Awareness and Adaptivity Requirements

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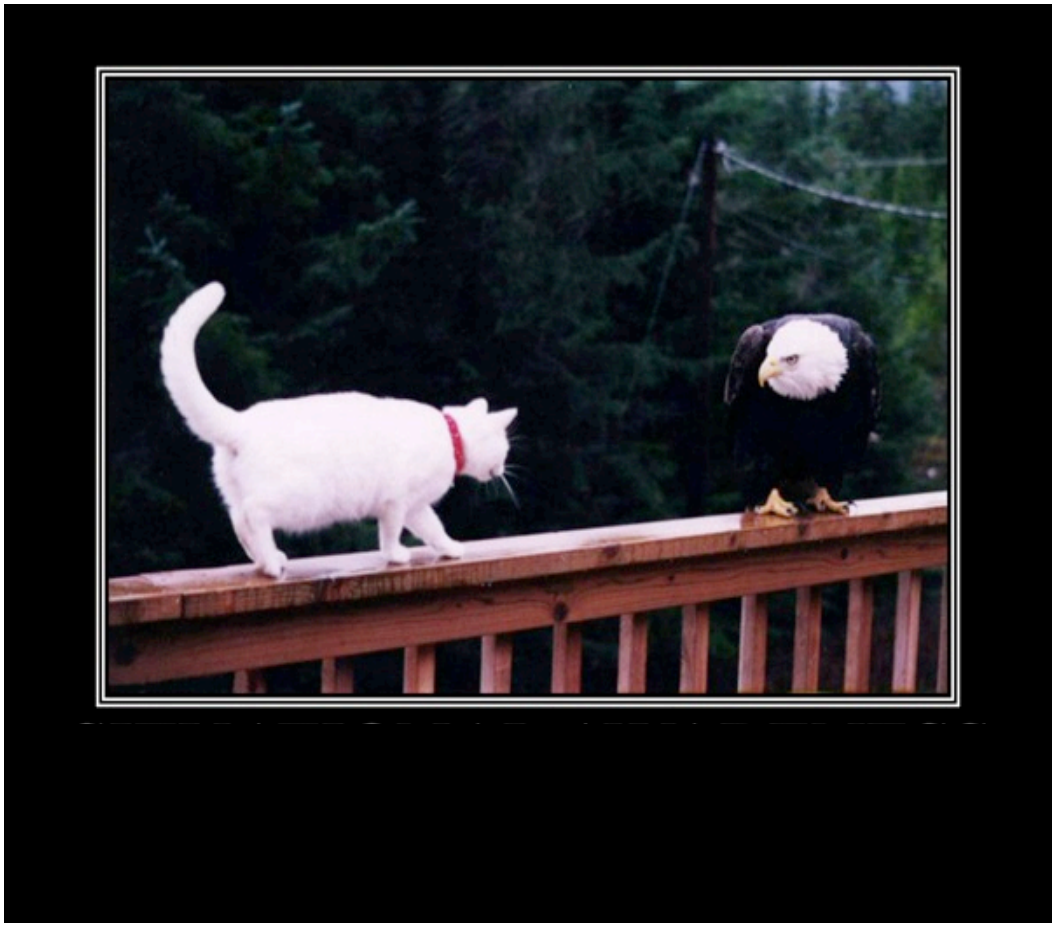
SEAMS'10, Cape Town
May 3-4, 2010



Abstract

Adaptive systems usually achieve adaptivity through a feedback loop, an architectural prosthesis that introduces monitoring, diagnosis and reconciliation functions to the system proper. We are interested in studying the *requirements* that lead to such feedback loop functionality. We introduce a class of requirements, called *awareness requirements*, which are best operationalized through a feedback loop instead of a collection of functions. These are characterized by the fact that they refer to other requirements, quality constraints or domain assumptions, and their success or failure. We then discuss *adaptivity requirements* as a special class of awareness requirements which talk about changes to the status of other requirements.

Thanks

- This is on-going joint work with Alexei Lapouchnian (UToronto) and Vitor Souza (UniTN).
- Thanks to my colleagues at the University of Trento for helpful comments and feedback: Raian Ali, Amit Chopra, Fabiano Dalpiaz, Paolo Giorgini, Nauman Qureshi, Angelo Susi.

