global position) are considered biddable

6.1.6. Attributes, II

We treat one attribute each for hubs, links, vehicles and the monitor. First we treat hubs.

127 Hubs

a. have *hub states* which are sets of pairs of identifiers of links connected to the hub[22],

b. and have *hub state spaces* which are sets of hub states[23].

128 For every net,

a. link identifiers of a hub state must designate links of that net.

b. Every hub state of a net must be in the hub state space of that hub.

129 Hubs have geodetic and cadestral location.

130 We introduce an auxiliary function: xtr_lis extracts all link identifiers of a hub state.

[22] A hub state "signals" which input-to-output link connections are open for traffic.
[23] A hub state space indicates which hub states a hub may attain over time.

type
127a.. $H\Sigma = (LI \times LI)$**-set**
127b.. $H\Omega = H\Sigma$**-set**
value
127a.. **attr**_$H\Sigma$: H $\rightarrow$ $H\Sigma$
127b.. **attr**_$H\Omega$: H $\rightarrow$ $H\Omega$
axiom
128. $\forall\ \delta:\Delta,$
128. **let** hs = hubs(δ) **in**
128. $\forall$ h:H $\cdot$ h $\in$ hs $\cdot$
128a.. xtr_lis(h)$\subseteq$xtr_lis(δ)
128b.. $\wedge$ **attr**_Σ(h) $\in$ **attr**_Ω(h)
128. **end**
type
129. HGCL
value
129. **attr**_HGCL: H $\rightarrow$ HGCL
130. xtr_lis: H $\rightarrow$ LI**-set**
130. xtr_lis(h) $\equiv$
130. $\{$li $|$ li:LI,(li$'$,li$''$):LI$\times$LI $\cdot$
130. (li$'$,li$''$) $\in$ **attr**_$H\Sigma$(h) $\wedge$ li $\in$ $\{$li$'$,li$''\}\}$

Then links.

131 Links have lengths.

132 Links have geodetic and cadestral location.

133 Links have states and state spaces:

a. States modeled here as pairs, (hi', hi''), of identifiers the hubs with which the links are connected and indicating directions (from hub h' to hub h''.) A link state can thus have 0, 1, 2, 3 or 4 such pairs.

b. State spaces are the set of all the link states that a link may enjoy.

type
131. LEN
132. LGCL
133a.. $L\Sigma$ = (HI×HI)-**set**
133b.. $L\Omega$ = $L\Sigma$-**set**
value
131. **attr**_LEN: L → LEN
132. **attr**_LGCL: L → LGCL
133a.. **attr**_$L\Sigma$: L → $L\Sigma$
133b.. **attr**_$L\Omega$: L → $L\Omega$
axiom
133. ∀ n:N •
133. **let** ls = xtr−links(n), hs = xtr_hubs(n) **in**
133. ∀ l:L•l ∈ ls ⇒
133a.. **let** $l\sigma$ = **attr**_$L\Sigma$(l) **in**
133a.. 0≤**card** $l\sigma$≤4
133a.. ∧ ∀ (hi′,hi″):(HI×HI)•(hi′,hi″) ∈ $l\sigma$ ⇒
133a.. {get_H(hi′)(n),get_H(hi″)(n)}=**obs_mereo**_L(l)
133b.. ∧ **attr**_$L\Sigma$(l) ∈ **attr**_$L\Omega$(l)
133. **end end**

Then vehicles.

134 Every vehicle of a traffic system has a position which is either ‘on a link’ or ‘at a hub’.

a. An ‘on a link’ position has four elements: a unique link identifier which must designate a link of that traffic system and a pair of unique hub identifiers which must be those of the mereology of that link.

b. The ‘on a link’ position real is the fraction, thus properly between 0 (zero) and 1 (one) of the length from the first identified hub “down the link” to the second identifier hub.

c. An ‘at a hub’ position has three elements: a unique hub identifier and a pair of unique link identifiers — which must be in the hub state.

