INVENTIVE

Fuzzy Time Intervals for Simulating Actions

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Outline:

- Motivation
  - Why crisp plans and schedules fail?
- PSI project and modeling approach
- Ontology stack and modeling choices
- Minimal model of time – how requirements are met
- Basic (crisp) theory
- Fuzzy extension
  - Time intervals
  - Time phases and periods
- THROUGHOUT: How to use for simulating actions

- Conclusions and outlook

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Why Crisp Plans and Schedules Fail?

At execution time a design manager …

- May find out that:
  - A designer is not available at 08:00:03.1458 CET as planned
  - Designer D will not accomplish activity A at 08:00:03.1458 CET as he swore
- Observes that:
  - Designer D is less busy in other projects than he reports
  - Resource R will be depleted more quickly than estimated
  - Designer D is not that well trained for using tool T as he claims
  - Factually required No of debug-verify iterations will be more than planned
  - Different designers will spend different times for ramping up for activity A
    - Ramping up longer may result in doing the job quicker
    - But, … not at all necessarily
- Nobody is (crisply) perfect

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Performance Simulation Initiative

- R&D project of Cadence Design Systems GmbH
  - Goal: Assess and Manage Performance in Engineering Design
  - Domain: Microelectronics and Integrated Circuits
  - Method: knowledge-intensive simulation of:
    - A Design System and
    - A Dynamic Engineering Design Process
- A “horizontal” framework:
  - Plugged-in focused activities
  - Cooperation with other projects
    - PRODUKTIV+ (BMBF, http://www.edacentrum.de/produktivplus/)
    - ACTIVE IP (EC FP7, http://active-project.eu/)

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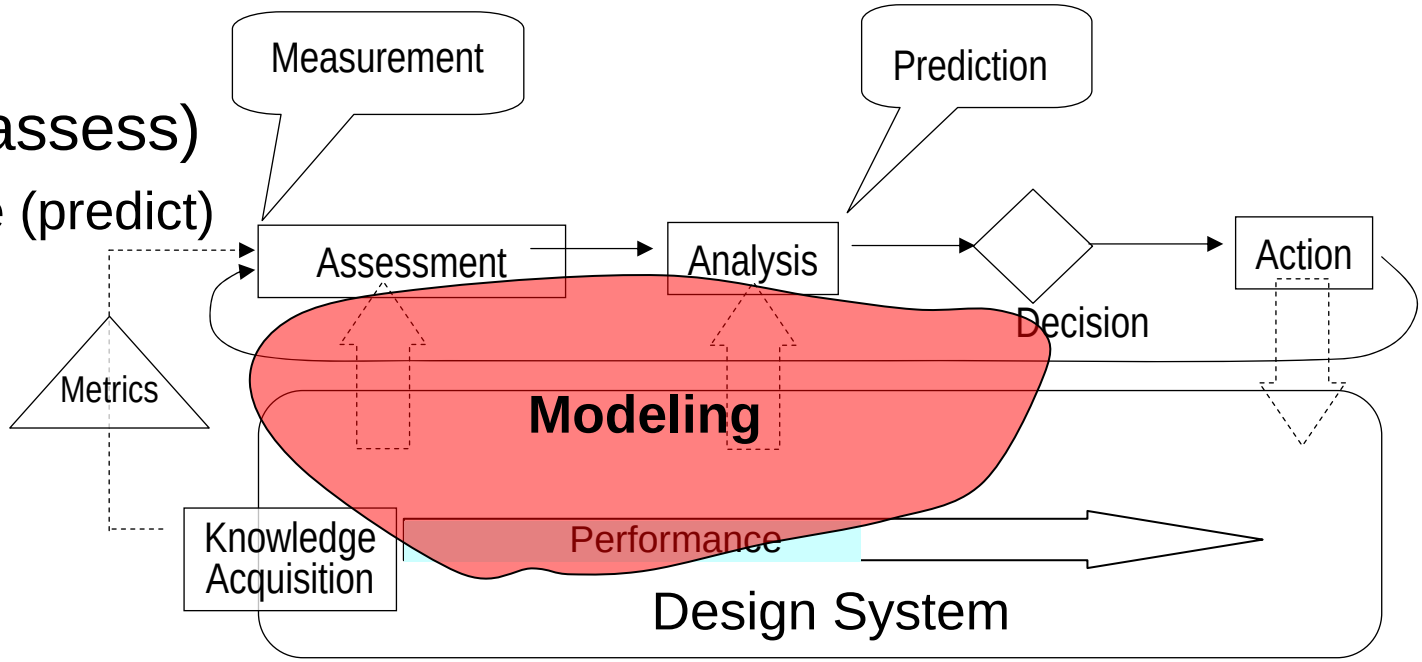
How to Lower Failure Risks in Performance?

