ON SELF-ADAPTATION IN SYSTEMS-OF-SYSTEMS

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INTRODUCTION

- SoS is an structural concept
  - Defined by their composite emergent behavior
  - Depending on the *architecture* of the SoS

- Adaptivity as an emergent behavior
  - It is also one of the defining features of a SoS
    - Operational independence, Emergent behavior (Maier)
    - Autonomy, connectivity, emergence (Boardman & Sauser)
  - Self-adaptation encompasses many facets
    - Includes aspects such as autonomy and emergence
  - This relationship must be exploited
  - *Adaptive Architecture* as the basis of SoS
    - A dynamic architecture of adaptive services
TOWARDS ADAPTIVE SOS (I): SELF-ADAPTATION TO ARCHITECTURE

- Self-adaptation research has many facets
  - Emergent and autonomous self-adaptation
  - Autonomic Systems
    - Internal operation without external assistance
  - Self-organizing Systems & Architectures

- Adaptive architectures
  - Origin in self-* Systems
  - Dynamic software architecture
    - Including self-configuration
  - Evolving into self-adaptive system architecture
    - Self-healing, dependability
    - Adaptivity as a generic notion
TOWARDS ADAPTIVE SOs (II): DYNAMIC & ADAPTIVE ARCHITECTURE

- Definition of Dynamic ADLs
  - Complex architectures (including SoS)
  - Formal approaches (esp. $\pi$-calculus-based)

- Self-adaptive architectures as their evolution
  - The next step in Sw Eng (Kramer & Magee)
  - Approaches to adaptive architecture
    - General-purpose middleware, e.g. Rainbow
    - Domain-specific middleware, e.g. Music
    - Synchronized, reflective, policy-based architectures

- Difficult to measure “self-attributes”
  - Lack of a clear reference model
  - A formal approach (process calculus) is advocated
TOWARDS ADAPTIVE SOs (III): ADAPTATION IN SOs

Facets of adaptation in the SOs definition

- Autonomy, connectivity and emergence
- SOs requires that “connective media” are autonomic
  - Self-adaptive architecture model of emergence
  - (Still) Lack of a high-level architecture approach
- Preliminary: exporting work from other contexts
  - Service-oriented, Model-driven, Dynamic Arch.
  - Promising approach: Federated Systems
- Adaptive architecture as a good basis
  - High-level patterns must still be generalized
  - A formal foundation seems necessary
  - Measuring capabilities would be also required
ARCHITECTING ADAPTIVE SOS (I): THE CASE OF LOCI

- Structuring architecture in terms of evolution
- Modules defined as “areas of change” rather than functionality
- Locus (Morrison, 2007)
  - Change contexts: parts of the system which always evolve in synchrony
- Evolutionary steps
  - Incarnations of a locus
- Reminiscent of Evolution Styles (more recent)

Composition of Loci, using the Evolver-Producer pattern (Morrison et al, 2007)
ARCHITECTING ADAPTIVE SOS (II): THE CASE OF STRATA

- The rhythm of change is different at different scales
  - Software Evolution
- Software is able to follow different evolutionary patterns at different levels
- Known as *strata*
  - Including SoS
- Lower strata evolve easily
  - Upper strata evolve is much less frequent
- Upper strata change often imply structural change

Strata of Evolution, according to (Mittermeir, 2006)
ARCHITECTING ADAPTIVE SOSS (III): PACE LAYERING

- Deriving from “building” architecture theory
- Shearing Layers of Change
- Processes affect systems in different timescales
  - Different parts (layers) are evolving at a different pace
  - Able to adapt = slippage of layers
- Design principle: structure layers according to this
- Seems natural in SoS
  - Administrative barriers

Shearing Layers of Change, according to (Brand, 1994)
CONCLUSIONS

- There is a deep relationship between adaptivity and systems-of-systems
  - Research in self-adaptive (and autonomic) systems can (must) be applied in this context
  - Adaptive architecture seems to be a reasonable approach to tackle their design
- System evolution itself appears as the main driver for adaptation of SoS
  - Defined as the highest stratum
  - Pace layering as a reasonable design strategy
  - Just a first step in this direction
THANKS FOR YOUR ATTENTION