Logics and Calculi for All

Workshop dedicated to L. S. Barbosa on the occasion of his 60th Anniversary

Formal Methods: from the Cathedral of 'Components as Coalgebras' to the Open Source Software Bazar

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   - preservation laws present in chemical equations $\Longrightarrow$ reversibility of processes
2. support a real-life, pragmatic description of the system usage by humans

Proliferation of Formal Methods

- Petri nets
- Process Algebras (PA):
  CCS, CSP, ACP
  - Timed PA
  - Probabilistic PA: PEPA/PRISM
- Model-based Specification Approaches:
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- Rewriting Logic:
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Limited in terms of data structure and control flow!

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- $\Longrightarrow$ 'Components as Coalgebras': semantic framework to which process calculi and popular notations (e.g. UML) can be mapped $\Longrightarrow$ rigorous component development and behavioural refinenment for componentd

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Formal notations may be extended by

- adding mechanism to define complex data types
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Approach used in PAT (Process Analysis Toolkit)

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But

- implementation-oriented control structures
- richness of available data types

$\Longrightarrow$ negative consequences: forget original logical capabilities and abuse new features

Grow Internally

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- functional approach to define data types
- rewrite logic to provide control flow

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Approach used in Maude

Any extension is grown internally using the core language

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- can be used at the meta-level to provide the semantics of programming languages, other formal methods and higher-level and domain-specific notations
- provide a tool capable to combine, armonise and link multidisciplinary concepts under a unified semantics (interdisciplinary)

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- initially two distinct perspectives, from psychology and from software engineering
- 1980s: mathematical-logical formalisms used to describe not just computer systems, but the system usage by humans

HCI: FM Backward vs Forward

Application to safety-critical systems

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Application to safety-critical systems

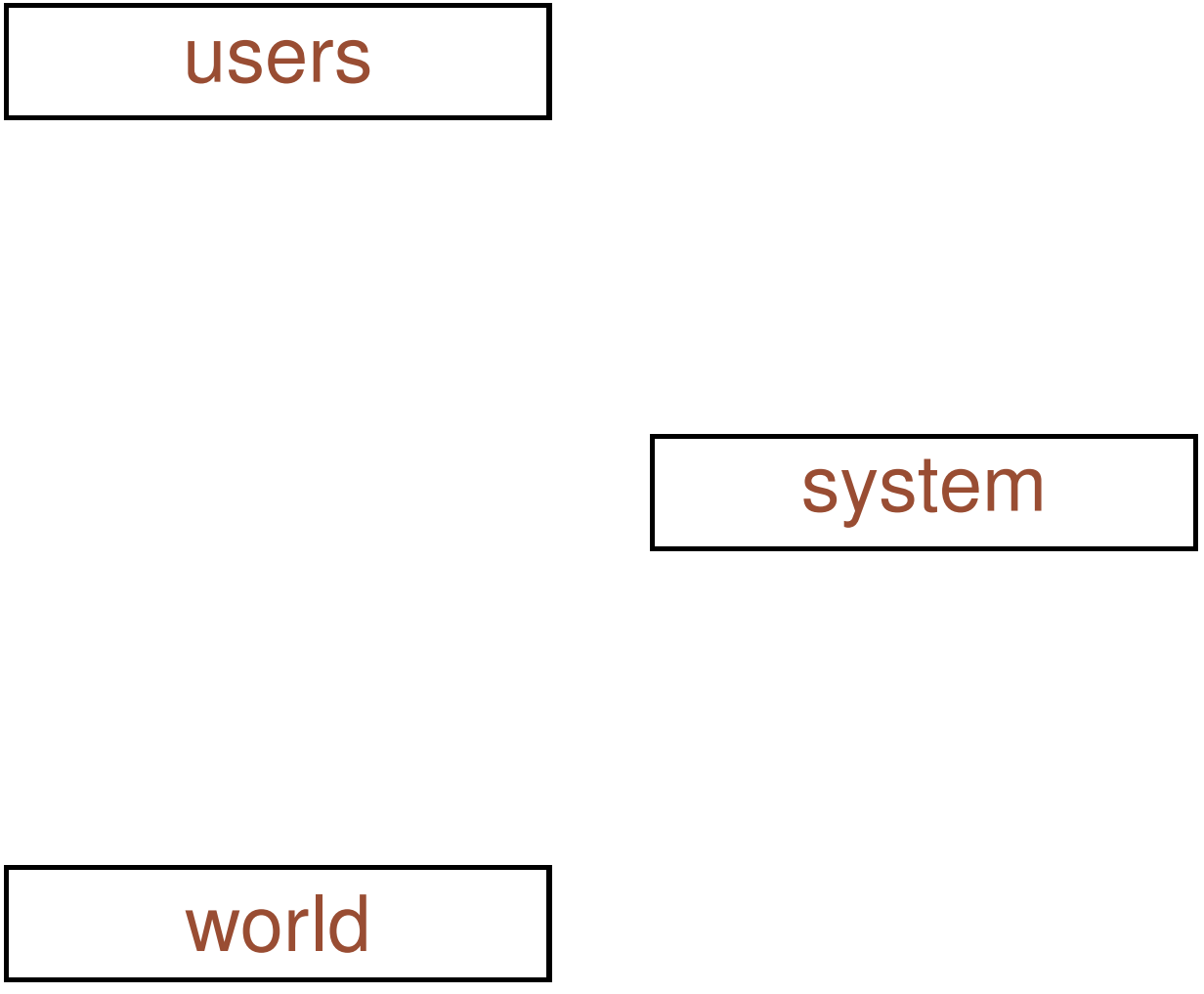
- backward perspective considers either the formal description of expected effective behaviour or the formal analysis of errors performed by the operator as reported by accident analysis
- forward perspective defines a cognitive plausible user behaviour, based on formal assumptions to bind the users act driven by cognitive processes and composes such a cognitive model with the system model

