Software Engineering for Self-Adaptive Systems: A Research Roadmap

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Introduction

- Goal of the paper is to summarize the state-of-the-art and to identify critical challenges for the systematic software engineering of self-adaptive systems
- Self adaptive systems are systems that can adapt themselves dynamically to a change in their internal or external environment.
- Paper is divided into four parts:
  - Requirements
  - Modeling dimensions
  - Engineering
  - Assurances

Requirements

- A self-adaptive system must continuously monitor changes in its context and react accordingly.
- What aspects of the environment should be monitored?
- Requirements engineering for self-adaptive system is a wide open research area.
- One of the biggest issues designing a self-adaptive system is that all adaptations cannot be known advance
- Requirements for self-adaptive systems may involve degrees of uncertainty or may be specified as incomplete.

Research Challenges in Requirements

- A new requirements language is needed which can deal with uncertainty
- Need a Mapping Architecture
- Managing uncertainty
- Requirements reflection
- Traceability

Modeling Dimensions

- Classification of modeling dimensions aims towards defining a framework for modeling self-adaptive systems.
  - Adaptation
  - Timing
  - Dependability

Illustrative Case

- An Unmanned Vehicle with a collision avoidance system, is extended with a Self-adapting control system, which adds the functionality of avoiding collisions with Humans or Animals that might unexpectedly cross the road or come in it’s path

Modeling Dimensions (Adaptation)

- Type of adaptability (Parametric or Compositional)
- Degree of automation
- Form of organization (Weak or Strong Organization)
- Techniques for adaptability (data-oriented or process-oriented)
- Place of change (application logic, supporting middle-ware, or the infrastructure.)

Modeling Dimensions (Adaptation) Contd.

- Abstraction of adaptability (requirements, design, and implementation)
- Impact of adaptability (Generic or Specific)
- Trigger of adaptability (External or Internal)
- Degree of decision making (Pre-defined or Run-time)

Modeling Dimensions (Timing)

- Responsiveness (ranges from guaranteed to best-effort.)
- Performance (ranges from predictable to degradable)
- Triggering (ranges from event to time)

Modeling Dimensions (Dependability)

- Reliability, availability, confidentiality
- Safety (ranges from critical to non-critical)
- Maintainability (ranges from autonomous to human-based)
- Data integrity (ranges from short-term to long-Term)

Research Challenges in Modeling Dimensions

- Adaptation: A self-adaptive software system often needs to perform a trade-off analysis between several potentially conflicting goals. Practical techniques for specifying and generating utility functions are needed.
- Timing: Monitoring could outweigh the benefits of improvements in quality of service to adaptation. More research on lightweight monitoring is needed. Predicting the exact behavior of a software system due to run-time changes is a challenging task. More advanced and predictive models of adaptation are needed for systems.
- Dependability: Adapting safety-critical software systems while ensuring the safety requirements have remained largely an out-of-reach goal for the practitioners and researchers. There is a need for verification and validation techniques that guarantee safe and sound adaptation of safety-critical systems

Engineering

- Major challenge, especially if predictability and cost-effectiveness are desired.
- Adaptive Systems have a long history with successes in various fields. Learning from them is a worthwhile endeavor
- Especially learn from Control Engineering
- Focused on control loop model

Engineering – Feedback Control Loop

Involves feedback processes with four key activities: collect, analyze, decide and act.

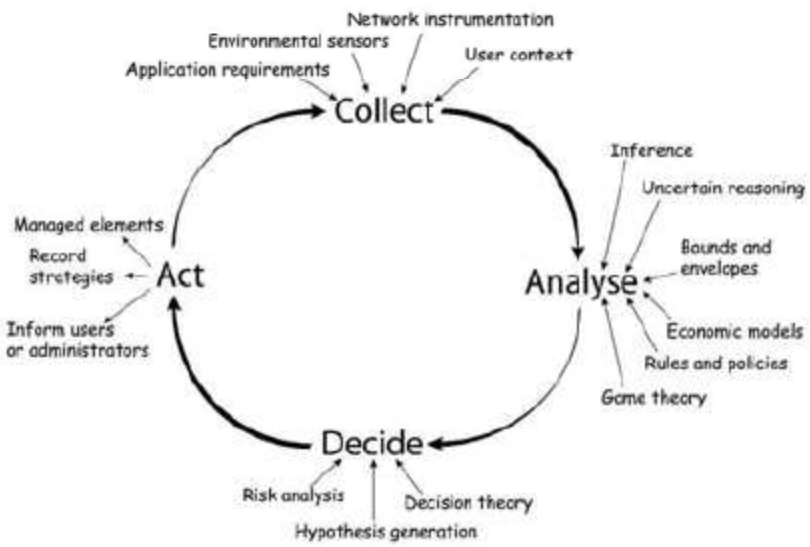

Figure 1: Activities of the control loop.

