SYSTEM-OF-SYSTEMS THAT ACT **LOCALLY** FOR OPTIMIZING **GLOBALLY**

EU FP7 - SMALL/MEDIUM-SCALE FOCUSED RESEARCH PROJECT (STREP)
FP7-ICT-2013.3.4: ADVANCED COMPUTING, EMBEDDED AND CONTROL SYSTEMS
D) FROM ANALYZING TO CONTROLLING BEHAVIOUR OF SYSTEM OF SYSTEMS (SOS)

Kick-off Meeting

Requirements for SoS Control / TSoS Modelling and Analysis

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October 23, 2013
Aachen, Germany

LOCAL4GLOBAL

Local[4]Global
Contact Information

For information regarding this Project: Check the Project Web-Site: http://local4global-fp7.eu

	Participants
1	CERTH - Centre for Research and Technology
2	ETHZ – Eidgenössische Technische Hochschule Zürich
3	RWTH – RWTH Aachen University
4	IK4 – IK4 TEKNIKER
5	TUC – Technical University of Crete
6	TRV – TRANSVER GmbH
7	TUM – Technische Universtität Muenchen

Project Acronym: Local4Global

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FP7-ICT-2013.3.4: ADVANCED COMPUTING, EMBEDDED AND CONTROL SYSTEMS
D) FROM ANALYZING TO CONTROLLING BEHAVIOUR OF SYSTEM OF SYSTEMS (SOS)

TUC - People Involved

- Prof. Markos Papageorgiou

  - Person in charge of scientific and technical/technological aspects
  - WP2 Leader
  - Member of the Steering Committee

- Prof. Ioannis Papamichail

  - Contact person for administrative, financial and legal matters
  - RTD

- Dr. Christina Diakaki

  - Contact person for scientific and technical/technological aspects
  - Contact person for administrative, financial and legal matters
  - RTD

Discussion items

- Overview of WP2: TSoS Modelling, Analysis and Software Needs
- Setting the scene for TSoS Modelling and Analysis requirements
  - Definitions
  - System vs. System of Systems
  - Systems Engineering vs. Systems of Systems Engineering
  - Core elements of SoSE
  - Decision making and control methods for SoS
  - Example applications of SoS concepts
  - The Local4Global expected output
  - What has to be done within Local4Global Task 2.1?
  - Outline of Task’s 2.1 expected outcome (Deliverable 2.1)

Overview of WP2: TSoS Modelling, Analysis and Software Needs

- **Objectives**
  - Modelling and analysis requirements (generic TSoS) $\Rightarrow$ Task 2.1
  - Software requirements (generic TSoS) $\Rightarrow$ Task 2.2
  - Use case specific implementation requirements $\Rightarrow$ Task 2.3
- **Outcomes**

  Task 2.1 $\Rightarrow$ D2.1. TSoS Modelling and Analysis Requirements
  Task 2.2 $\Rightarrow$ D2.2. TSoS/Local4Global Embedded Software Needs
  Task 2.3 $\Rightarrow$ D2.3. TSoS Use Case Requirements
- **Time frame**
  - Start: October 1, 2013
  - Duration: 9 months
  - Deliverables' due date: month 9
  - End: June 30, 2014
- **Partners**
  - WP2 Leader: TUC
  - Task 2.1 Leader: TUC
    - Other Contributors: CERTH, ETHZ
  - Task 2.2 Leader: IK4
    - Other Contributors: CERTH, ETHZ
  - Task 2.3 Leaders: TRV (traffic use case), RWTH (building use case)
    - Other Contributors: CERTH, ETHZ, TUC, TUM

Setting the scene for TSoS Modelling and Analysis requirements:

Definitions (1)

- **System of Systems** (**SoS**) is an integration of a finite number of constituent systems that pool their resources and capabilities together for a period of time to create a new, more complex system which offers more functionality and performance than simply the sum of the constituent systems
- For **a system to be characterised as SoS**, it must exhibit the majority of the following traits:
  - Operational independence of component systems
  - Managerial independence of component systems
  - Geographical distribution
  - Emergent behaviour
  - Evolutionary and adaptive development
  - Heterogeneity of the involved systems
  - Inter-disciplinarily study
  - Networks of systems