- Measure
- Analyze (assess)
  - Simulate (predict)
- Decide
- Apply corrective actions



- For all that: **MODEL ADEQUATELY** to real world and common sense

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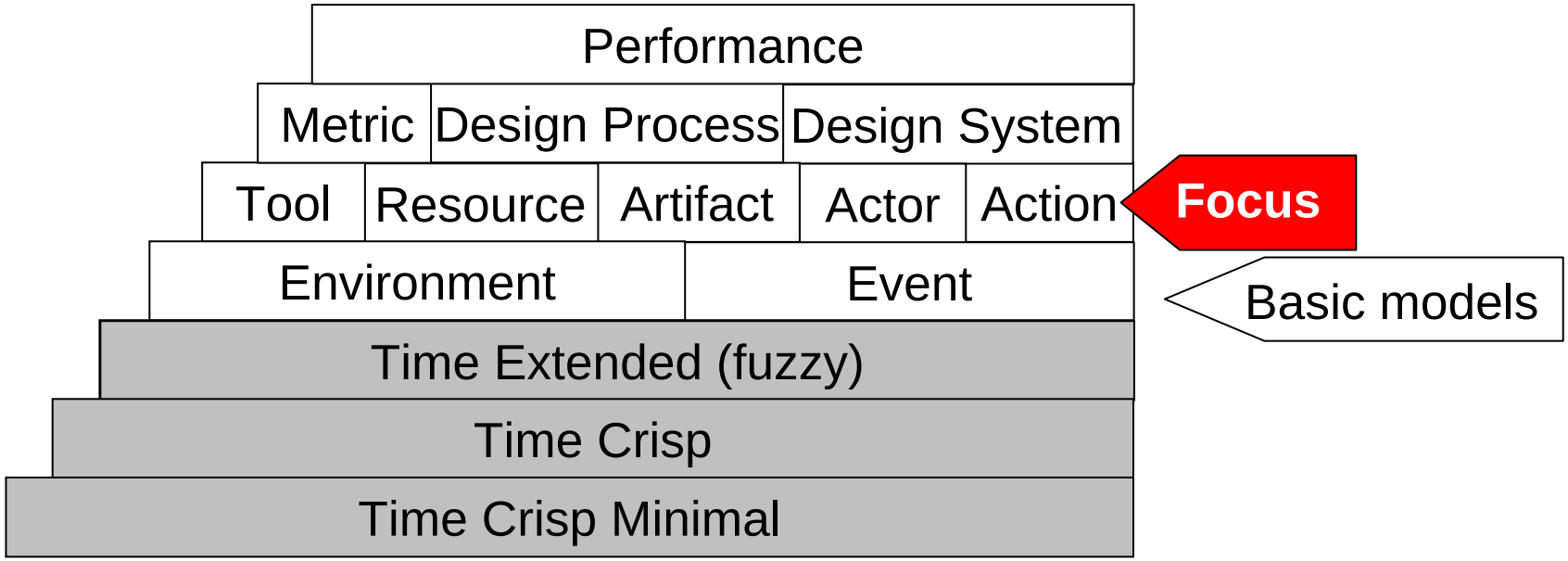
Model (Ontology) Stack



