Reflecting on Self-Adaptive Software Systems

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Outline

I. **Motivation**

II. **Reflection**

III. **Reflection prism**

IV. **Challenges**

V. **Conclusions**

Motivation

- **Understand the fundamental underlying concepts of self-adaptive systems**
- **What is the “self” in self-adaptive systems**
- **Explore the crucial role of reflection in self-adaptive systems**
- **Propose topics for future research**

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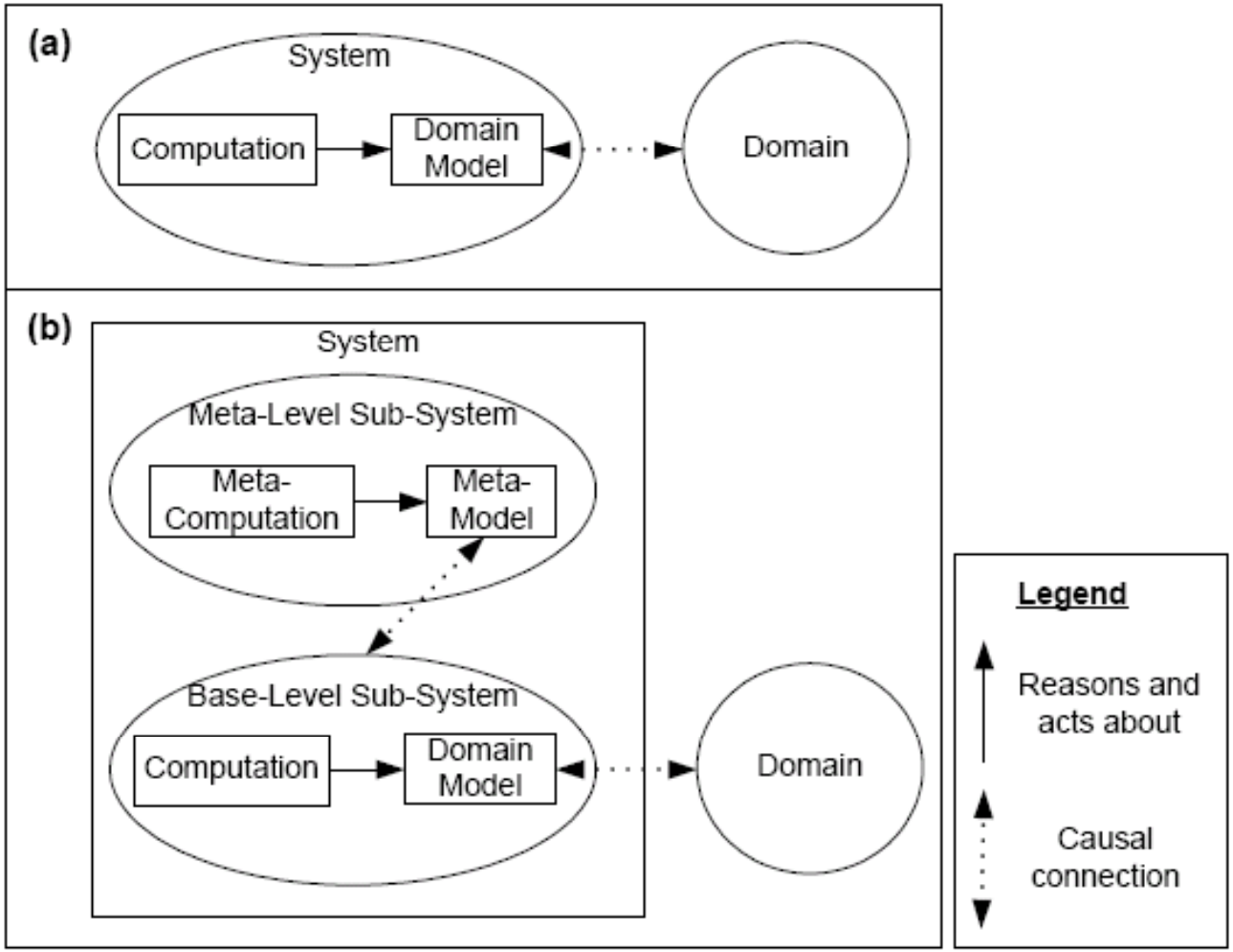
Reflection

- **Reflection is about meta-computation**
  - Computation about computation
  - “The capability of a system to reason about and act upon itself.”
- **Some milestones**
  - 1984 Smith: Reflection in Lisp
  - 1987 Maes: Reflection in OO languages
  - 1999 Cazolla et al. Architectural reflection
  - 2003 Tanter et al. Reflection and AOP
  - 2008 Coulson et al. Reflection and middleware