Meier (1998) [first five traits]

DeLaurentis (2004) [last three traits]

Setting the scene for TSoS Modelling and Analysis requirements:

Definitions (2)

- The methodology for planning, analysing, organizing, and integrating the capabilities of a mix of existing and new systems into a SoS capability greater than the sum of the capabilities of the constituent parts is typically referred to as **System of Systems Engineering** (**SoSE**)
- SoSE has evolved as a new and very challenging discipline and tends to borrow heavily from the more widely recognised area of **Systems Engineering** (**SE**), which is a discipline that provides the necessary engineering and management guidance to successfully design and develop complex systems rather than focus on their separate individual components
- **Many of the basic tenets of SE hold good for SoSE** such as the need for a holistic approach, understanding stakeholders and their full range of requirements, constant iteration through the design process etc.
- In contrast, however, to the traditionally studied complex systems, **true SoS are rarely designed from scratch**; rather they are configured for a specific purpose over a given period of time and it is this aspect that requires a new approach

Setting the scene for TSoS Modelling and Analysis requirements:

System vs. SoS (*DoD, 2008; Barot, et al, 2012*)

Aspect of environment	System	SoS
Management & Oversight		
Stakeholder involvement	Clear set of stakeholders	Stakeholders with potentially competing interests & priorities
Governance	Aligned management & funding	Added complexity due to management & funding of both SoS and individual systems
Operational environment		
Operational focus	Designed & developed to meet common objectives	Called upon to meet a set of objectives using systems with potentially diverse individual objectives
Implementation		
Acquisition/development	Aligned to well-established processes with specific requirements	Added complexity due to multiple individual acquisition programs with typically stated overall capability objectives , which may need to be translated into formal requirements; needs learning and adaptation processes
Test & evaluation	Generally possible	More challenging due to the difficulty of multiple systems' synchronisation given the complexity of all the moving parts and potential for unintended consequences

Setting the scene for TSoS Modelling and Analysis requirements:

SE vs. SoSE (*adopted by Gorod, 2008*)

	SE	SoSE
Focus	Single Complex System	Multiple Integrated Complex Systems
Objective	Optimization	Satisficing
Boundaries	Static	Dynamic
Problem	Defined	Emergent
Structure	Hierarchy	Network
Goals	Unitary	Pluralistic
Approach	Process	Methodology
Time frame	System Life Cycle	Continuous (multiple life cycles)
Centricity	Platform	Network
Tools	Many	Few
Management framework	Established	?
Standards	Few	?

Setting the scene for TSoS Modelling and Analysis requirements:

Core elements of SoSE

- **Translating** SoS capability objectives into SoS requirements over time
- **Understanding** the constituent systems and their relationships over time
- **Assessing** extent to which SoS performance meets capability objectives over time
- **Developing**, **evolving** and **maintaining** an architecture for the SoS
- **Monitoring** and **assessing** potential impacts of changes on SoS performance
- **Addressing** SoS requirements and solution options
- **Orchestrating** upgrades to SoS

(*according to DoD, 2008*)

Setting the scene for TSoS Modelling and Analysis requirements:

Decision making and control methods for SoS

- Span from **hierarchical (centralised) control** to **hybrid schemes** to a **fully distributed approach** in which each system contains the logic and authority to choose its own actions
- **Optimisation** plays a crucial role; no single approach appears to be a panacea for all cases; connectivity, system type and degree of autonomy of individual systems are significant factors for selecting an approach
- SoS problems are often **multi-objective**, containing **multiple stakeholders** with possibly conflicting objectives
- Approaches such as **competitive games** may also assist the understanding of the implications of autonomous systems interacting with each other

Setting the scene for TSoS Modelling and Analysis requirements:

Example applications of SoS concepts (1)