How to **MODEL ADEQUATELY**? - One possible way: Fuzzy Time Intervals

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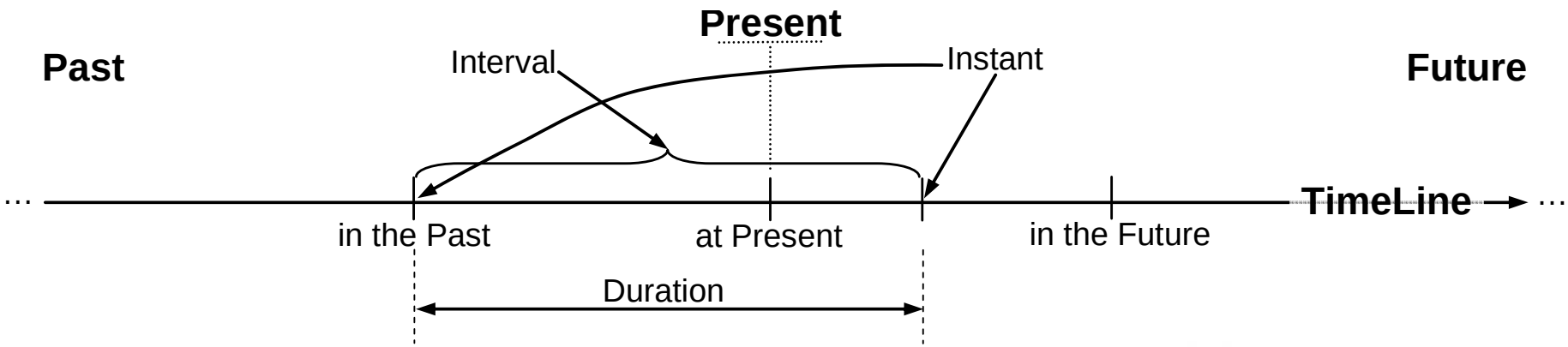
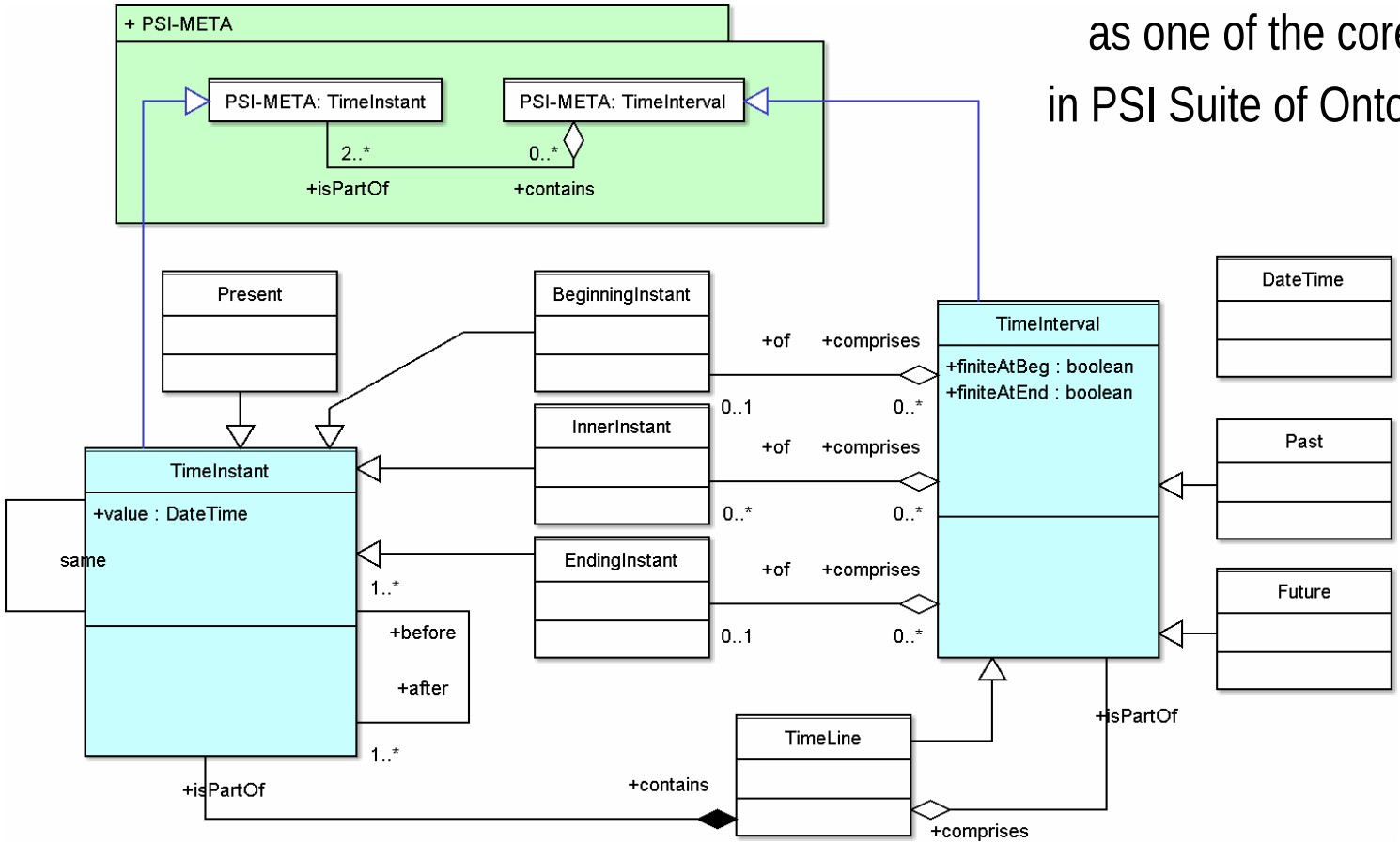
Modeling Choices

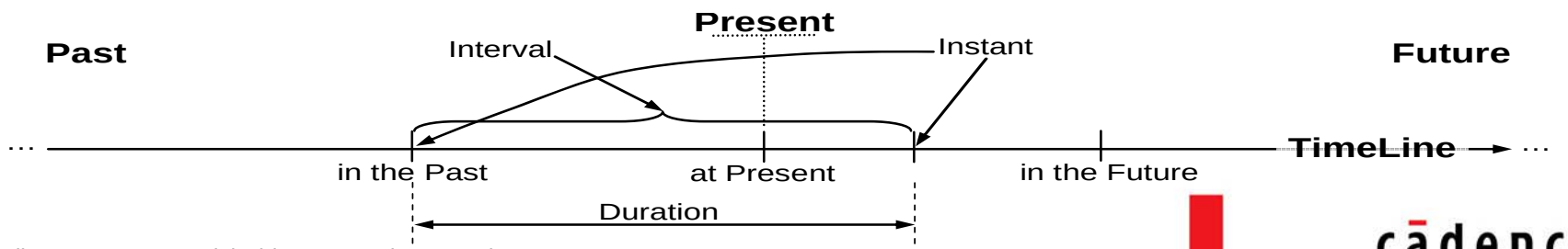
- Keep trivial, however efficiently applicable
  - Time is: linear, anisotropic, discrete
- Make effective for modeling actions in processes
  - Properly extend basic (crisp) theory
  - Time intervals are fuzzy
  - Finite and infinite intervals
  - Phases and periods