type
134. VPos = onL | atH
134a.. onL :: LI HI HI R
134b.. R = **Real** **axiom** $\forall$ r:R $\cdot$ 0$\leq$r$\leq$1
134c.. atH :: HI LI LI
value
134. **attr**_VPos: $V_\Delta \rightarrow$ VPos
axiom
134a.. $\forall$ n_Δ:N_Δ, onL(li,fhi,thi,r):VPos $\cdot$
134a.. $\exists$ l_Δ:$L_\Delta$$\cdot$$l_\Delta$$\in$**obs_part**_LS(**obs_part**_N_Δ(n_Δ))
134a.. $\Rightarrow$ li=**uid**_L_Δ(l)$\wedge$\{fhi,thi\}=**obs_mereo**_L_Δ(l_Δ),
134c.. $\forall$ n_Δ:N_Δ, atH(hi,fli,tli):VPos $\cdot$
134c.. $\exists$ h_Δ:$H_\Delta$$\cdot$$h_\Delta$$\in$**obs_part**_$HS_\Delta$(**obs_part**_N($n_\Delta$))
134c.. $\Rightarrow$ hi=**uid**_H_Δ(h_Δ)$\wedge$(fli,tli) $\in$ **attr**_LΣ(h_Δ)

135 We introduce an auxiliary function `distribute`.

a. `distribute` takes a net and a set of vehicles and

b. generates a map from vehicles to distinct vehicle positions on the net.

c. We sketch a "formal" `distribute` function, but, for simplicity we omit the technical details that secures distinctness — and leave that to an axiom!

136 We define two auxiliary functions:

a. xtr_links extracts all links of a net and

b. xtr_hub extracts all hubs of a net.

```
type
135b.. MAP = VI →m VPos
135b.. ∀ map:MAP · card dom map = card rng map
value
135. distribute: VS∆ → N∆ → MAP
135. distribute(vs∆)(n∆) ≡
135a..   let (hs,ls) = (xtr_hubs(n∆),xtr_links(n∆)) in
135a..   let vps = {onL(uid_(l∆),fhi,thi,r)|l∆:L∆·l∆∈ls∧{fhi,thi}⊆obs_mereo_L(l)∧0≤r≤1
135a..         ∪ {atH(uid_H(h∆),fli,tli)|h∆:H∆·h∆∈hs∧{fli,tli}⊆obs_mereo_H∆(h∆)} in
135b..   [ uid_V∆(v)↦vp|v∆:V∆,vp:VPos·v∆∈vs∧vp∈vps ]
135.   end end
```

136a.. xtr_links$_\Delta$: N$_\Delta$ $\rightarrow$ L$_\Delta$-**set**
136a.. xtr_links$_\Delta$(n$_\Delta$)$\equiv$**obs_part**_LS(**obs_part**_LA(n$_\Delta$))
136b.. xtr_hubs$_\Delta$: N$_\Delta$ $\rightarrow$ H$_\Delta$-**set**
136a.. xtr_hubs$_\Delta$(n$_\Delta$)$\equiv$**obs_part**_HS$_\Delta$(**obs_part**_HA$_\Delta$(n$_\Delta$))

And finally monitors. We consider only one monitor attribute.

137 The monitor has a vehicle traffic attribute.

a. For every vehicle of the road transport system the vehicle traffic attribute records a possibly empty list of time marked vehicle positions.

b. These vehicle positions are alternate sequences of 'on link' and 'at hub' positions

i such that any sub-sequence of 'on link' positions record the same link identifier, the same pair of "'to' and 'from' hub identifiers and increasing fractions,

ii such that any sub-segment of 'at hub' positions are identical,

iii such that vehicle transition from a link to a hub is commensurate with the link and hub mereologies, and