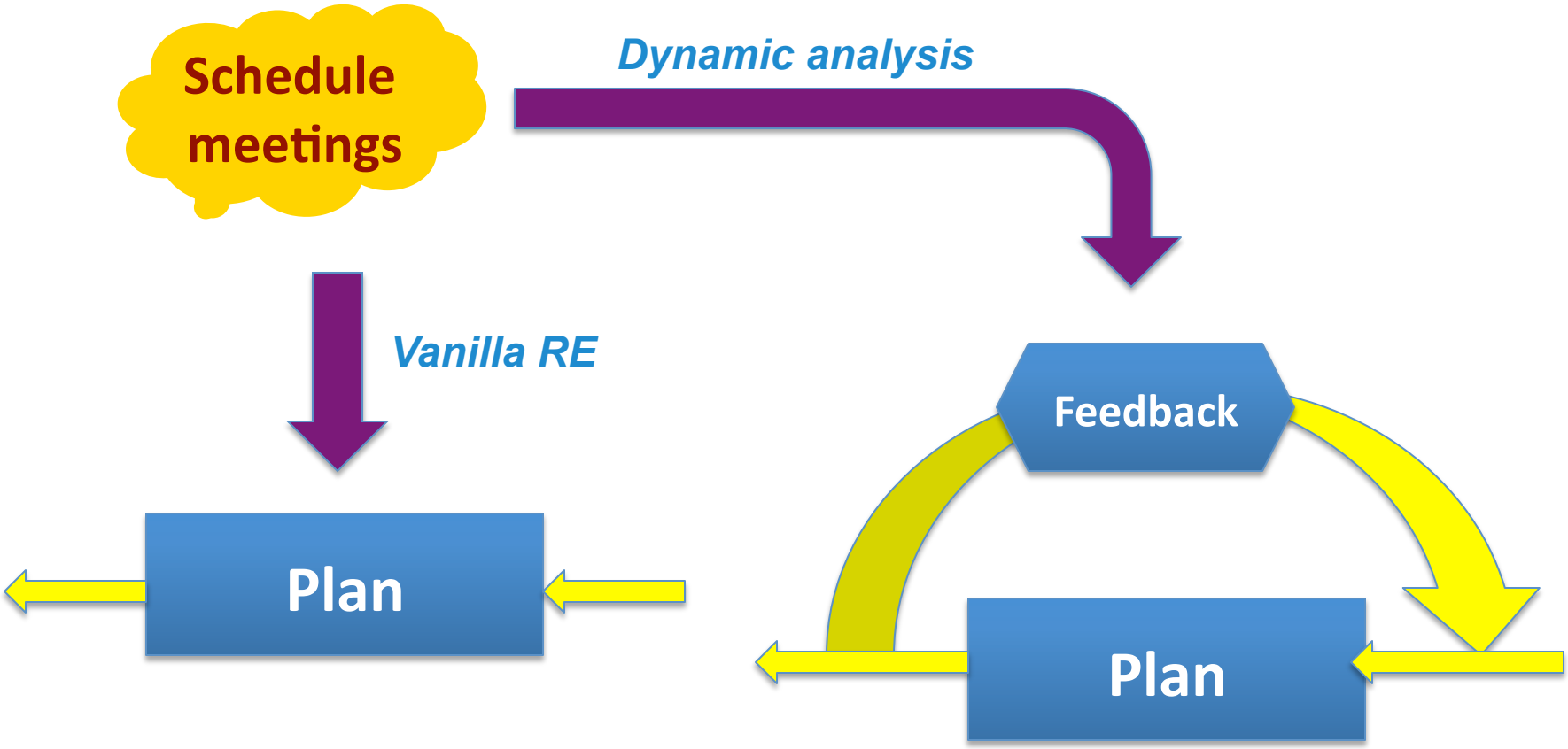
Adaptive software systems

- Change their behaviour at run-time in response to changes in their environment.
- Adaptation mechanism consists of a feedback loop whereby the outputs of the system are monitored and compensation action is taken, if system is not fulfilling its purpose.
- ***'purpose'*** = requirements,

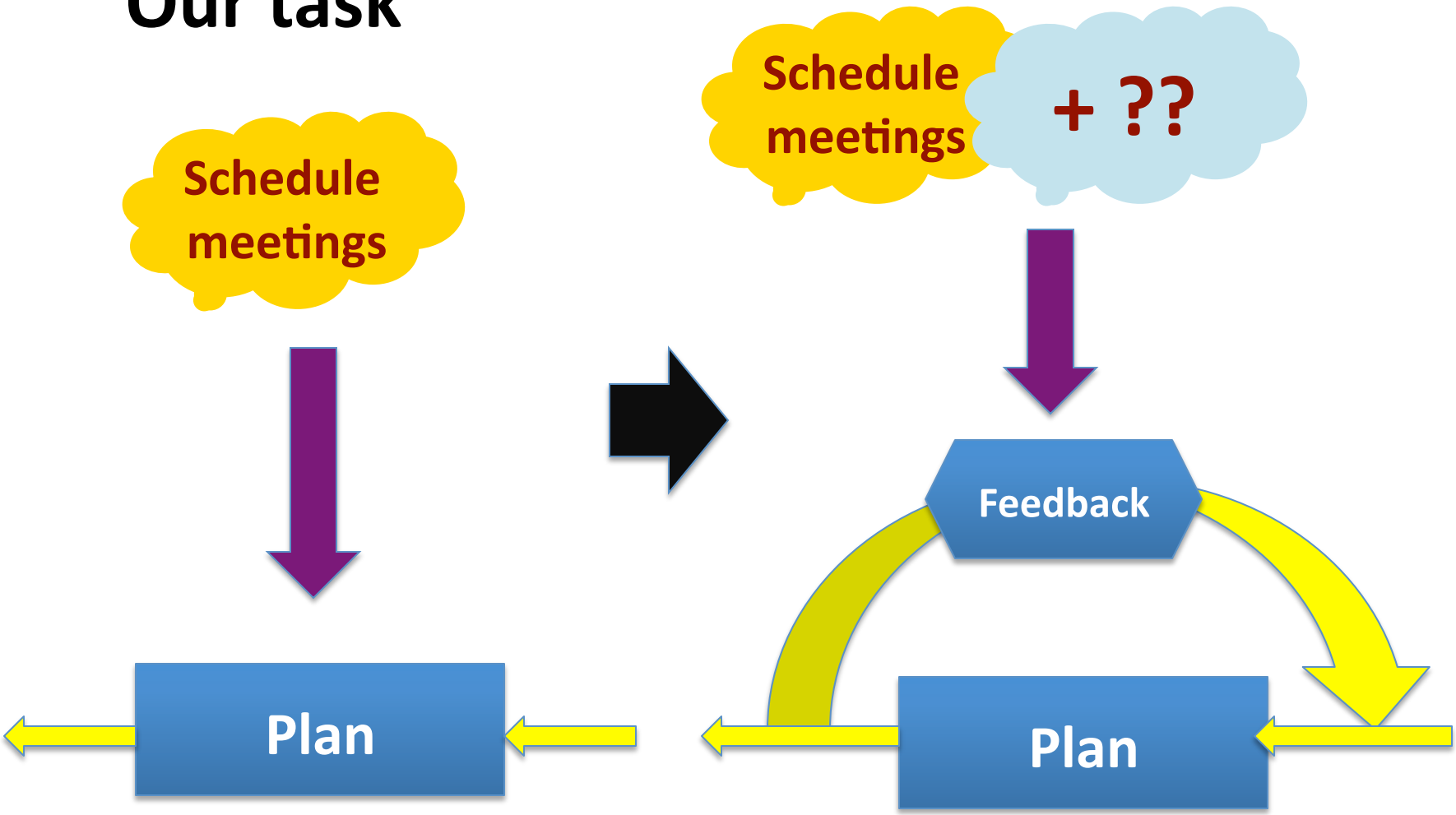
  'not fulfilling its purpose' $\Rightarrow$ system is *aware* of success/ failure of its requirements.