Time Minimal

Implemented in OWL-DL
as one of the core ontologies
in PSI Suite of Ontologies v.2.2





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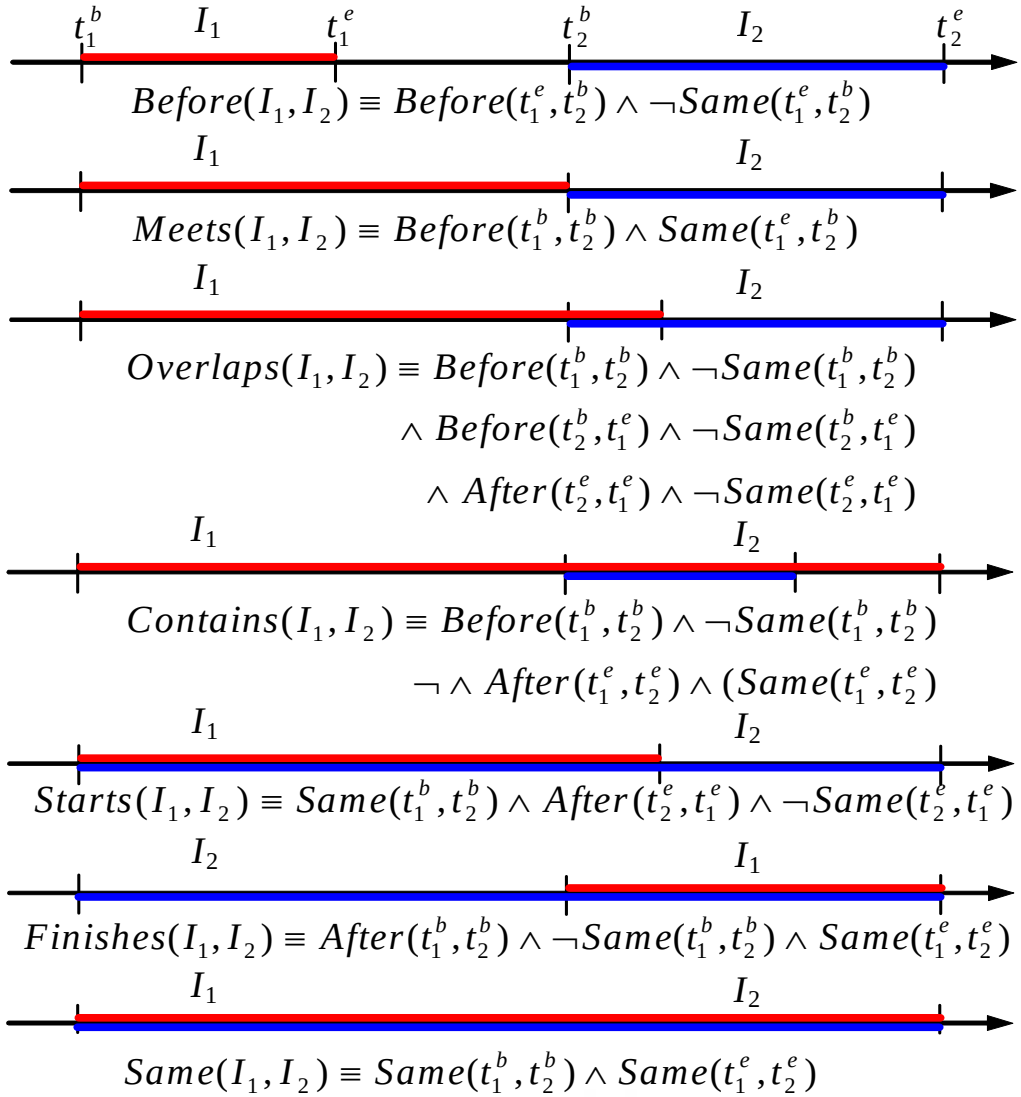
How Requirements are Met?

- Covered:
  - Absolute time points
  - Differently structured and grained time stamps
  - Time intervals and their durations
  - Time intervals open or closed by beginning and ending instants
- Partially covered:
  - Finite and infinite time intervals
- Not covered:
  - Relationships on intervals, vagueness, phases and periods, subjective perceptions, infinity, many more …

Time Crisp: Allen's Theory

- Extension of Time Minimal
- Interval relationships expressed using relationships among instants
- Implemented in OWL-DL
  - Draft release candidate for PSI Suite v.2.3



