Context-Aware Self-Adaptive Software-Intensive Systems
How to Build Smarter Systems for a Smarter Planet

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Engineering Autonomic Systems (EASy)

Outline

Something profound is happening
Software Engineering @ Runtime
Our research projects
Something profound is happening ...
The Smart Systems Revolution

Instrumented  Interconnected  Intelligent

Self-Adaptive Systems (SAS)

A SAS can alter its behaviour at runtime in response to its perception of
- its environment and
- its own state
in the form of self-adaptation.

SAS abilities
- Assess its own behaviour
- Observe its context or environment
- Adapt without shut down

Provide Elasticity

From satisfaction of requirements through traditional, top-down engineering

The system shall do this ... but it may do this ... ... as long as it does this.

To satisfaction of requirements by regulation of complex, decentralized systems

How much environment uncertainty can we afford? What’s the cost? What benefits do we accrue by accommodating context uncertainty?
Glean Ideas from Nature Viability Zone

The internal mechanisms of humans continuously work together to maintain essential variables within physiological context and limits—the *n*-dimensional viability zone.

The goal of human self-managing behavior is directly linked to survivability:

- If the external or internal environment pushes the system outside its physiological equilibrium zone, the system will work towards returning to the equilibrium zone.


Software Engineering for Smart Systems

- Requirements@runtime
- Models@runtime
- Monitoring@runtime
- Analysis@runtime
- Self-Adaptation@runtime
- CM@runtime
- V&V@runtime
- Assurance@runtime

- Profound impact on SE and CS
- Rethink software design and evolution for highly adaptive software systems
- Feedback loops and control theory are key

Boundary between development-time and run-time is disappearing

Our Research Objective

Conduct fundamental research on situation-aware self-adaptive software-intensive systems to optimize their dynamic capabilities

Context Management  Feedback Control  Runtime V&V

Context is Key
Uncertainty Provides Context

Environmental uncertainty  Behavioral uncertainty

Context information

- Coutaz, Crowley, Dobson, Garlan: Context is key, CACM 48(3) (2005)
Make Context First Class

Context representation
- Modeling of relevant context
- Context management strategies
- Adaptation of context models at runtime

Context management
- Adaptive context management strategies
- Gathering, provisioning
- Context reasoning

Make feedback loops first class

Regulate objectives maintain equilibrium

Analyze
Monitor
Plan
Adapt

Autonomic control loop

Runtime V&V is Key

- V&V ensures that software satisfies requirements and quality attributes
- Runtime V&V ensures proper system operation during adaptation
- Certifiable V&V methods are critical for smart systems


Integrate runtime V&V tasks into adaptation process

Control science—a systematic way to study certifiable V&V methods and tools to allow humans to trust decisions made by self-adaptive smart systems.

Our Past Autonomic and SAS Projects

- **Industrial projects**
  - Müller, Mylopoulos: Design and Evolution of Autonomic Application Software, IBM/NSERC CRD (2006-10)
  - Müller, Kontogiannis, Mylopoulos, Wong: Logging, Monitoring and Diagnosis Systems for Enterprise Software Applications (LMD), CA/NSERC CRD (2007-11)

- **Conferences and workshops**

- **Courses**
Our Smart Systems Projects

- SAVI—Smart Applications on Virtual Infrastructure
  - NSERC Strategic Network
  - All students, Sudhakar Ganti
- SmarterContext—Smart Personal Web
  - Norha Villegas, IBM CAS
- YaKit—Smart Messaging System
  - Ron Desmarais, Przemek Lach
- Smart Resource Management
  - Ron Desmarais, Sowmya B., Venkatesh S., Ulrike Stege
- SDDS—Smart Services
  - Dynamic discovery, dynamic security assurance
  - Atousa Pahlevan, Alex Thomo
- Smart Phone Applications
  - Sahar Ebrahimi, Ishita Jain, Qian Yang

SAVI Themes and Vision

- Theme 1
  - Smart Applications
- Theme 2
  - Extended Cloud Computing
- Theme 3
  - Smart Converged Edge
- Theme 4
  - Integrated Wireless/Optical Access
- Theme 5
  - Application Platform Testbed
Managing Dynamic Context to Optimize Smart Interactions and Smart Services
Norha M. Villegas

- User-driven context management framework
- Context models at three different levels of abstraction
- Context monitoring and reasoning engine
- Personal web sphere model
- Personal web case study
- Goal: Make more offers to the user

IBM CAS Project of the Year 2011


Keynote Speakers: Raffaello D'Andrea, ETH Zürich
Co-Founder of Kiva Systems acquired by Amazon for $775M
Franco Zambonelli, Uni. of Modena & Reggio Emilia, Italy

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