Baseline

- FLEA+KAOS [Feather98], ReqMon [Robinson06], …



Our task



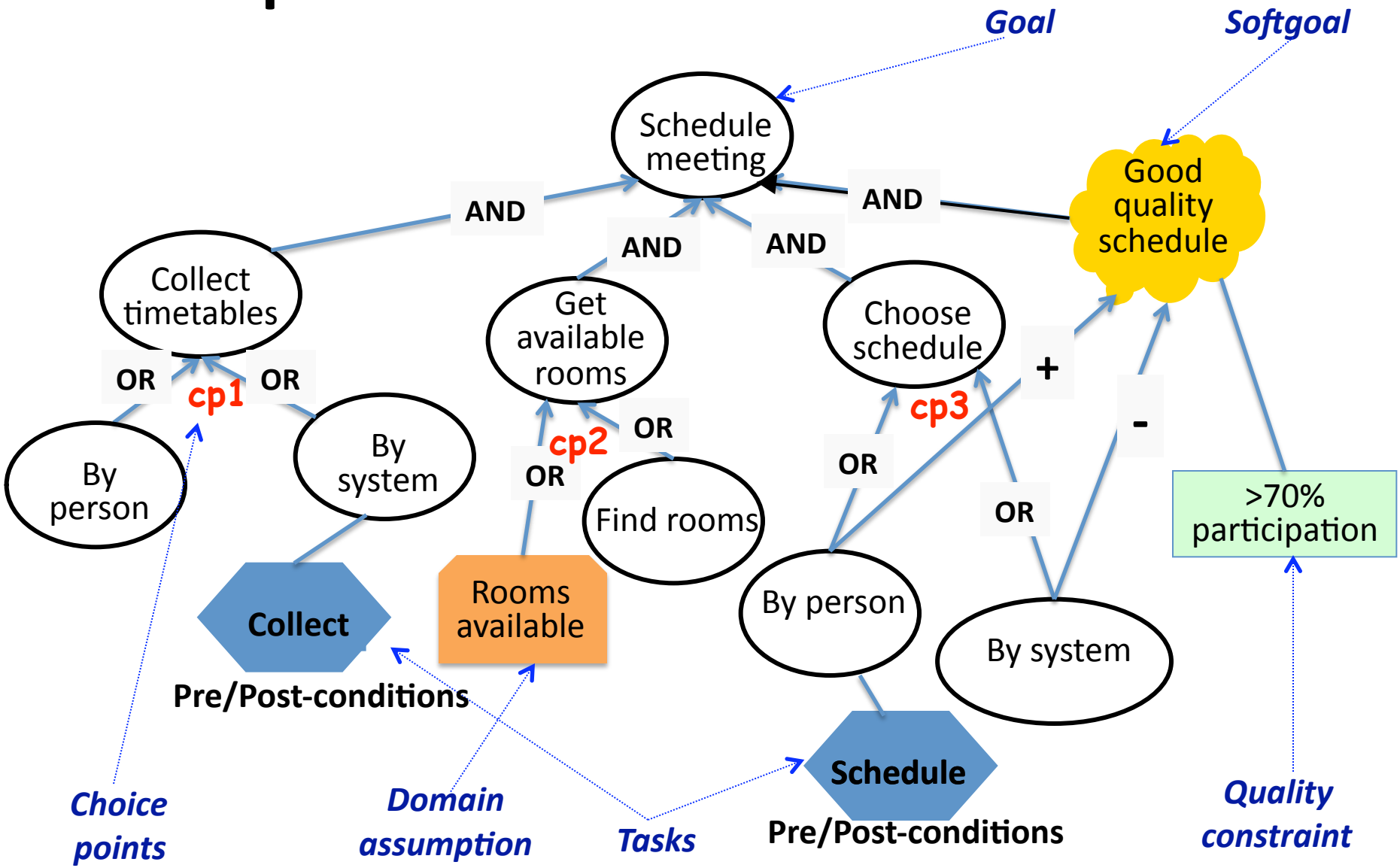
… in words

- Requirements as run-time objects to reflect on [Finkelstein08].
- To do so, we need to talk about the success/failure of requirements at run-time.
- Many proposals – [Letier04], [Whittle09], [Baresi10], …
- Our perspective: (i) *Awareness* gives rise to the need for feedback; (ii) Model awareness requirements; (iii) Propose a new operationalizion for requirements, specifically tailored to awareness.