iv such that vehicle transition from a hub to a link is commensurate with the hub and link mereologies.

```
type
137.    Traffic = VI →m (T × VPos)*
value
137.    attr_Traffic: M → Traffic
axiom
137b..   ∀ δ:Δ •
137b..       let m = obs_part_M_Δ(δ) in
137b..       let tf = attr_Traffic(m) in
137b..       dom tf ⊆ xtr_vis(δ) ∧
137b..       ∀ vi:VI • vi ∈ dom tf •
137b..          let tr = tf(vi) in
137b..          ∀ i,i+1:Nat • {i,i+1}⊆dom tr •
137b..             let (t,vp)=tr(i),(t′,vp′)=tr(i+1) in
137b..             t<t′
137(b.)i.           ∧ case (vp,vp′) of
137(b.)i.                (onL(li,fhi,thi,r),onL(li′,fhi′,thi′,r′))
137(b.)i.                  → li=li′∧fhi=fhi′∧thi=thi′∧r≤r′
137(b.)i.                  ∧ li ∈ xtr_lis(δ)
137(b.)i.                  ∧ {fhi,thi} = obs_mereo_L(get_link(li)(δ)),
137(b.)ii.               (atH(hi,fli,tli),atH(hi′,fli′,tli′))
137(b.)ii.                 → hi=hi′∧fli=fli′∧tli=tli′
137(b.)ii.                 ∧ hi ∈ xtr_his(δ)
137(b.)ii.                 ∧ (fli,tli) ∈ obs_mereo_H(get_hub(hi)(δ)),
137(b.)iii.              (onL(li,fhi,thi,1),atH(hi,fli,tli))
137(b.)iii.                → li=fli∧thi=hi
137(b.)iii.                ∧ {li,tli} ⊆ xtr_lis(δ)
137(b.)iii.                ∧ {fhi,thi}=obs_mereo_L(get_link(li)(δ))
137(b.)iii.                ∧ hi ∈ xtr_his(δ)
137(b.)iii.                ∧ (fli,tli) ∈ obs_mereo_H(get_hub(hi)(δ)),
137(b.)iv.               (atH(hi,fli,tli),onL(li′,fhi′,thi′,0))
137(b.)iv.                 →  etcetera,
137b..               _  → false
137b..       end end end end end
```

6.1.7. Routes

- We bring a model of routes.

TO BE WRITTEN

6.2. Perdurants
6.2.1. Vehicle to Monitor Channel

138 Let δ be the traffic system domain.

139 Then focus on the set of vehicles

140 and the monitor —

141 and we obtain an appropriate channel array for communication between vehicles and the traffic observing monitor.

value
139. **let** vs:VS · vs = **obs_part**_VS(**obs_part**_F(δ)),
140. m:M · m = **obs_part**_M(δ) **in**
channel
141. {v_m_ch[**uid**_VI(v),**uid**_MI(m)]|v:V·v ∈ vs} **end**

6.2.2. Link Disappearance Event

We formalise aspects of the above-mentioned link disappearance event:

142 The result net, n':N', is not well-formed.

143 For a link to disappear there must be at least one link in the net;

144 and such a link may disappear such that

145 it together with the resulting net makes up for the "original" net.

value

142. link_diss_event: N × N′ × **Bool**
142. link_diss_event(n,n′) **as** tf
143. **pre**: **obs_part**_Ls(**obs_part**_LS(n))≠{}
144. **post**: ∃ l:L•l ∈ **obs_part**_Ls(**obs_part**_LS(n)) ⇒
145. l ∉ **obs_part**_Ls(**obs_part**_LS(n′))
145. ∧ n′ ∪ {l} = **obs_part**_Ls(**obs_part**_LS(n))

6.2.3. Road Traffic

Global Values

- There is given some globally observable parts.

146 besides the domain, δ_Δ:Δ_Δ,

147 a net, n:N,

148 a set of vehicles, vs:V-**set**,

149 a monitor, m:M, and

150 a clock, clock, behaviour.

151 From the net and vehicles we generate an initial distribution of positions of vehicles.

- The n:N, vs:V-**set** and m:M are observable from any road traffic system domain δ.

value

146. $\delta_\triangle:\Delta_\triangle$
147. n:N = **obs_part**_N($\delta_\triangle$),
147. ls:L-**set**=linksLs(δ),hs:H-**set**=hubs($\delta_\triangle$),
147. lis:LI-**set**=xtr_lis(δ),his:HI-**set**=xtr_his($\delta_\triangle$)
148. vs:V-**set**=**obs_part**_Vs(**obs_part**_VS(**obs_part**_F(δ)$_\triangle$)),
148. vis:VI-**set** = {**uid**_VI(v)|v:V·v ∈ vs},
149. m:**obs_part**_M(δ), mi=**uid**_MI(m), ma:**attributes**(m)
150. clock: $\mathbb{T}$ → **out** {clk_ch[vi|vi:VI·vi ∈ vis]} **Unit**
151. vm:MAP·vpos_map = distribute(vs)(n);

Channels

152 We additionally declare a set of vehicle to monitor channels indexed

a. by the unique identifiers of vehicles

b. and the (single) monitor identifier.[24]

and communicating vehicle positions.

channel

152. {v_m_ch[vi,mi]|vi:VI•vi ∈ vis}:VPos

[24]Technically speaking: we could omit the monitor identifier.