In Terms of Category Theory

Application to safety-critical systems

- backward perspective
  - backward morphism
  - backward refinement
- forward perspective
  - forward morphism
  - forward refinement
    $\Longrightarrow$ non-determinism reduction

HCI: FM Forward Perspective



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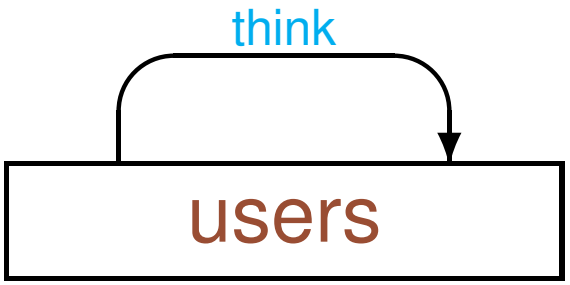

system

world

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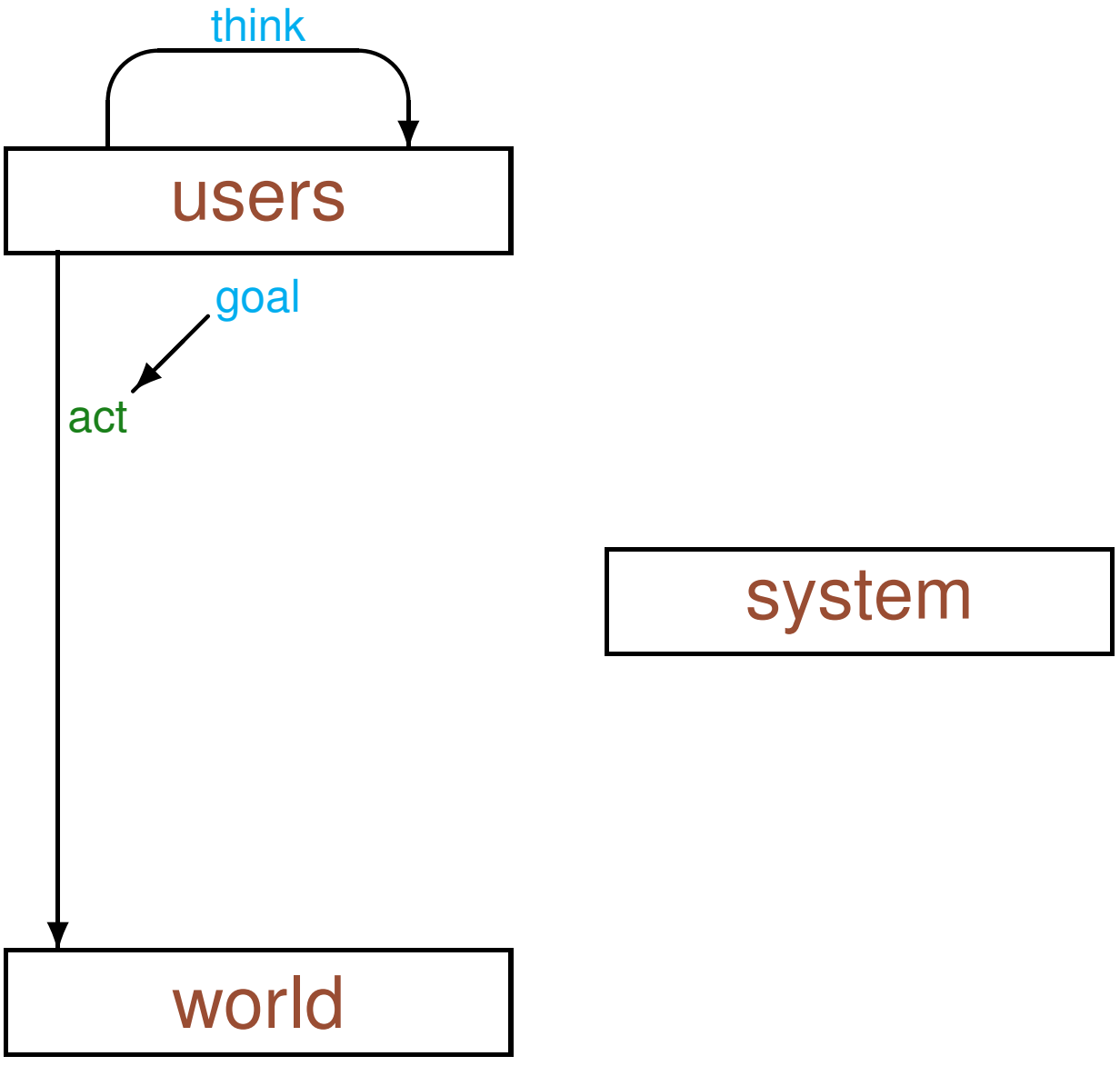