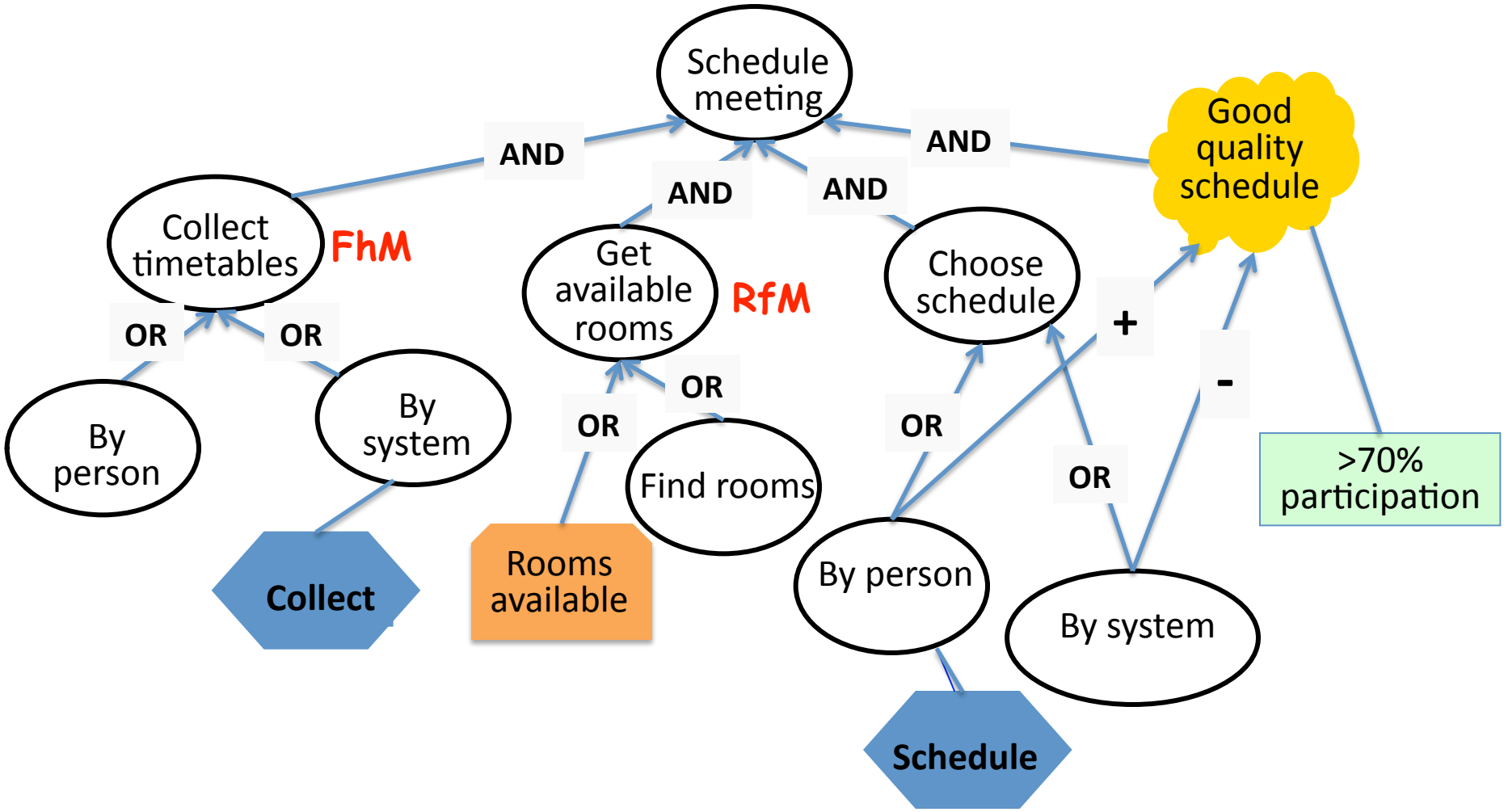
Awareness

- Awareness: Consciousness, sentience, ability to sense and respond to the environment.
- Many types of awareness play a role in the design of software systems (security/process/context/location …)
- Important topic, not only in Computer Science.
- In Philosophy, awareness plays an important role in several theories of consciousness. Our notion of awareness requirements draws on the distinction between higher-order awareness (awareness of one's own mental states) and first-order awareness (awareness of things external) [Rosenthal05].

