

ON SELF-ADAPTATION IN SYSTEMS-OF-SYSTEMS

M. Pilar Romay, UAH & UCM, Spain

Carlos E. Cuesta, VorTIC3, URJC, Spain

Luis Fernández-Sanz, UAH, Spain

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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. π -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

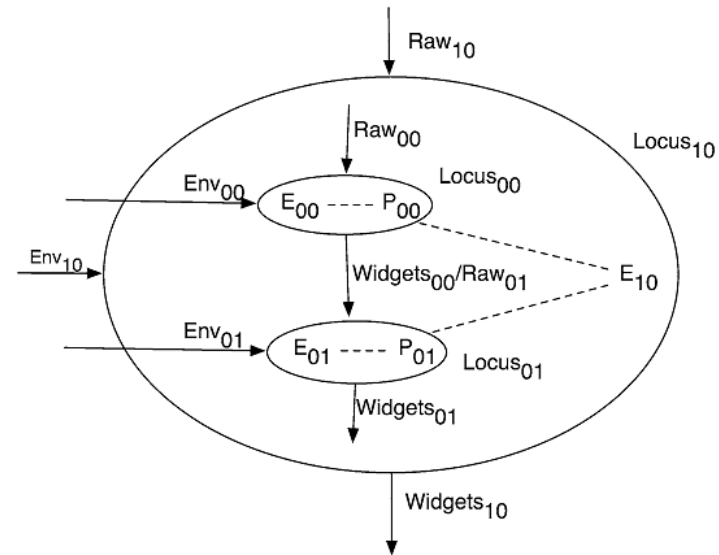


TOWARDS ADAPTIVE SoS (III): ADAPTATION IN SoS

- 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

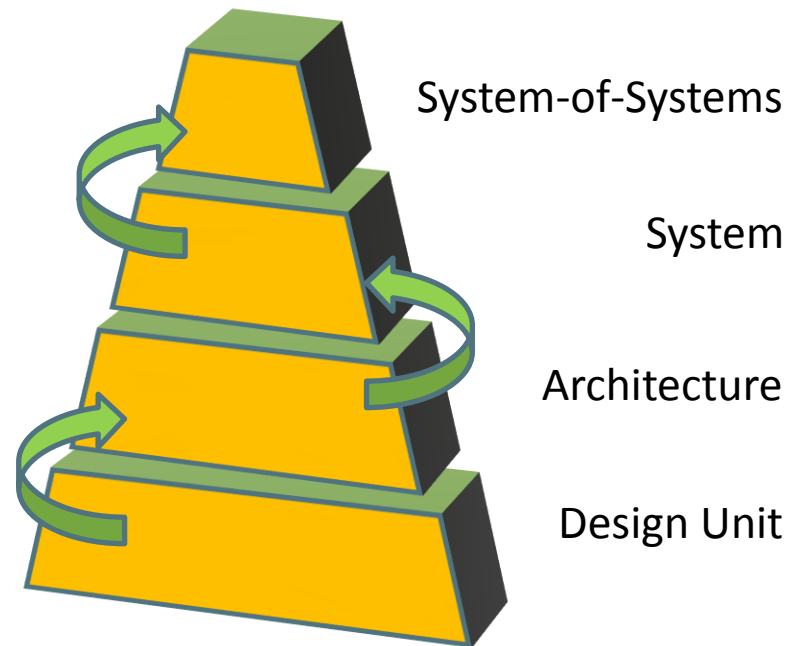
- Structuring architecture in terms of evolution
- Modules defined as “areas of change” rather than functionality
- Locus (Morrison, 2007)
 - Change contexts: parts of the system which always evolve in synchrony
- Evolutionary steps
 - Incarnations of a locus
- Reminiscent of Evolution Styles (more recent)



Composition of Loci, using the Evolver-Producer pattern (Morrison et al, 2007)

ARCHITECTING ADAPTIVE SoS (II): THE CASE OF STRATA

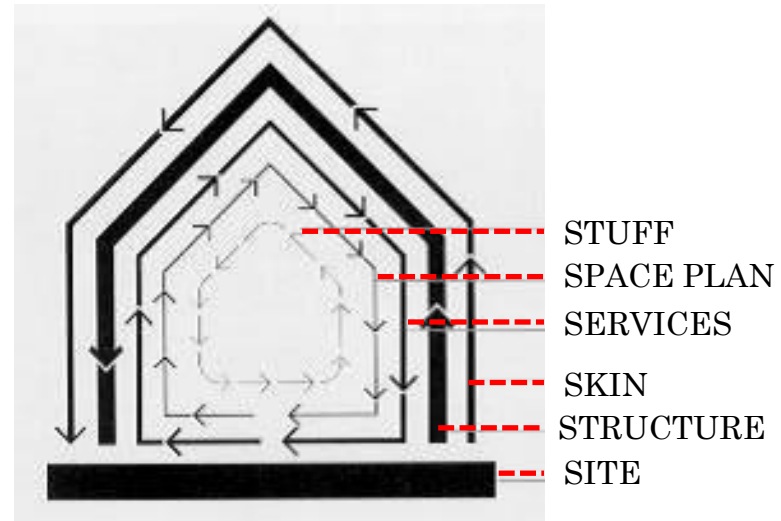
- The rhythm of change is different at different scales
 - Software Evolution
- Software is able to follow different evolutionary patterns at different levels
- Known as *strata*
 - Including SoS
- Lower strata evolve easily
 - Upper strata evolve is much less frequent
- Upper strata change often imply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



Strata of Evolution, according to (Mittermeir, 2006)

ARCHITECTING ADAPTIVE SoS (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