Control Loop Model

- Control loop is a central element of control theory.
- Provides well-established mathematical models, tools and techniques to analyze the system.

Research Challenges in Engineering

- Modeling. Making the control loops explicit and exposing self-adaptive properties.
- Architecture. Developing reference architectures for adaptive systems.
- Design. Compiling a catalogue of common control-loop schemes and characterizing control-loop elements.
- Middleware Support. Support for framework for self-adaptive functionality.
- Human-Computer Interaction.

Assurances

- Goal is to provide evidence that the set of stated functional and nonfunctional properties are satisfied.
- Traditional verification and validation rely on stable descriptions of models and properties.
- System dynamics and changing requirements of self-adaptive systems make it impossible to build a steady model before system deployment
- Models need to be built and maintained at run-time.
- A framework for adaptive system assurance is needed.

Proposed Framework for V&V

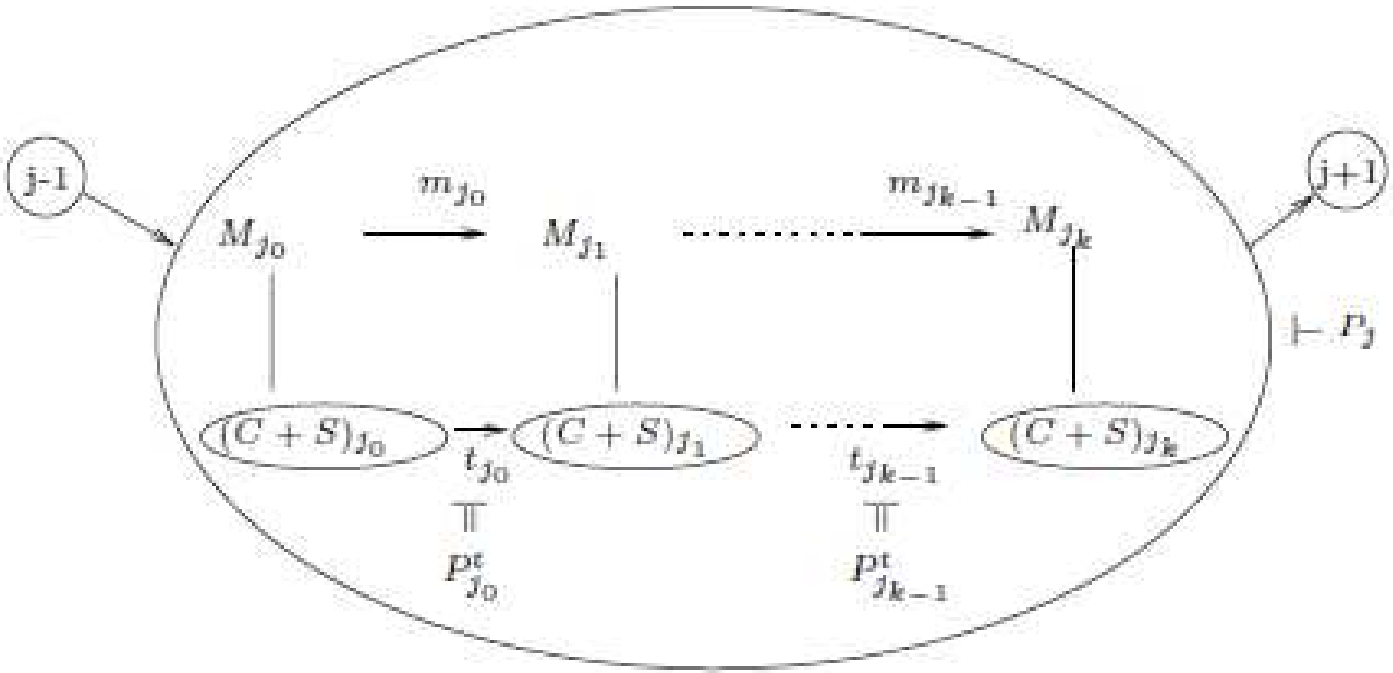

Figure 2: V & V model.

Research Challenges in Assurances

- Dynamic identification of changing requirements: System requirements can change implicitly, as a result of a change in context.
- Adaptation-specific model-driven environments: These Models will allow the application of verification and validation methods during the development process and can support self-adaptation at run-time.
- Agile Run-time Assurances: The key requirement for run-time verification is the existence of efficient agile solution algorithms which do not require high space/time complexity.
- Liability and social aspects: Adaptive functionality in safety-critical systems is already a reality.

THE END!