Requirements



Requirements + control parameters



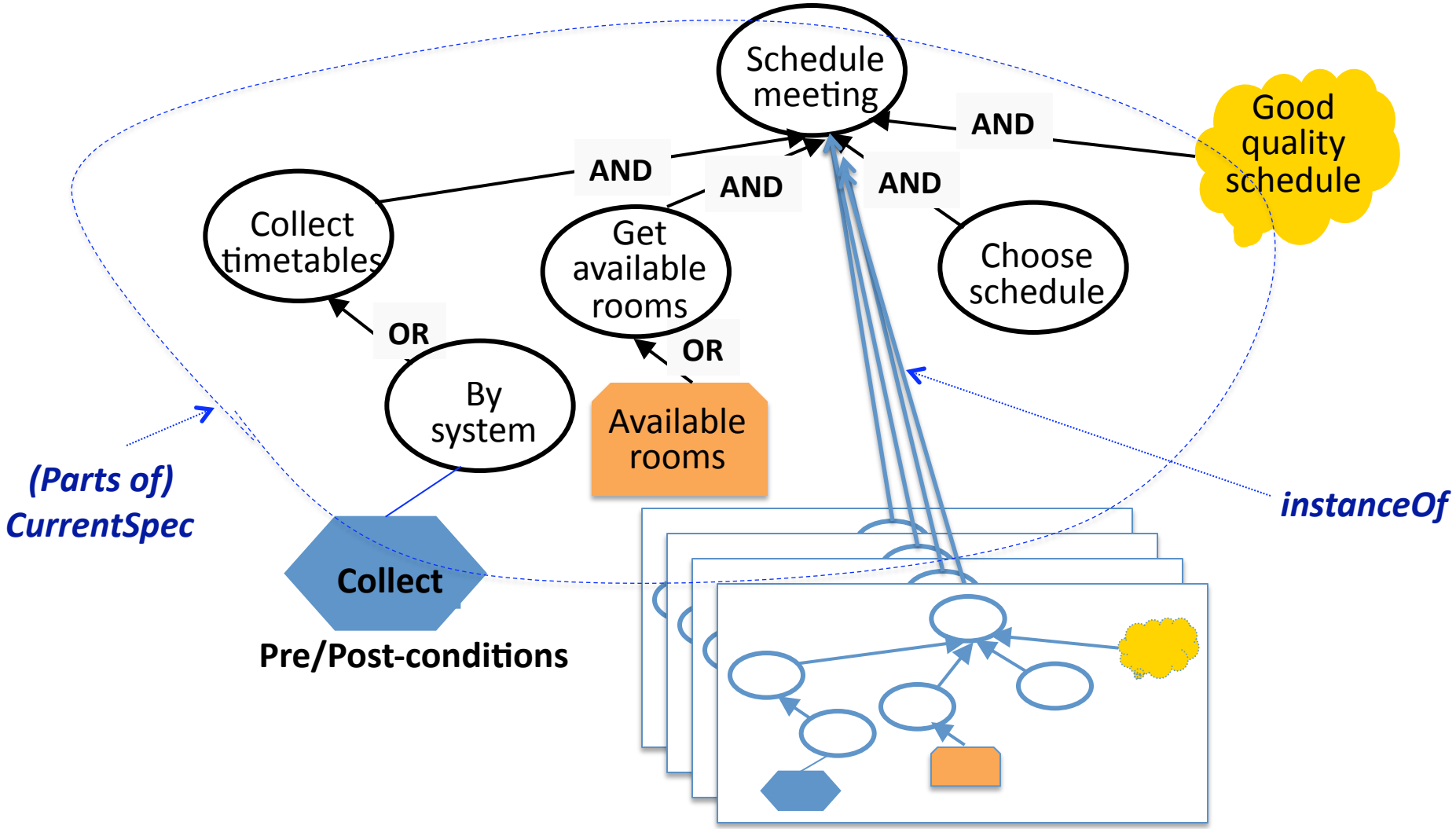
Requirements and specifications

- Requirements include (hard) goals, softgoals, tasks and quality constraints with associated relationships.
- All are to be understood as generic (classes) to be instantiated for any specific requirements fulfillment task.
- A specification consists of a collection of tasks (T), domain assumptions (DA), quality constraints (QC), and control parameter values, which together fulfill root-level goals.

Specification space

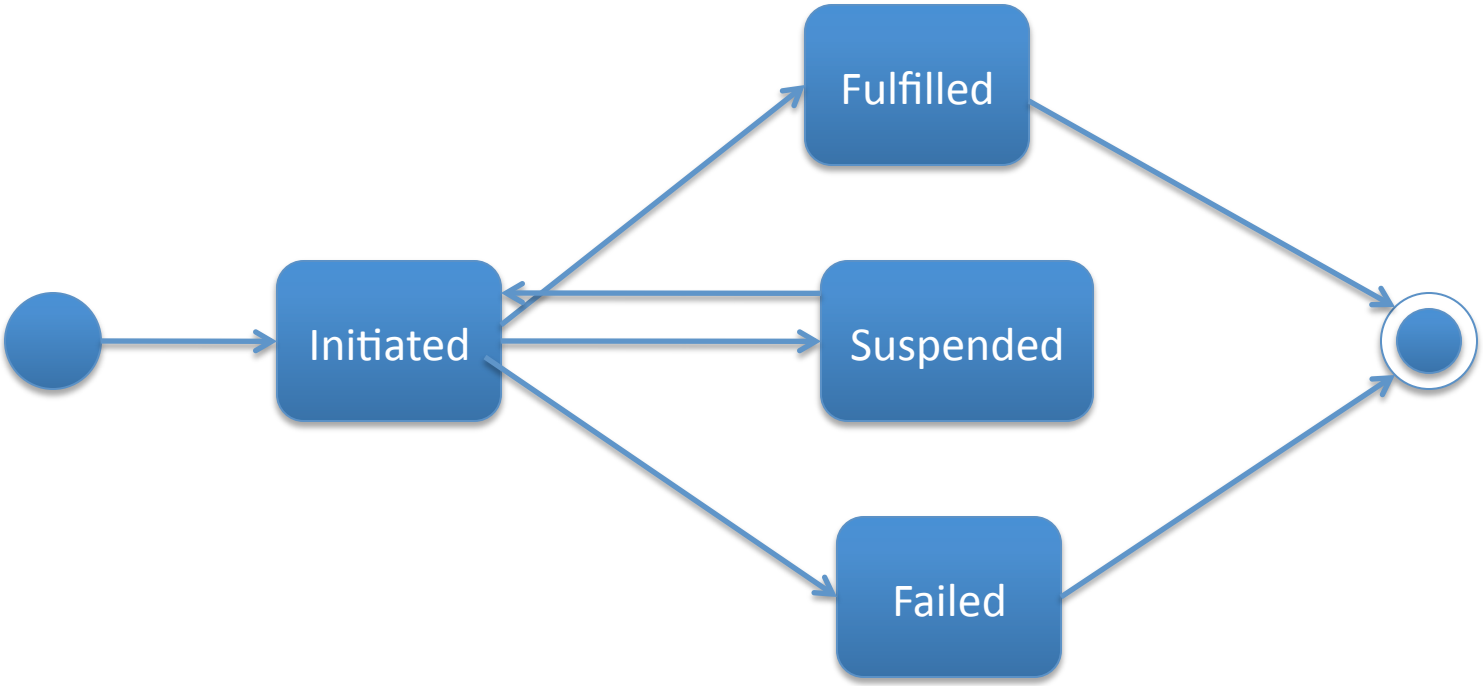
- From a requirements model M with n OR-refinements, we can derive $O(2^n)$ specifications. Each alternative consists of making a choice for each OR-refinement. Control parameters add to this, possibly an infinite space.
- One of these specifications is implemented by the running version of a system. We'll refer to this specification as ***CurrentSpec***.

Requirements at run-time



Object lifetimes: Goals

Analogous FSMs describe the lifetimes of other requirement objects (QC, DA, T)



Uncertainty

- Operationalizations here (and in all GORE frameworks) basically mean: If tasks T are carried out and quality constraints QC and domain assumptions DA hold, then requirements R are fulfilled.