Behaviour Signatures

153 The road traffic system behaviour, rts, takes no arguments; and "behaves", that is, continues forever.

154 The vehicle behaviour

a. is indexed by the unique identifier, uid_V(v):VI,

b. the vehicle mereology, in this case the single monitor identifier mi:MI,

c. the vehicle attributes, obs__attribs(v)

d. and — factoring out one of the vehicle attributes — the current vehicle position.

e. The vehicle behaviour offers communication to the monitor behaviour; and behaves "forever".

155 The **mon**itor behaviour takes

a. the monitor identifier,

b. the monitor mereology,

c. the monitor attributes,

d. and — factoring out one of the vehicle attributes — the discrete road traffic, drtf:dRTF;

e. the behaviour otherwise behaves forever.

value

153. trs: **Unit** $\rightarrow$ **Unit**

154. veh$_\Delta$: vi:VI $\times$ mi:MI $\rightarrow$ vp:VPos $\rightarrow$

154. **out** vm_ch[vi,mi] **Unit**

155. mon$_\Delta$: m:M$_\Delta$ $\times$ vis:VI-**set** $\rightarrow$ RTF $\rightarrow$

155. **in** {v_m_ch[vi,mi]|vi:VI•vi $\in$ vis},clk_ch **Unit**

The Road Traffic System Behaviour

156 Thus we shall consider our **road traffic system**, rts, as

a. the concurrent behaviour of a number of vehicles and, to "observe", or, as we shall call it, to monitor their movements,

b. the **mon**itor behaviour.

value

156. trs() =

156a.. $\parallel$ {veh$_\triangle$(**uid**_VI(v),mi)(vm(**uid**_VI(v)))|v:V·v $\in$ vs}

156b.. $\parallel$ mon$_\triangle$(mi,vis)([vi$\mapsto\langle\rangle$|vi:VI·vi $\in$ vis])

- where, wrt, the monitor, we
  - dispense with the mereology and the attribute state arguments
  - and instead just have a **mon**itor traffic argument which
    - records the discrete road traffic, MAP,
    - initially set to "empty" traces ($\langle\rangle$, of so far "no road traffic"!).
- In order for the monitor behaviour to assess the vehicle positions
  - these vehicles communicate their positions
  - to the monitor
  - via a vehicle to monitor channel.
- In order for the monitor to time-stamp these positions
  - it must be able to "read" a clock.

157 We describe here an abstraction of the vehicle behaviour **at** a Hub (hi).

a. Either the vehicle remains at that hub informing the monitor of its position,

b. or, internally non-deterministically,

   i moves onto a link, tli, whose "next" hub, identified by thi, is obtained from the mereology of the link identified by tli;

   ii informs the monitor, on channel vm[vi,mi], that it is now at the very beginning (0) of the link identified by tli,

   iii whereupon the vehicle resumes the vehicle behaviour positioned at the very beginning of that link,

c. or, again internally non-deterministically,

d. the vehicle "disappears — off the radar" !

157. veh$_\triangle$(vi,mi)(vp:atH(hi,fli,tli)) $\equiv$
157a.. v_m_ch[vi,mi]!vp ; veh$_\triangle$(vi,mi)(vp)
157b.. $\sqcap$
157(b.)i. **let** {hi′,thi}=**obs_mereo**_L(get_link(tli)(n)) **in**
157(b.)i. **assert:** hi′=hi
157(b.)ii. v_m_ch[vi,mi]!onL(tli,hi,thi,0) ;
157(b.)iii. veh$_\triangle$(vi,mi)(onL(tli,hi,thi,0)) **end**
157c.. $\sqcap$
157d.. **stop**

158 We describe here an abstraction of the vehicle behaviour **on** a Link (ii). Either

a. the vehicle remains at that link position informing the monitor of its position,

b. or, internally non-deterministically,

c. if the vehicle's position on the link has not yet reached the hub,

i then the vehicle moves an arbitrary increment ℓ_ϵ (less than or equal to the distance to the hub) along the link informing the monitor of this, or

ii else, while obtaining a "next link" from the mereology of the hub (where that next link could very well be the same as the link the vehicle is about to leave),

A the vehicle informs the monitor that it is now at the hub identified by thi,

B whereupon the vehicle resumes the vehicle behaviour positioned at that hub.