- Jamshidi's (2009) edited book presents **theoretical aspects** of SoS concepts' applications in fields such as US DoD, wireless sensor networks, services, space exploration, space communication and navigation networks, electrical power systems, sustainable environmental management, robotic swarms, transportation etc.
- **Practical aspects** of SoS concepts' applications are covered in numerous journal papers including:
  - Assessment of the technical feasibility of electric vehicles within the larger infrastructure system (grid, transport network…) (Al Junaibi and Farid, 2013)
  - Distributed control of freeway networks (Ferrara et al, 2012)
  - Dynamic management of risk related to the Transport of Dangerous Goods (Laarabi et al, 2013)
  - Assessment of financial innovation policies for U.S. transportation infrastructure (Mostafavi et al, 2012)
  - Design and simulation of a real-time residential automation system composed of heating, home automation and vehicle parking systems (Kaur et al, 2013)

…

Setting the scene for TSoS Modelling and Analysis requirements:

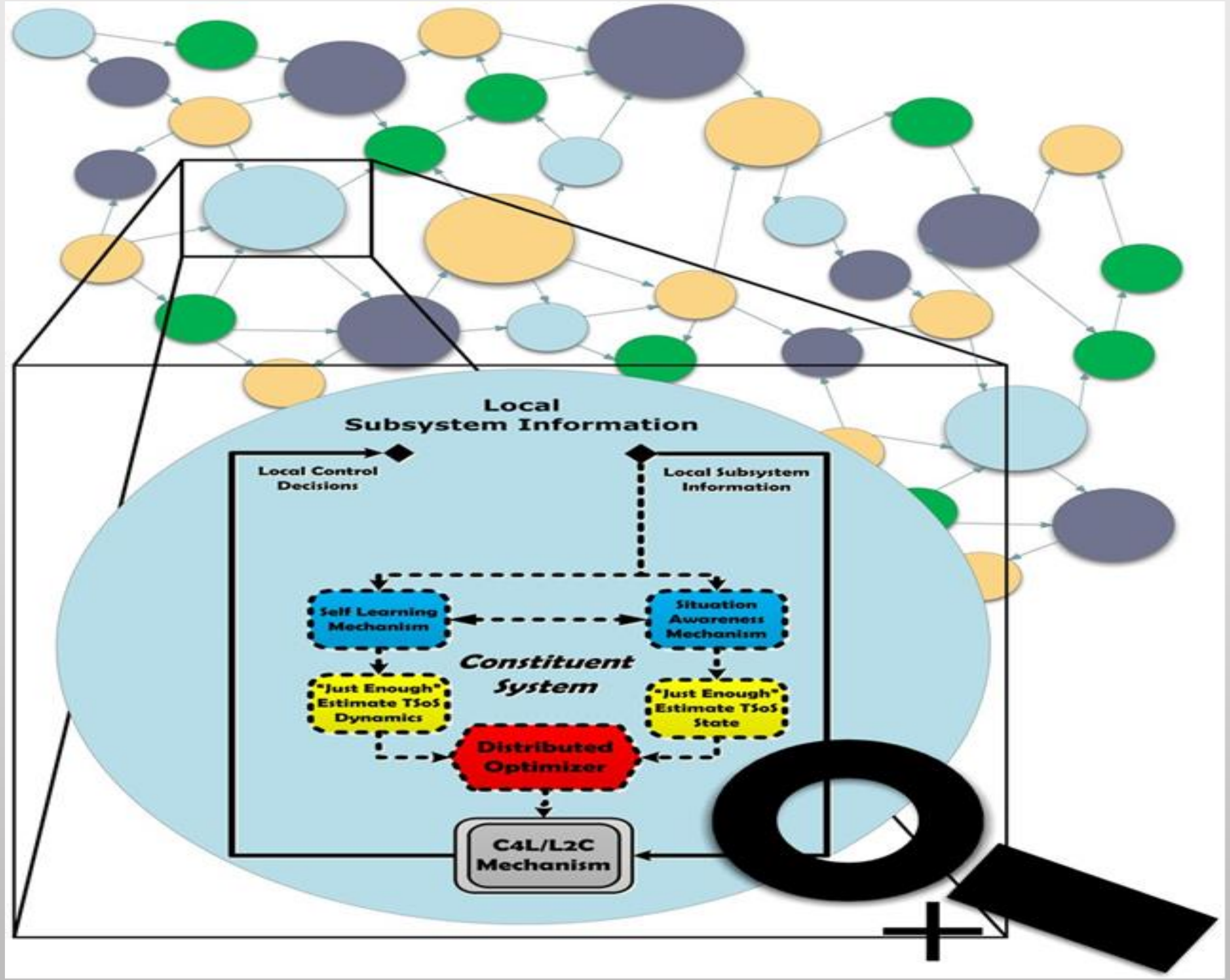
Example applications of SoS concepts (2)