  T, DA, QC |= R

- That's an optimistic view of the world …
  - ✓ Rooms may not be available for meetings,
  - ✓ Someone may not turn in his timetable, …
- Executions of an operationalization may fail

➔ *uncertainty!*

Adaptivity is all about governing/controlling uncertainty

Awareness requirements

- Refer to other requirements (Goals/Tasks/Quality Constraints/Domain Assumptions) and their success/ failure.
- Consider

  r = ‘schedule meeting’, da = ‘always rooms available’

  r1 = ‘r will be completed within 2hrs’ (delta)

  r2 = ‘r won’t fail >3 times per year’ (aggregate)

  r3 = ‘avg r time won’t increase between months’ (trend)

  r4 = ‘da won’t fail >3 times per year’

Expressing awareness requirements

- We need a language that allows us to express constraints on instances of a class … An OCL-like language will do:

r = goal class SM, da = domainA class RA

r1 = goal class R1, attr r: SM | dur(self.r) ≤ 2hrs

r2 = goal class R2, attr r: SM |

size(select x SM.inst st failed?(x) ∧ within(x,1yr,now)) ≤ 3

r3 = avg(dur(select x SM.inst st within(x,1mo,now)))

≤ avg(dur(select x SM.inst st within(x,1mo,now-1mo)))

r4 = size(select x RA.inst st failed(x) ∧ within(x,1yr,now) ≤ 3

Strata of awareness

- Of course, one could have awareness requirements about other awareness requirements.
- For example,

  r = ‘schedule meeting’, da = ‘always rooms available’

  r1 = ‘r will be completed within 2hrs’

  r1’ = ‘r1 won’t fail >3 times per year’
- To avoid paradoxes, we need to stratify our requirements space: base requirements are at stratum 0, awareness requirements about base requirements are at stratum 1, …
- In general, an awareness requirement at stratum n+1 talks about a requirement at stratum n, and can only talk about requirements at strata ≤n.

Adaptivity Requirements

- An *adaptivity requirement* is an awareness requirement that can also talk about changes of status for another requirement.
- For example, da = 'always rooms available'

  r = 'schedule meeting', r1 = 'r will be completed within 2hrs'

  r2 = 'r will be completed within 3hrs'
- Possible adaptivity requirements

dur(r1.r.collectTT) > 2hrs ⇒ **fail**(r1) ∧ **initiate**(r2) (relax)

2.2hrs > dur(r1.r) > 2hrs ⇒ **fulfill**(r1) (good-enough)

dur(r1.r.collectTT) > 3hrs ⇒ **fail**(r1) ∧ **fail**(r) (abort)

failed?(r.da) ⇒ **initiate**(gmr) (compensation)

dur(r1.r.collectTT) > 2hrs ⇒ **changePar**(FhM:=FhM-20%)

(compensation)

Adaptivity Reqs: Changing CurrentSpec

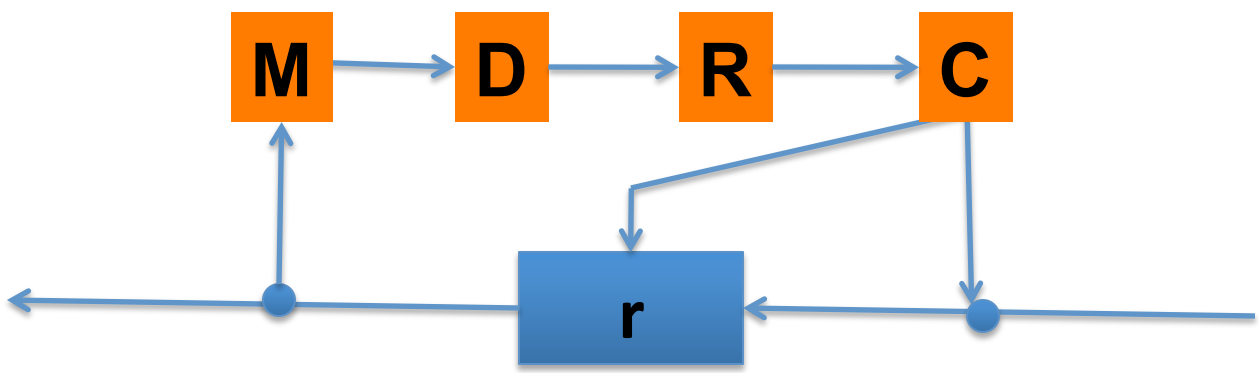
- So far, examples of adaptivity requirements affect the status of requirement *instances*. But sometimes, we want adaptation to amount to a "from now on" change.
- Suppose CurrentSpec assumes there are rooms available. If this DA fails more than 3 times within a month, we want to change choice point 2 for CurrentSpec and increase the # of rooms available for meetings (RfM):

  size(select x RA.inst st failed?(x) ∧ within(x,1yr,now) > 3
  ⇒ **changeSpec**(cp2≠1,RfM:=RfM+10)

- It would be useful to have variations of **changeSpec** that (i) maximize familiarity in the new spec relative to the old one, or (ii) minimize new implementation needed for the adaptation, etc. (*many* variations)

Reactive Operationalizations

- Sometimes, a goal is fulfilled by simply waiting for its fulfillment. More generally, for a goal G consisting of G1∧G2, we may choose to do nothing until G1 or G2 are true (... *opportunistic* operationalization).
- Let's postulate that each awareness requirement (on another requirement r) is to be operationalized reactively with a feedback loop consisting of monitor, diagnose, reconcile, compensate tasks.