Reflection



(a) Traditional System **(b) Reflective System**

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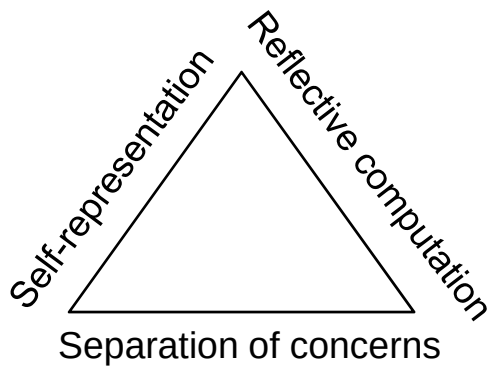
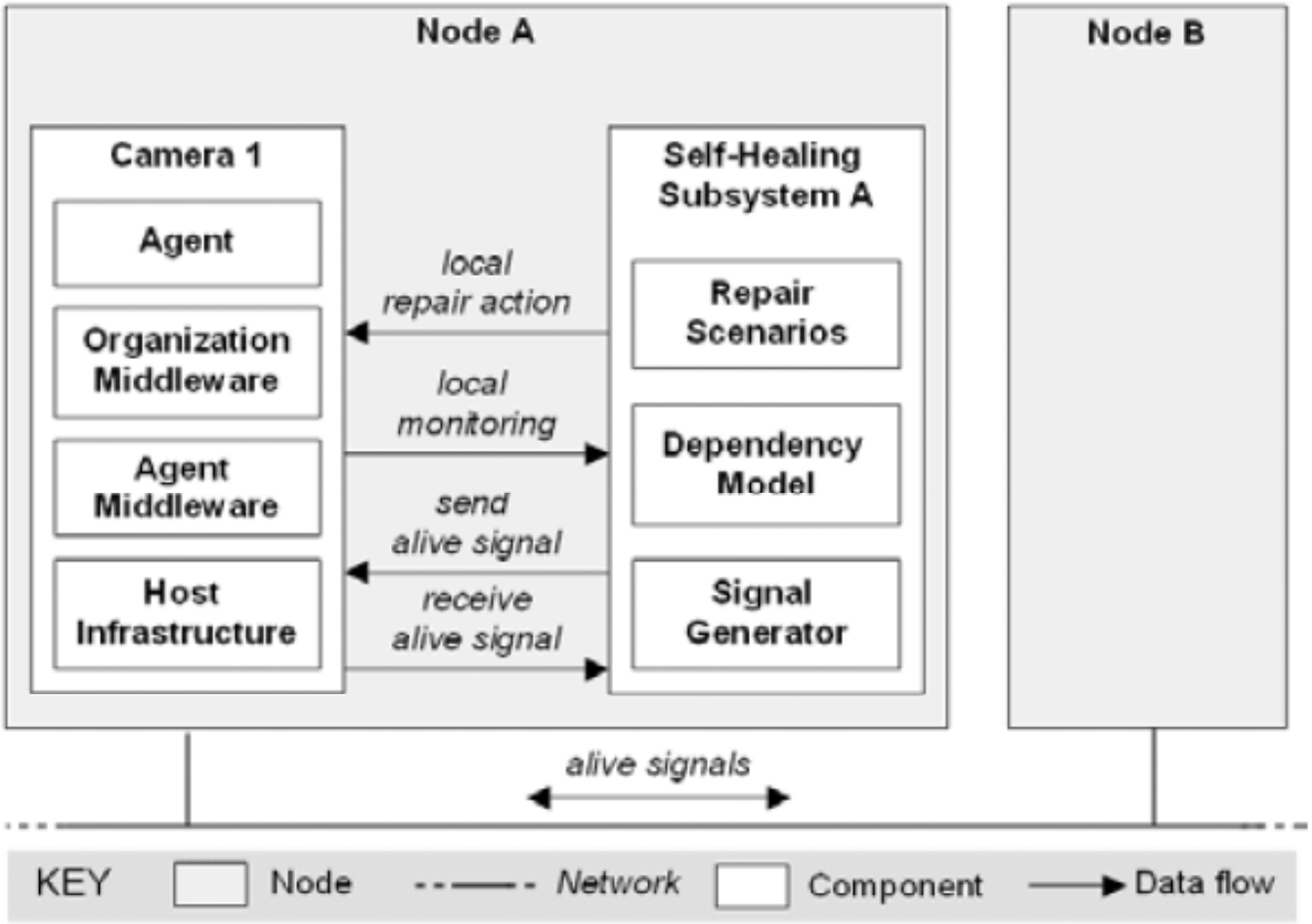
Reflective Prism