…

- Design of the initialisation process of the propulsion control system of a hybrid electric vehicle (McMurran and Jones, 2013)
- Failure detection, isolation and recovery of a configurable radar interferometer formed by two satellites flying closely and operating both individually and jointly (Schwab et al, 2012)
- Evaluation of the operational effectiveness of weapon systems (Lit et al, 2013)
- Modelling and simulation of wind farms (Rannat et al, 2012)
- Air quality optimisation (Carnevale et al, 2012)
- Design of strategies to improve sustainable biodiversity in a country (Phillis and Kouikoglou, 2012)
- Design and implementation of a group-based programming abstraction aimed at creating logical collections of sensing devices (Vicaire et al, 2012)
- Analysis of product development and marketing strategies (Belay et al, 2012)
- Modelling of healthcare systems and design of strategies that improve the level of health of a population (Grigoroudis and Phillis)
- Development of flexible, cost-effective training environments (Ciocoiu et al, 2012)

Setting the scene for TSoS Modelling and Analysis requirements:

The Local4Global expected output



Setting the scene for TSoS Modelling and Analysis requirements:

What has to be done within Local4Global Task 2.1?

- **Deep and extensive understanding** of the modelling and analysis requirements for TSoS control to ensure that
  - The **self-learning mechanism** will be capable of accurately and efficiently learning and estimating the dynamics and state of the generic (arbitrary) TSoS
  - The **situation awareness mechanism** will be able to acquire the TSoS state using local information
- **Deep and extensive understanding** of the extension requirements of standard control-theoretical approaches to generic TSoS to ensure that both the **distributed optimiser** and the **C4L/L2C mechanism** will be developed in an appropriate manner
- **Based on**:
  - A deep and thorough literature research
  - A deep and extensive analysis of TSoS-related R&D endeavours
  - Formation of Local4Global Advisory Board with key players such as system providers and operators, authorities and users, other TSoS-related endeavours
  - **Close cooperation with the case studies task (Task 2.3) to ensure that the formulated requirements will fit for purpose**

Setting the scene for TSoS Modelling and Analysis requirements:
Outline of Task’s 2.1 expected outcome (Deliverable 2.1)

D2.1. TSoS Modelling and Analysis Requirements shall cover but may not be limited to the following aspects:

- Evolution and definition of TSoS
- From SE to SoSE approach
- Modelling and analysis requirements for controlling TSoS including:
  - Different combinations of dynamics (continuous, discrete)
  - Types of variables and states
  - Available tools
- Efficiency analysis requirements including
  - Optimality, stability and robustness requirements
  - Measurement and analysis methods

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DSSL / TUC

- The Technical University of Crete (TUC) was founded in 1977 in Chania, Crete, Greece, with the mission to develop modern engineering specialties, place emphasis on research in fields of advanced technology, and establish close cooperation with the industry and other production organizations in Greece (www.tuc.gr)
- The Dynamic Systems and Simulation Laboratory (DSSL) is the particular TUC's unit involved in Local4Global project. DSSL (www.dssl.tuc.gr):
  - Belongs to the section of Decision Systems of the School of Production Engineering and Management, was founded in 1988, and has been headed since 1994 by Prof Markos Papageorgiou
  - Has profound knowledge and broad experience in the theories of modelling, simulation, statistics, optimisation, automatic control, and their practical application to traffic and transportation systems, water networks, production systems, and further areas
  - Has been involved in numerous research and demonstration projects at a national, European and international level, gaining a remarkable experience through the implementation, testing, and evaluation of its several techniques and tools in real conditions
  - Will bring all the knowledge and experience in Local4Global and will gain by extending its perspectives in several respects