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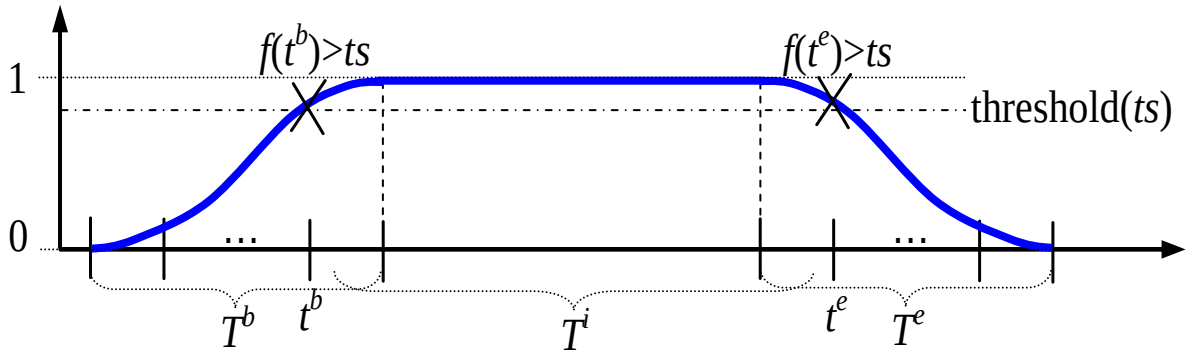
Time Fuzzy: Extension of Time Crisp

- Fuzzy time interval:

$$I = \{T^b, T^i, T^e, f\}$$



- T^i - the Core – inner instants
- Beginning and Ending sets:
  - Beginning ($T^b = \{t_j^b\}$): $\forall t_j^b : t_j^b > t^b \rightarrow t_j^b \in T^i$
  - Ending ($T^e = \{t_j^e\}$): $\forall t_j^e : t_j^e < t^e \rightarrow t_j^e \in T^i$

- Discrete membership function: $f : Z \rightarrow [0,1]$ - individual for A-s, R-s, …
- Thresholds: reputation and confidence
- Implementation issues:
  - Low expressiveness of OWL-DL …
  - Computational overhead …

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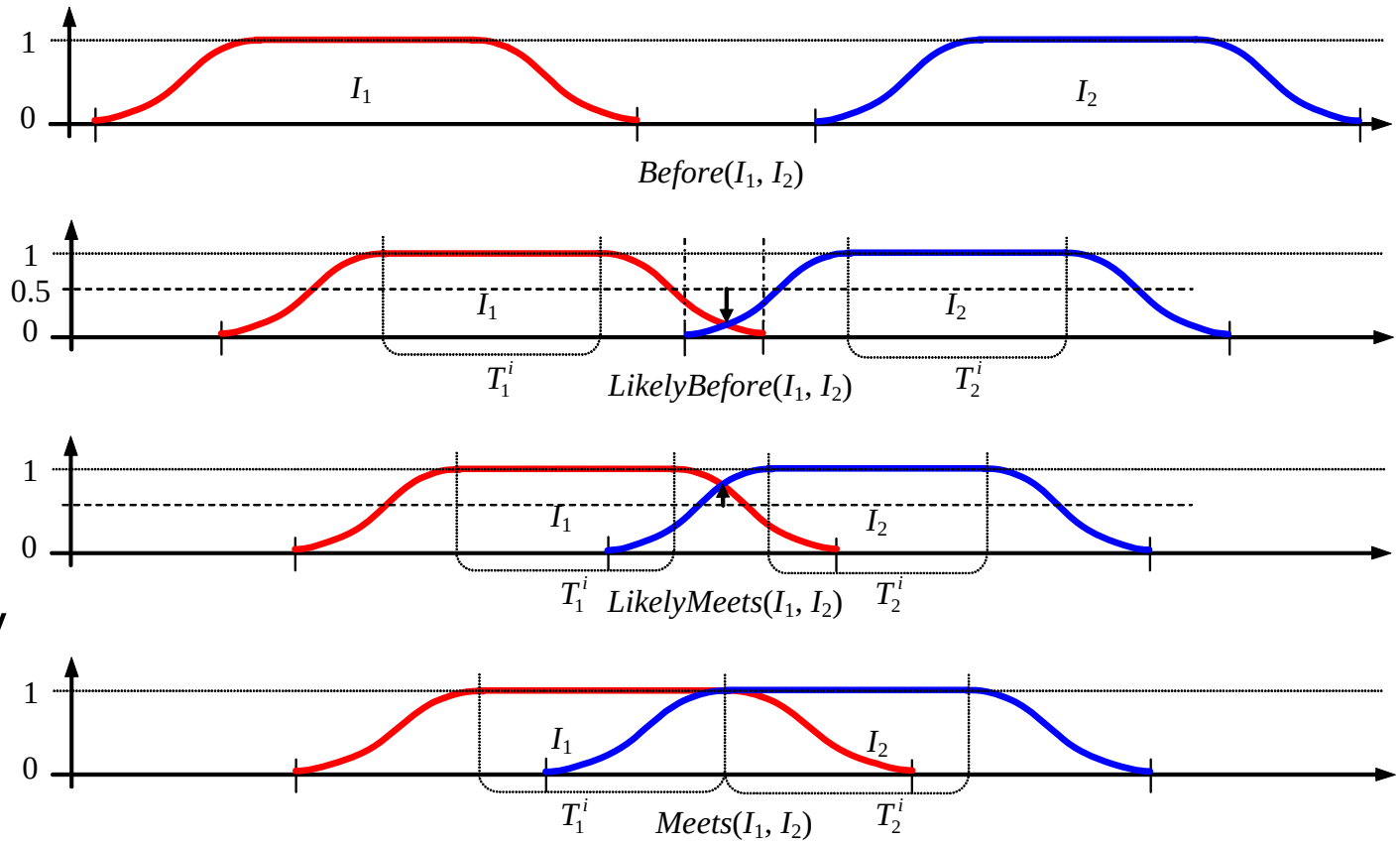
Time Fuzzy: Extension of Time Crisp