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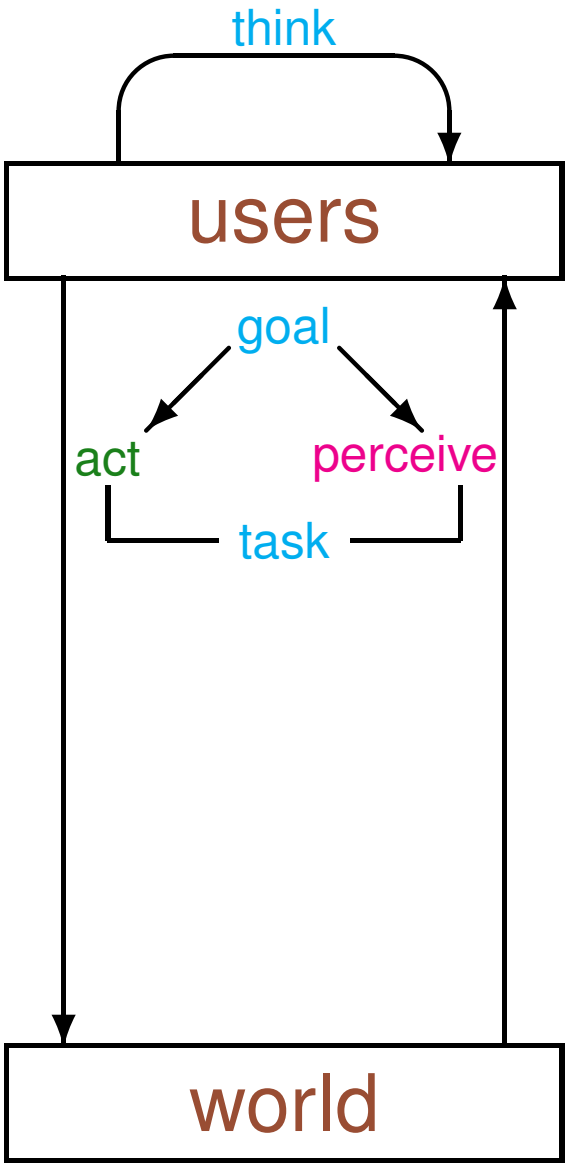

