From Adaptive Systems Design to Autonomous Agent Design

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Introduction

- Increase of interest in adaptive systems in the SE community
  - Growing complexity of software-intensive systems
  - Software systems are becoming *ubiquitous*; proliferation of communication technologies; Expectation that systems will integrate seamlessly and collaborate to achieve user goals and adapt to *changing circumstances*
- Adaptive systems
  - Reduce maintenance overhead, improve robustness and security, help with performance optimization, adjust to changing environments and user preferences, self-* properties
  - **Self-Adaptation**: change in behaviour in response to the perception of the environment and of the system itself.

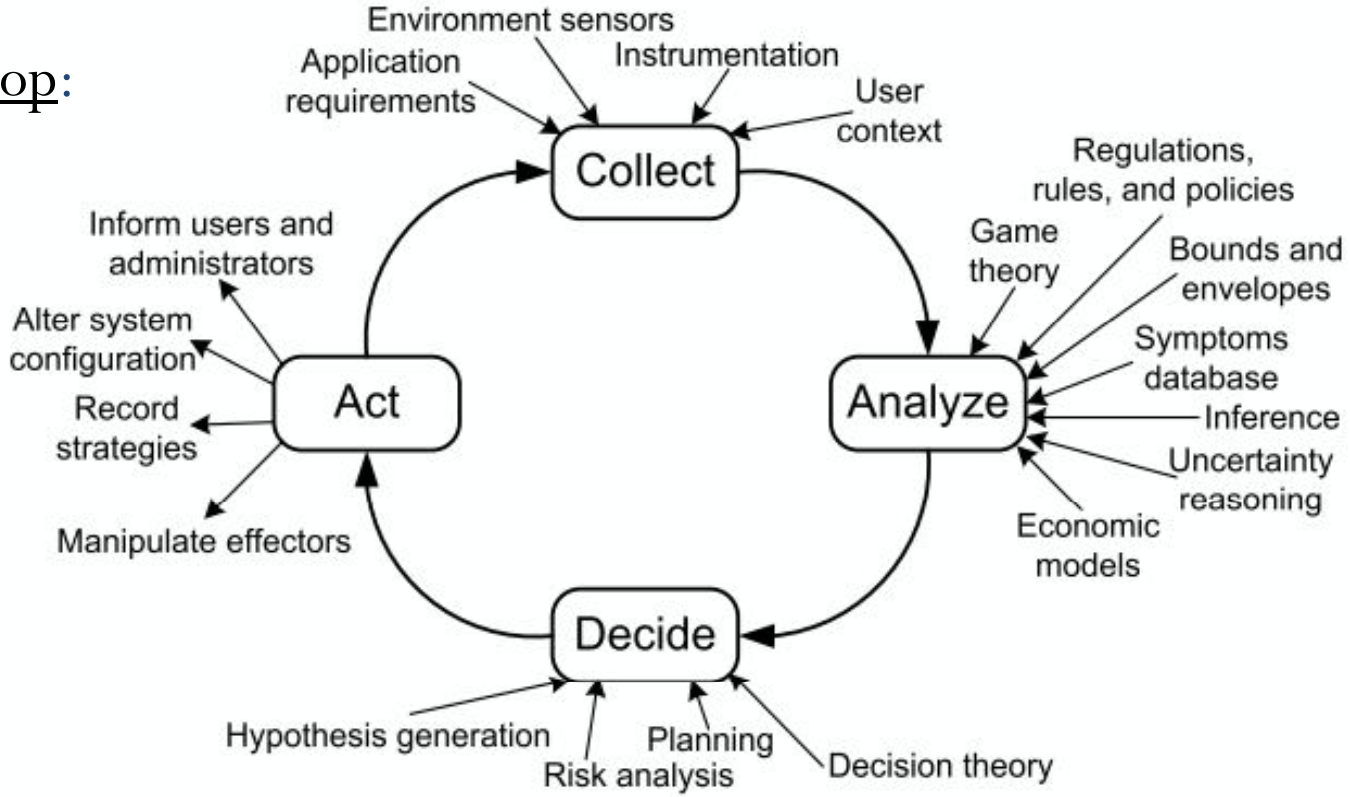
Control loops vs. Agents I

- A number of ways to implement self-adaptation including
  - Control loops
    - Attracting a lot of focus in the SE community; starting to be applied in software
    - Roots in control engineering; control theory provides the formal foundation; huge body of knowledge; lots of practical applications.
    - **Separation of functionality and adaptivity** (process vs. controller)
    - Various types of control (feedback, feedforward, etc.)
  - Agent technology
    - Originates in AI, lots of formal foundations (KRR, planning, etc.)
    - Strong emphasis on social aspects, agent communication, collaboration
    - Distributed decision making, planning, reasoning
    - Effective in dynamic and incompletely known environments, goals that are unknown at design time.