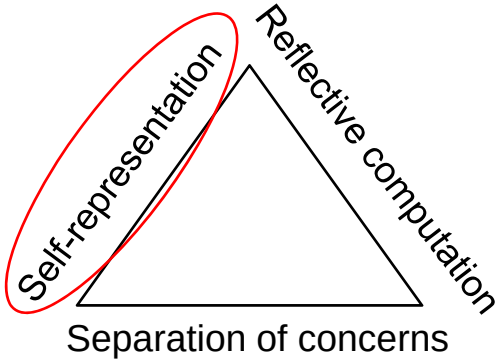
- **Crucial properties of reflection for self-adaptive systems**
- **Basis**
  - Work of Maes, Cazolla, Coulson (among others)
  - Our experience with self-adaptive systems
- **Prism with 3 sides**
  - Self-representation
  - Reflective computation
  - Separation of concerns



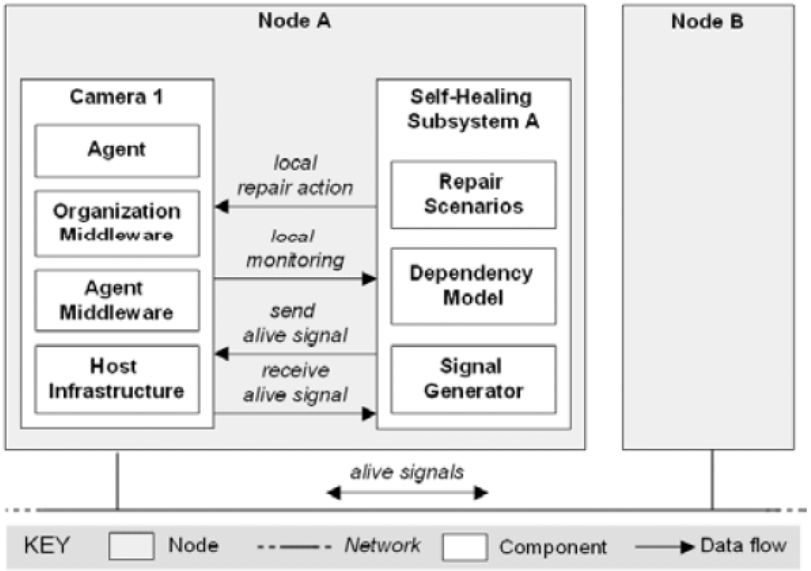
Case study: self-healing



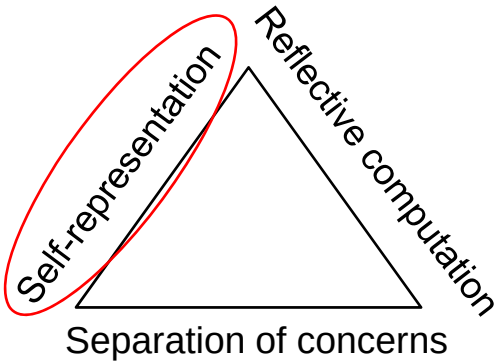
Self-representation



- **Type of representation**
  - Procedural = self-representation is part of implementation
  - Declarative = self-representation is independent entity
- **Case study**
  - Declarative
  - Dependency model

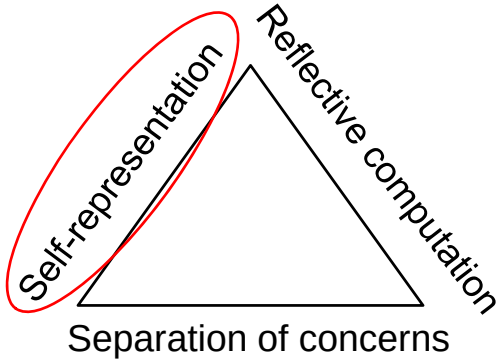


Self-representation



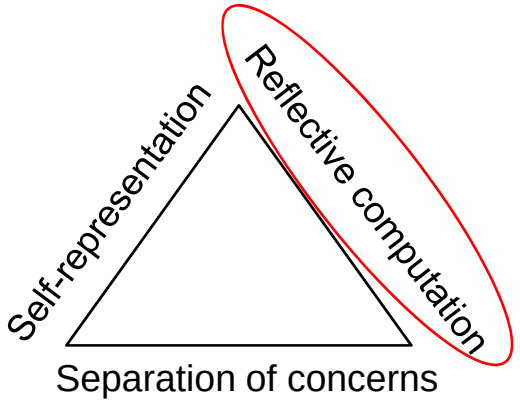
- **Granularity**
  - Smallest element that is reified
    - Programming language: class, object, method..
    - Self-adaptive systems typically architectural elements
- **Case study**
  - From data types (id's of cameras) to high-level concepts (such as role contracts of agents)