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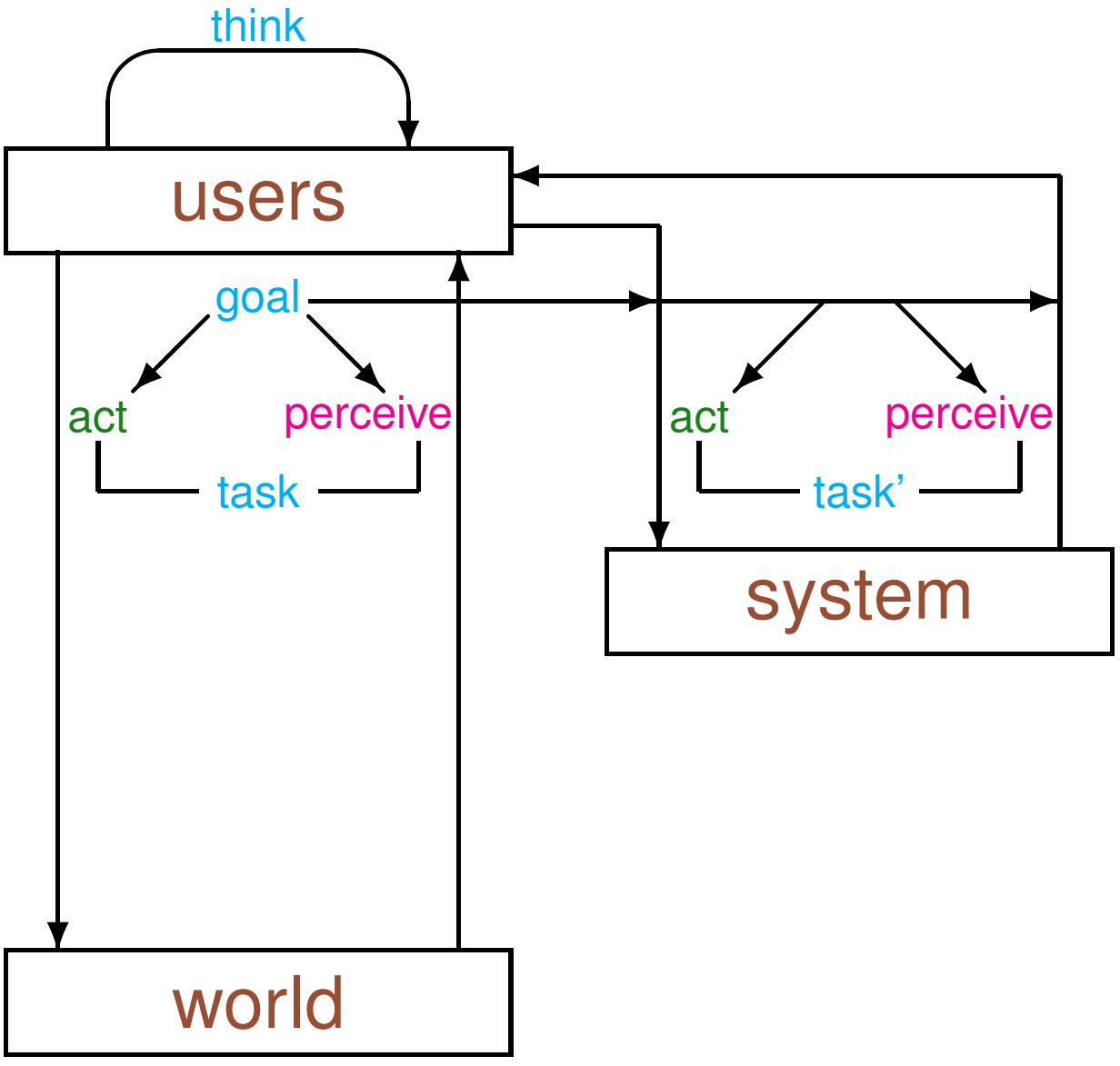