Relationships on Intervals 1 of 2

- Approach similar to Crisp
- Correctly degenerates to Crisp
- Substantially more expressive



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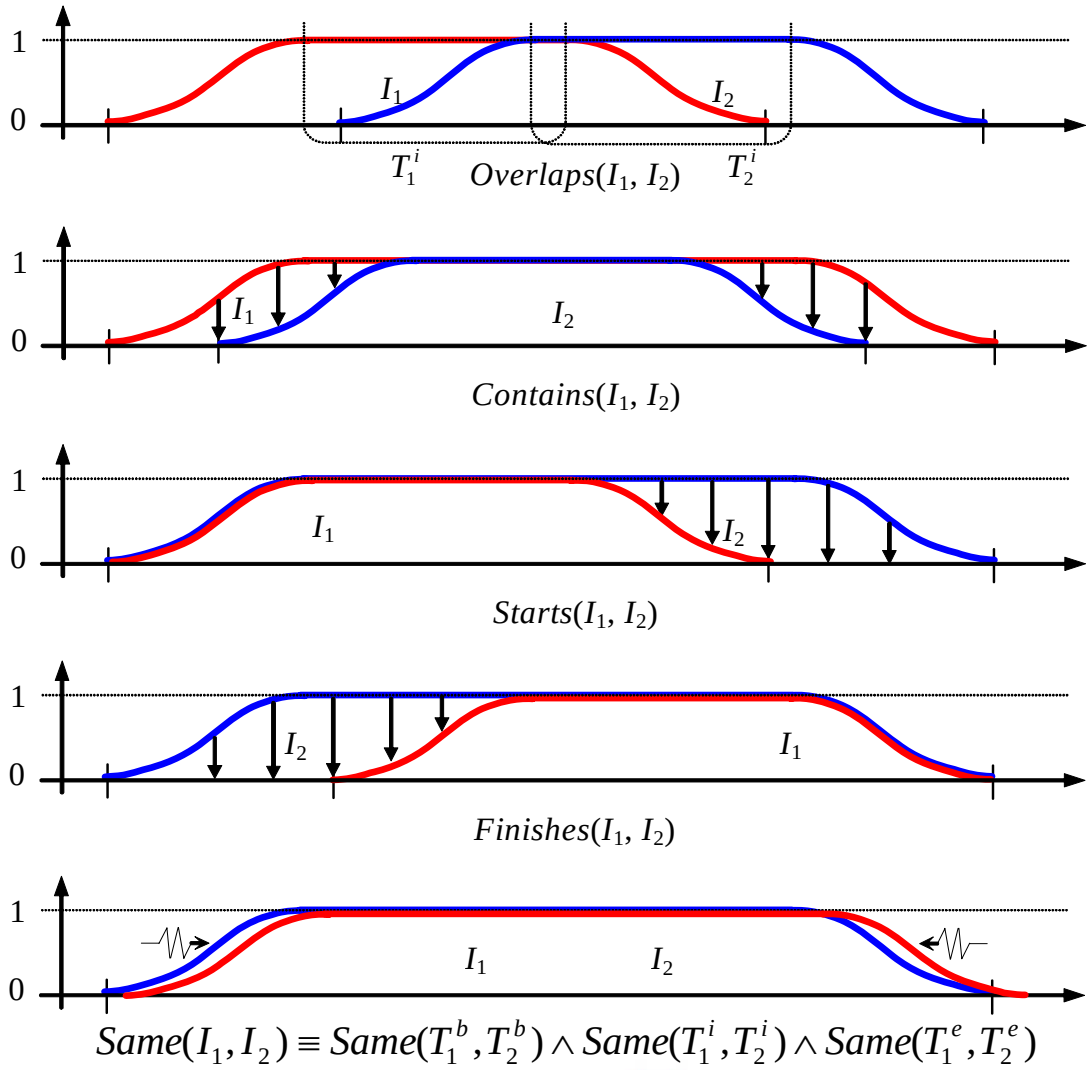
Time Fuzzy: Extension of Time Crisp

Relationships on Intervals 2 of 2

- Expressiveness gain:
  - Relaxation on interval ends
  - More shades in intersection and similarity
- E.g.:
  - $Same(I_1, I_2)$
  - Not always true in Crisp sense
  - Is true when:
    - Either $f_1 \equiv f_2$
    - Or begs and ends contain one instant