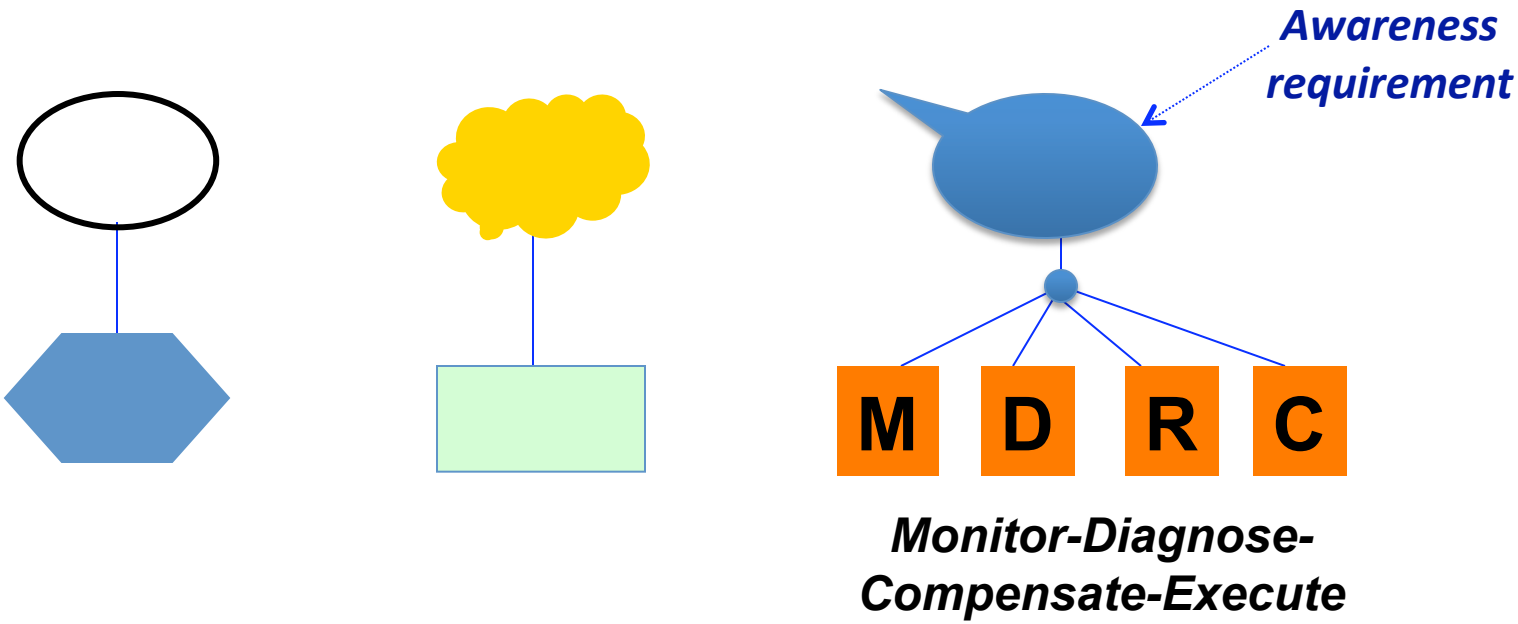


Monitor-Diagnose-Reconcile-Compensate

- Monitor – the environment; usually applies to tasks, quality constraints and domain assumptions, ***not*** to goals.
- Diagnose – interpret monitored data; figure out the status of goals given information on the execution of tasks; see [Wang09], [Souza09] for principled ways of interpreting log data about tasks to offer a diagnosis about the failure of goals.
- Reconcile – what's the adaptation, at the instance/class level.
- Compensate – change management, may include new implementation and/or adoption of results of aborted execution.

Operationalizations revisited

- We now have three types of operationalizations, as shown below.
- The first two are proactive, the last reactive.

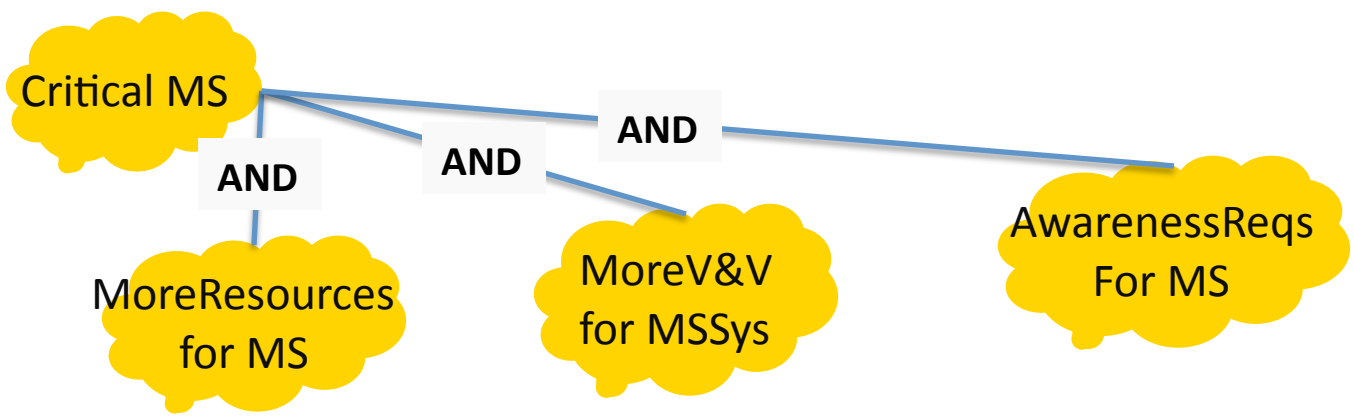


What operationalization, when?

- It might seem that proactive operationalizations are only appropriate for stratum 0 requirements, and reactive ones only for higher strata.
- Not so: either operationalization is in principle applicable to any requirement …
  - ✓ … I schedule a meeting by waiting for someone to do it.
  - ✓ … I ensure room availability by cancelling meetings.
- The use of proactive operationalizations for stratum 0 requirements, and the reactive ones for higher strata is just a convention that design theories of the future may do away with.

Where do awareness reqs come from?