Control loops vs. Agents II

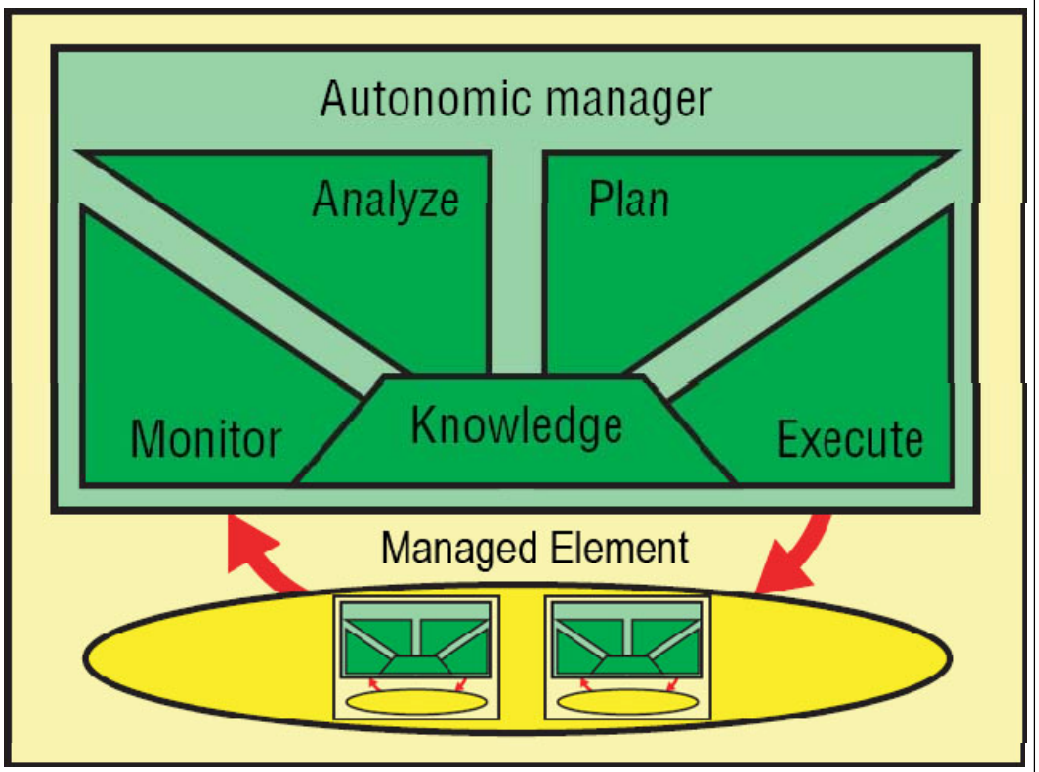
- Overlap between the two paradigms
  - Monitoring/sensing of the environment is followed by analysis/reasoning and then by the enactment of the appropriate behaviour.

Control loop:



Autonomic Element

- From the original Autonomic Computing proposal
  - Positions agents as THE technology for adaptive systems design
  - MAPE loop; Autonomic Manager/Managed Element
  - Resulting adaptive system – MAS!
  - Powerful and flexible



- **PRICE**:
  - Complexity
  - Heavy formalization
  - Lack of transparency and predictability

Aim of the Paper

- Motivate the research into the development of new methods for using agent technology in modern adaptive systems
- Can agents be of help in addressing various problems in adaptive systems design? Which ones?
- How can they be integrated with other approaches?
- Which kind of agent technology and what kind of agent architecture should be used in particular circumstances?
- What are the methods for systematically developing agents-based and hybrid adaptive systems

Where can agents help/hurt?

- Recent work on *dimensions of adaptive systems* may help
  - **Goal flexibility** [rigid, constrained, unconstrained]: agents can handle situations where goals are not known a priori
  - **Anticipation of change** [foreseen, planned for, unforeseen]: planned for – planning agents, unforeseen – social layer
  - **Autonomy** [degree of outside intervention] – both feedback loops and agent-based approaches support some form of it
  - **Organization** [(de)centralized] – decentralization is a major problem. Management of conflicts, coordination. Social layer can help.
  - **Predictability of adaptation** [(non)deterministic] – can consequences of adaptation be predicted? Control-based – predictable. Agents – emergent behaviour is difficult to predict
- Depending on where one wants to be w.r.t. the values of these dimensions, can choose agents vs. other approaches

Which Agent Technology?

- Range of techniques
  - Simple stateless reactive agents (similar to ECA rules)
    - Perception, simple reasoning, action. All analysis/reasoning at design time.
  - Reactive agents with state
    - Model of the state, model of the dynamics of the enviromnent
  - Planning
    - Classical, decision-theoretic. Reasoning at runtime.
  - Belief-desire-intention agents
  - …
- Methods do not normally address the problem of the selection of the appropriate agent technology

Methods for systematic development of adaptive systems

- Modeling of dynamic, flexible, reasoning MAS not well supported by notations like *i**, approaches like Tropos
  - Need to avoid overspecification. Need to support "grey" boxes – flexible behaviours with constraints
- Requirements-driven approach for adaptive systems design
  - RE for system requirements + RE for adaptation: separation of concerns
  - Meta-requirements for meta-processes (controllers)
    - Including Monitoring, Analysis/Diagnosis, Compensation goals explicitly represented
  - *Explicit* modeling of adaptation situations

Application to Agents

- Will these ideas work for agents?
  - Need to avoid overspecification
  - Little support for reasoning, planning capabilities, incompletely known environments, goals that are unknown at design time
  - Decentralized nature of adaptation in MAS is not well-supported
  - Need explicit modeling of the complex social behaviour (ideas like commitments may help)
  - Separation of functional behaviour and adaptation can be problematic for agents

The Road Ahead

- We believe that agents and MAS have capabilities that can enhance conventional adaptive systems
  - Combined use of agents and non-agent-based approaches
- Help with deciding whether to use agent technology and which type of agent/MAS to use is needed
- New methods are needed to balance the power of agents with improving predictability, transparency
- Emerging control theory-inspired methods for adaptive systems design can help with integrating of (at least simpler forms of) agent technology into adaptive systems

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