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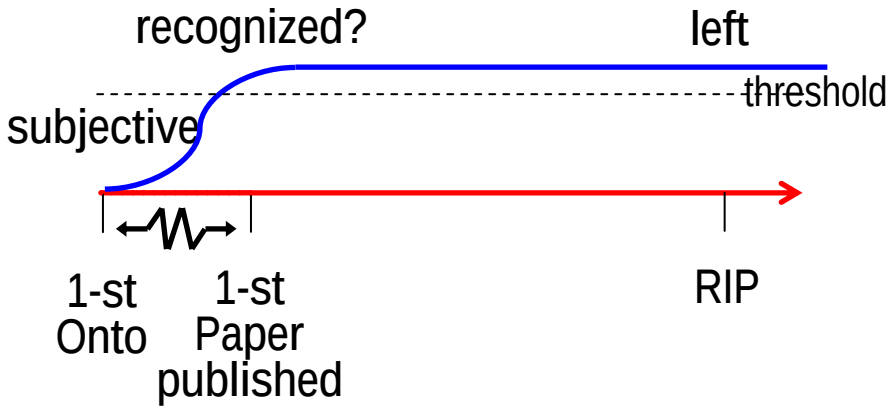
Finite and Infinite Intervals

Fuzzy: modeling vague durations of events and actions

- From now on I'm a knowledge engineer!
  - My first naïve ontology is accomplished
- Crafting ontologies? – never more:
  - My first paper was badly rejected
- At least:
  - the Sun always shines …

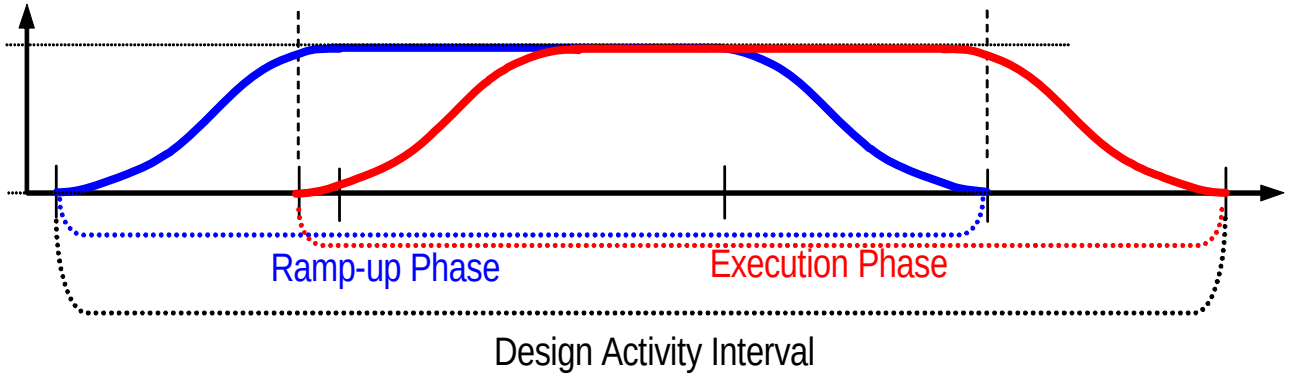


$$I^{\infty}:$$
$$T^{e} = \varnothing, \forall t_j \in T^{i} \exists t_i : (t_i \in T^{i}) \wedge After(t_i, t_j)$$

$$^{\infty}I:$$
$$T^{b} = \varnothing, \forall t_j \in T^{i} \exists t_i : (t_i \in T^{i}) \wedge Before(t_i, t_j)$$

$$^{\infty}I^{\infty}:$$
$$T^{b} = \varnothing, T^{e} = \varnothing, \forall t_j \in T^{i} \exists t_i, t_k : (t_i, t_k \in T^{i}) \wedge Before(t_i, t_j) \wedge After(t_k, t_j)$$

Phases



- Phases of an Activity: sub-activities
  - Often have facilitation dependencies:
    - The more effective the source – the more efficient the target
  - E.g.: Ramp-up and Execution phases of a design Activity
- Durations of phases:
  - Subjective
  - Vague
- Modeled using Fuzzy interval sets $S = \{s_1,..., s_i, s_{i+1},...s_N\}$

$$\forall i = 1..N-1,\ j = i+1, (LikelyMeets(s_i, s_j) \vee Meets(s_i, s_j))$$

$$Same(\bigcup_{i=1}^{N} s_i, I)$$

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Periods

- Associated with regular or repeating events
  - Sunrise, breakfast, blames by the project manager
- Finite or infinite sets of periods
- Finite: $\Pi = \{\pi_1 ... \pi_i, \pi_{i+1}, ..., \pi_N\}$
  - Order: $\forall i = 1..N-1,\ j = i+1..N\ (Before(\pi_i, \pi_j) \vee Meets(\pi_i, \pi_j))$
- Infinite: ${}^{\infty}\Pi = \{...\pi_i, \pi_{i+1}, ..., \pi_n\}$ - at the beginning

  $\Pi^{\infty} = \{\pi_1 ... \pi_i, \pi_{i+1}, ...\}$ - at the end

  ${}^{\infty}\Pi^{\infty} = \{...\pi_i, \pi_{i+1}, ...\}$ - at both ends
  - Order: ${}^{\infty}\Pi^{\infty}:\ \forall i \exists j : (Before(\pi_i, \pi_j) \vee Meets(\pi_i, \pi_j))$