Self-representation

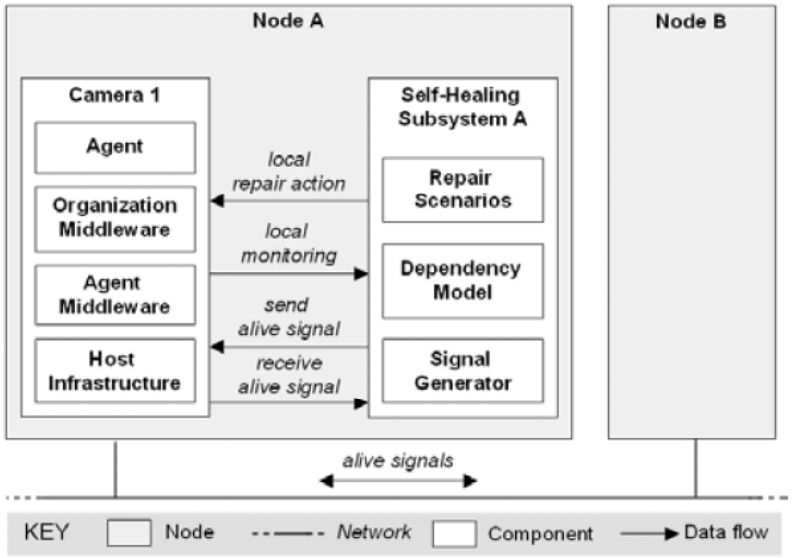


- **Completeness**
  - What is reified at meta-level
    - 3-KRS (Maes) complete
    - Self-adaptive frameworks: from partial to complete architecture model
- **Case study**
  - Partial: dependencies relevant for self-healing

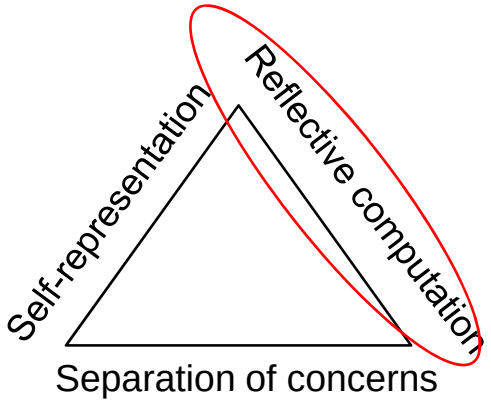
Reflective computation



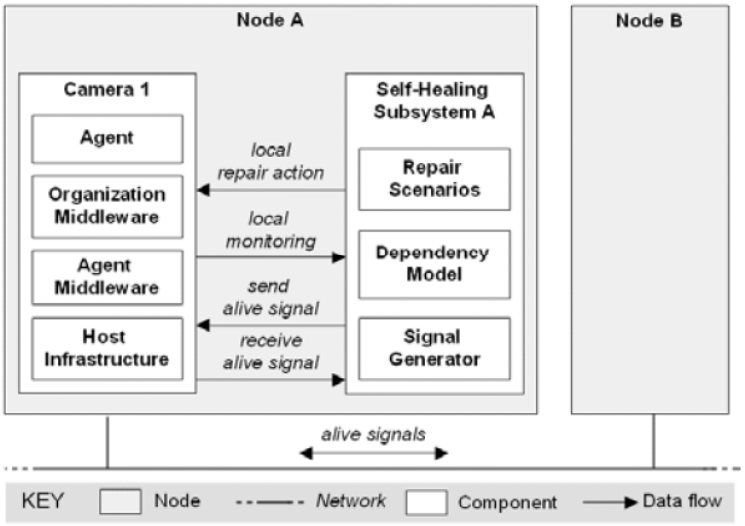
- **Type of reflection**
  - Structural
    - static structures – classes, method def. etc.
  - Versus behavioral
    - dynamic structures – objects' state, messages, etc.
- **Case study**
  - Behavioral aspects
    - organizations' state
  - Structural aspects
    - structure of camera network