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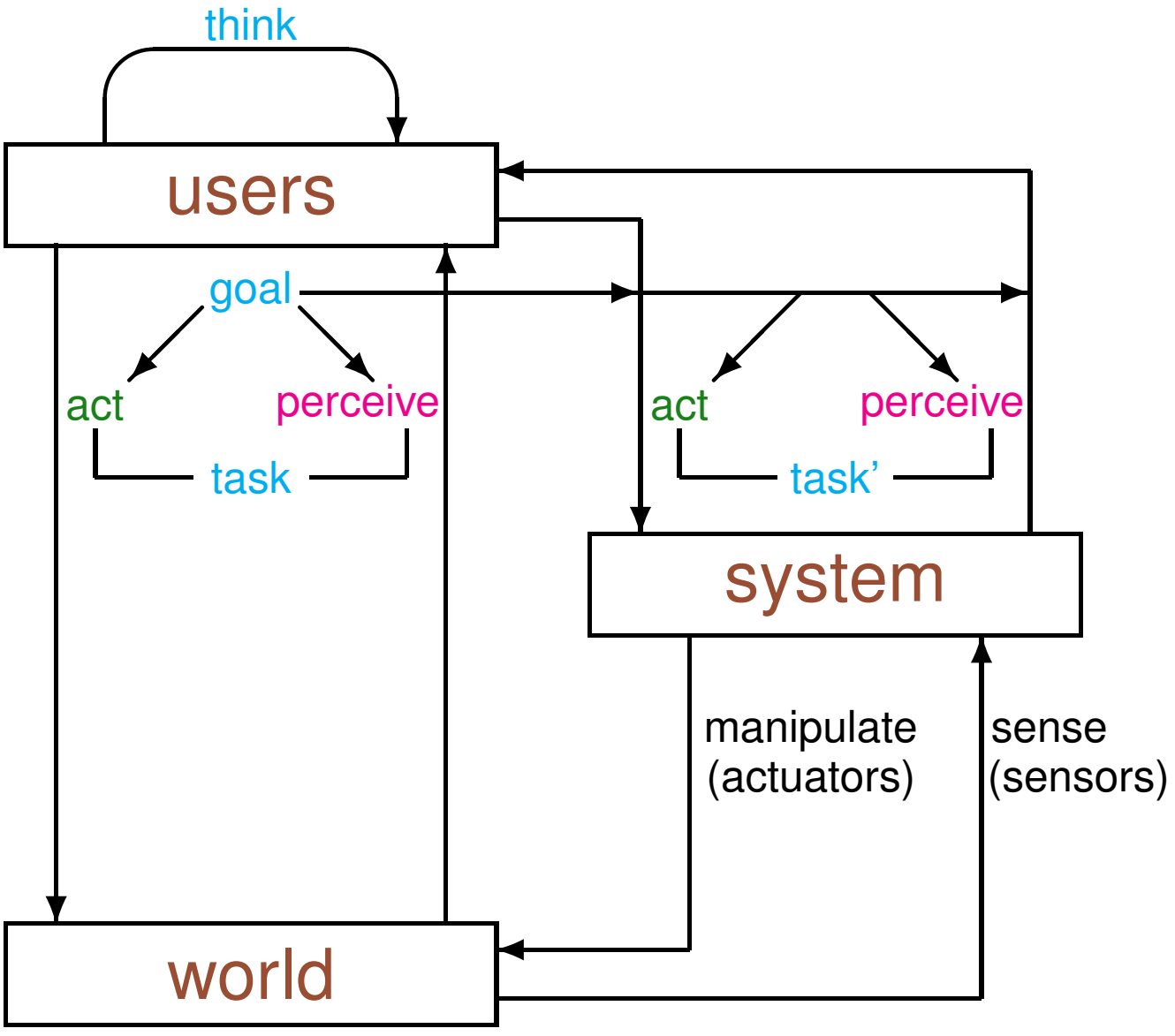

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1. a behaviour observed in real-life
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   backward: data from real-life to expand the original behaviour (elaborative mining)
   $\Longrightarrow$ may increase non-determinism
2. a behaviour predicted by the model
   has never been observed
   backward: data from real-life is used to remove part of the behaviour (refinement mining)
   $\Longrightarrow$ reduce non-determinism

The OSS Bazar

E. S. Raymond, *The Cathedral and the Bazar*, O'Really and Associates, 1999

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L. S. Barbosa, A. Cerone, A. K. Petrenko, S. A. Shaikh, *Certification of OSS Software: A role for formal methods?* Comp. Syst. Sci. Eng. 25(4), 2010

Answer: Backward Perspective

- forward perspective very challenging in the OSS context due to the absence of rigorous verification process and systematic testing and to the heterogenous community involved in the development process

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- forward perspective very challenging in the OSS context due to the absence of rigorous verification process and systematic testing and to the heterogenous community involved in the development process
- backward perspective may provide an effective way to use formal methods to assist the re-engineering process of running code: apply principles and calculi in the reverse direction, from concrete to abstract models, for understanding and documenting OSS implementations

Backward Techniques in OSS

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- logic mining is a semi-automatic extraction of domain-specific rules from code to improve the results of data reverse engineering
- documentation analysis use a broad range of mining technique to extract data (e.g. requirements) from OSS repositories

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and Beyond Formal Methods

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Documentation Analysis

- extract requirements
- analysis of contributors and community activities (text mining)
- analysis of learning process (process mining)
- probabilistic learning of big code (machine/deep learning) to produce statistically likely solution to problems hard to solve with FM: program synthesis, code property prediction, code deobfuscation

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And also thank you for the inspiration I got from you and for your great friendship.