159 or, internally non-deterministically,

160 the vehicle "disappears — off the radar" !

158. veh$_\triangle$(vi,mi)(vp:onL(li,fhi,thi,r)) $\equiv$
158a.. v_m_ch[vi,mi]!vp ; veh($_\triangle$vi,mi,va)(vp)
158b.. $\sqcap$
158c.. **if** r + $\ell_\epsilon \leq 1$
158(c.)i. **then** v_m_ch[vi,mi]!onL(li,fhi,thi,r+ℓ_ϵ) ;
158(c.)i. veh$_\triangle$(vi,mi)(onL(li,fhi,thi,r+ℓ_ϵ))
158(c.)ii. **else let** li′:LI•li′ $\in$ **obs_mereo**_H(get_hub(thi)(n)) **in**
158(c.)iiA. v_m_ch[vi,mi]!atH(li,thi,li′);
158(c.)iiB. veh$_\triangle$(vi,mi)(atH(li,thi,li′)) **end end**
159. $\sqcap$
160. **stop**

The Monitor Behaviour

161 The **mon**itor behaviour evolves around

a. the monitor identifier,

b. the monitor mereology,

c. and the attributes, ma:ATTR

d. — where we have factored out as a separate arguments — a table of traces of time-stamped vehicle positions,

e. while accepting messages

i about time

ii and about vehicle positions

f. and otherwise progressing "in[de]finitely".

162 Either the monitor "does own work"

163 or, internally non-deterministically accepts messages from vehicles.

a. A vehicle position message, vp, may arrive from the vehicle identified by vi.

b. That message is appended to that vehicle's movement trace – prefixed by time (obtained from the time channel),

c. whereupon the monitor resumes its behaviour —

d. where the communicating vehicles range over all identified vehicles.

161. $\mathsf{mon}_\triangle(\mathsf{mi,vis})(\mathsf{trf}) \equiv$
162. $\quad\quad \mathsf{mon}_\triangle(\mathsf{mi,vis})(\mathsf{trf})$
163. $\quad \sqcap$
163a.. $\quad\quad \lfloor\!\rceil\{\mathbf{let}\ \mathsf{tvp} = (\mathsf{clk\_ch?,v\_m\_ch[\,vi,mi\,]?})\ \mathbf{in}$
163b.. $\quad\quad\quad \mathbf{let}\ \mathsf{trf}' = \mathsf{trf} \dagger [\,\mathsf{vi} \mapsto \mathsf{trf(vi)}\widehat{\ }\langle \mathsf{tvp} \rangle\,]\ \mathbf{in}$
163c.. $\quad\quad\quad \mathsf{mon}_\triangle(\mathsf{mi,vis})(\mathsf{trf}')$
163d.. $\quad\quad\quad \mathbf{end\ end} \mid \mathsf{vi{:}VI} \cdot \mathsf{vi} \in \mathsf{vis}\}$

- We are about to complete a long, i.e., a 16 slide example.
- We can now comment on the full example:
  - The domain, $\delta : \Delta$ is a manifest part.
  - The road net, $n : N$ is also a manifest part.
  - The fleet, $f : F$, of vehicles, $vs : VS$, likewise, is a manifest part.
  - But the monitor, $m : M$, is a concept.

- One does not have to think of it as a manifest "observer".
- The vehicles are on — or off — the road (i.e., links and hubs).
- We know that from a few observations and generalise to all vehicles.
- They either move or stand still. We also, similarly, know that.
- Vehicles move. Yes, we know that.
- Based on all these repeated observations and generalisations we introduce the concept of vehicle traffic.
- Unless positioned high above a road net — and with good binoculars — a single person cannot really observe the traffic.
- There are simply too many links, hubs, vehicles, vehicle positions and times.

◈ Thus we conclude that, even in a richly manifest domain, we can also "speak of", that is, describe concepts over manifest phenomena, including time!

End of MAP-i Lecture # 6:
A Domain Description

Tuesday, 26 May 2015: 12:00–13:00