    $\Pi^{\infty}:\ \forall i \exists j > 1 : (Before(\pi_i, \pi_j) \vee Meets(\pi_i, \pi_j))$

    ${}^{\infty}\Pi:\quad \forall i < n \exists j : (Before(\pi_i, \pi_j) \vee Meets(\pi_i, \pi_j))$

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Conclusions and Outlook

- Did not plan to refine fuzzy reasoning …
  - Similar to (at least) two other approaches, but in different domains
- One of the basic models for reasoning about events and actions – in PSI
  - Used in Dynamic Engineering Design Process scheduling and simulation
  - Provides more flexible process representations
    - By “springing” events and actions using fuzzy time intervals Allows representing subjective perceptions
  - More realistic phases and periods
- Time Minimal, Crisp, Fuzzy:
  - Minimal – implemented, used in PSI software
  - Crisp – implemented as a draft release candidate
  - Fuzzy – in implementation
    - Some minor technical problems in representation and efficiency

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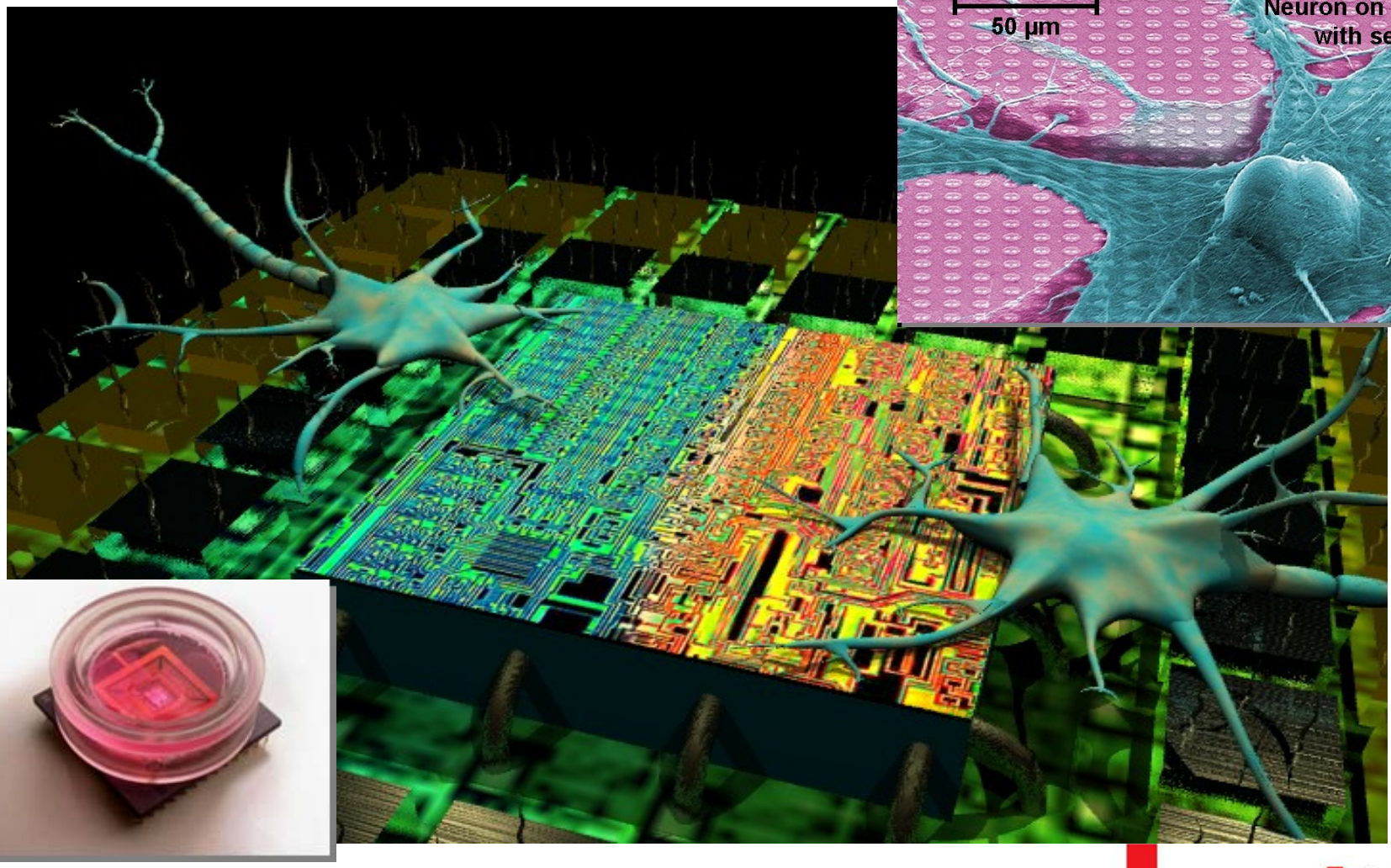
Questions Please



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