- The need for adaptivity comes from criticality and risk considerations. Criticality, in turn, can have its origins in safety, dependability, reliability, etc.
- Such non-functional requirements constitute the origins of awareness requirements.
- Consider: Meeting scheduling (MS) is a critical requirement for our organization; hence we allocate more resources to MS, we do more V&V for our MS system, AND we impose some awareness requirements for it as well …



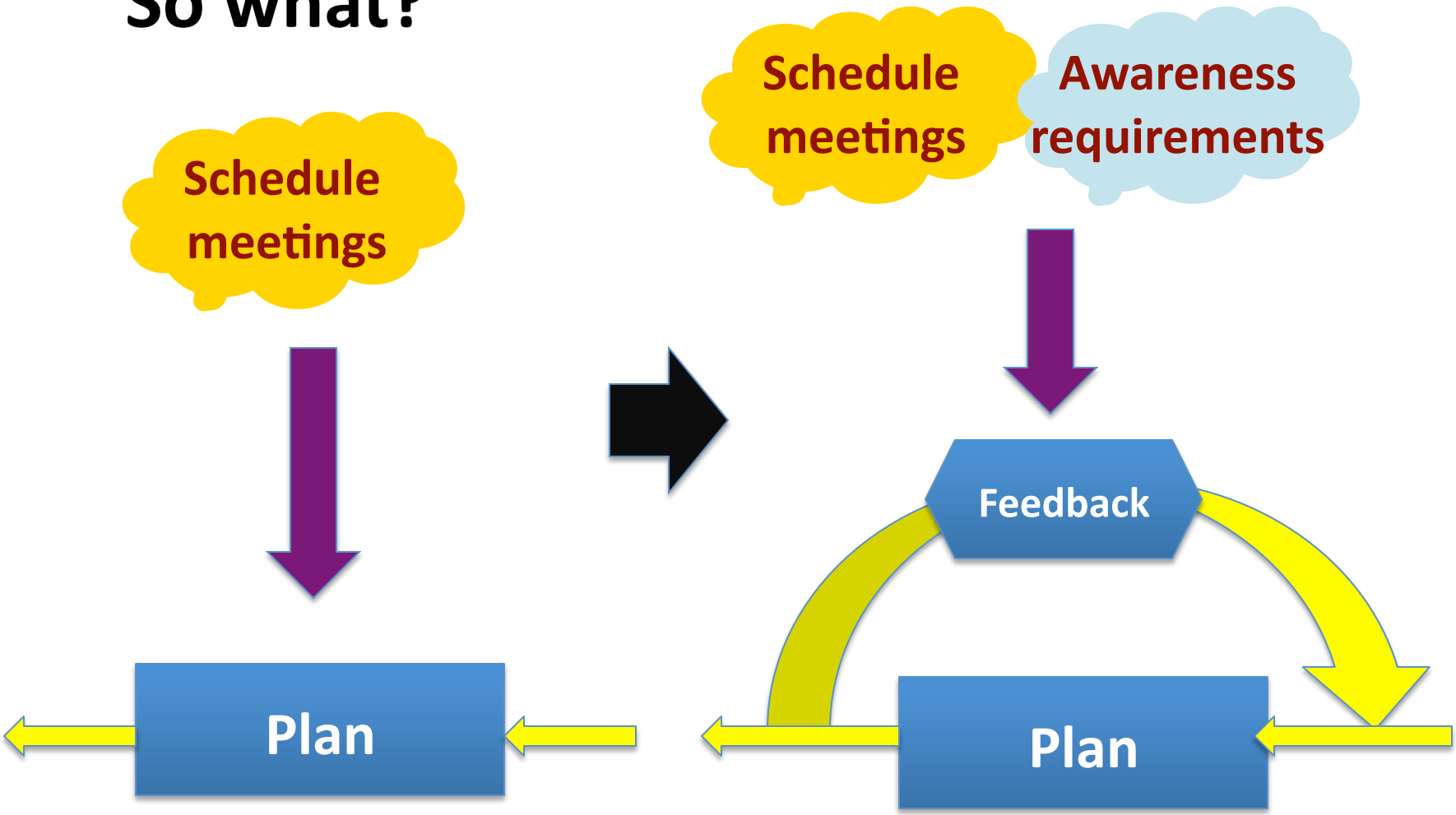
Stability

- Our examples so far are simple in that they each set a bound on failures. Consider now awareness requirements such as

  r1 = ‘r will fail ≤10 and ≥5 times per month’

- Such requirements make sense in cases of tradeoffs: we want to control failure rates, but knowing that such control is costly, we also want a failure lower bound …
- Such requirements raise the spectre of oscillating adaptations, e.g., switching between manual to automatic collection of timetables, that violate r1 wrt its lower/upper bound.

So what?


Schedule meetings
Plan
Schedule meetings
Awareness requirements
Feedback
Plan

Discussion

- The idea of having requirements that refer to other requirements was there in the NFR framework [Chung00]; but the language used was very simple and there was no notion of reactive operationalization.
- [Robinson08] uses an extension of OCL, OCL_{TM}, to talk about run-time requirements objects. This is probably the language we want to use for awareness requirements.
- Recent work by Baresi et al [Baresi10] proposes adaptive goals that "… represent adaptation strategies to be performed when a goal is not fulfilled satisfactorily." This seems to fit somewhere between our adaptivity requirements and reconciliation strategies in our proposal.

Conclusions

- We have sketched a theory of software adaptivity founded on the concept of awareness.
- The theory is based on a careful account of what awareness means in the context of requirements, how to express it, and how to operationalize it in terms of reactive plans.
- The two major extensions required for GORE frameworks to account for that theory are: (i) Ability to refer to requirements elements within an OCL-like language; (ii) A new reactive operationalization primitive.
- Given the complexity of the task-at-hand, we have strived to live by Einstein's words: Make everything as simple as possible, but not simpler …

Future work

- Three top issues to be addressed: semantics, semantics and semantics …
- Stability
- Implementation
- Case studies …

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