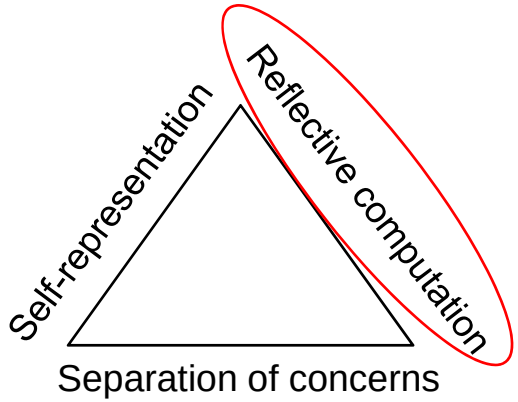
Reflective computation



- **Causality**
  - Domain – domain model
  - System – self-representation
- **Case study**
  - Traffic – domain model
    - monitoring traffic
  - Camera – self-representation
    - dedicated interfaces
    - + alive messages

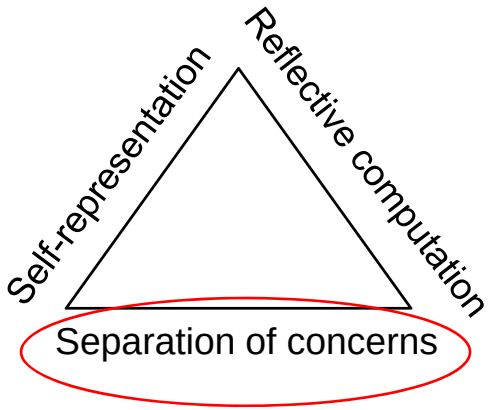


Reflective computation



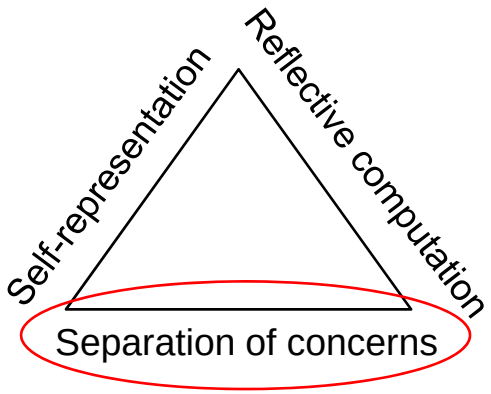
- **Level shifts**
  - Computation switches from base to meta level and back
  - Frequency: performance issue
- **Case study**
  - When failure is detected (background activity)

Separation of concerns



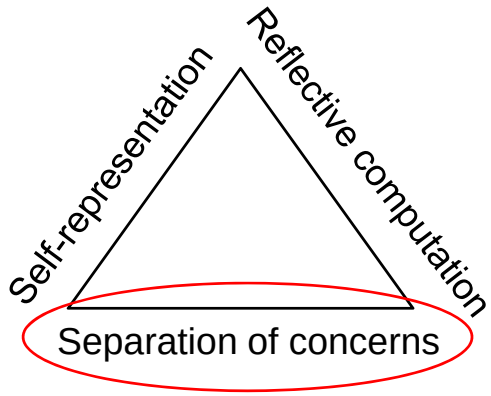
- **Disciplined split**
  - Base level is about the domain
  - Meta level is about the system
  - Different concerns
- **Case study**
  - Domain concern: monitoring traffic
  - Meta concern: self-healing

Separation of concerns



- **Transparency**
  - Extent to which base level is “unaware” of reflective levels
  - E.g. Touchpoints in IBM autonomic architecture: automatic generation based on description of manageability capabilities of managed resource
- **Case study**
  - Dedicated interfaces
  - Invasiveness of self-healing concern

Separation of concerns



- **Hierarchy**
  - Meta level layers
  - Kramer & Magee 2 levels:
    - Change layer: plans that react to exceptions in base level
    - Goal layer: if no plan is available, derive new plan
- **Case study**
  - Single level reflective system

Other Case Studies

- **High performance computing**
  - Sensor network scenario
  - Scheduling data-parallel programs on hardware architecture
  - Dynamic Model-Driven Architecture (DMDA platform)
- **Learning fault detectors**
  - Genetic approach

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Challenges

- **Expressiveness of self-representation**
  - State of the art ADLs are not designed for providing runtime representation of the system
  - Need for expressing dynamism
  - Need for modeling domain characteristics
- **Uncertainty**
  - Abstraction introduces certain inaccuracies
  - Domain is uncertain
  - Model need to take into account uncertainty explicitly

Challenges

- **Autonomy**
  - Decentralization <> system behavior
- **Transparency**
  - To what extent can probes and gauges be realized in a transparent manner?
  - Invasiveness of certain concerns of self-adaptation
    - Disciplined approaches for integration
- **Performance**
  - Selective/dynamic interception (Fractal, OpenCom)

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Conclusions

- **Reflection is a (the?) key issue of self-adaptation**
- **Original theory for computational reflection (level of programming languages) needs to be extended**
  - Domain issues
  - Uncertainty
- **Numerous challenges**