A Few Words First

Courtesy – Please mute your phone (*6 toggle).

Upcoming Chapter Meetings:

- **Dec 8, Holiday Social, St. Clair Winery/Bistro, 5:00pm-7:30pm, can bring guest FREE, but register for head count, see Event Listing on Chapter home page**
- **Jan 10, System-Aware Security for Cyber Physical Systems**
  Dr. Barry Horowitz, University of Virginia
- **Feb 14, MBSE Implementation Across Diverse Domains**
  Dr. Ron Carson, INCOSE Fellow, ESEP, Retired Boeing, now at Seattle Pacific U. and U. of Washington

CSEP Courses by *Certification Training International:*

Course details | Course brochure

Course Schedule (close by, but many more locations and dates):

201826Feb-02Mar | Las Vegas, NV
201802Apr-06Apr | Denver
201821May-25May | Austin, TX
201815Oct-19Oct | Albuquerque, NM

First slide, not recorded but retained in pdf presentation.

And Now - Introductions

Enchantment Chapter Monthly Meeting

9 November 2017 – 4:45-6:00 pm:

Architecting Cyber Physical Systems?

Dr. Cihan Dagli, Missouri University of Science & Technology, dagli@mst.edu

Abstract: Multi-faceted systems of the future will entail complex logic and reasoning with many levels of reasoning in intricate arrangement. The organization of these systems involves a web of connections and demonstrates self-driven adaptability. They are designed for autonomy and may exhibit emergent behavior that can be visualized. Our quest continues to handle complexities, to design and operate these systems. The challenge in Complex Adaptive Systems design is to create an organized complexity that will allow a system to achieve its goals. These complex adaptive systems have dynamically changing meta-architectures. Finding an optimal architecture for these systems is a multi-criteria decision making problem often involving many objectives in the order of 20 or more. This creates “Pareto Breakdown“ which prevents ordinary multi-objective optimization approaches from effectively searching for an optimal solution; saturating the decision maker with large set of solutions that may not be representative for a compromise architecture selection from the solution space. Possible approaches that can be adapted in overcoming this difficulty in architecting cyber physical systems will be discussed.

Download slides today-only from GlobalMeetSeven file library or anytime from the Library at www.incose.org/enchantment

NOTE: This meeting will be recorded

Today's Presentation

Things to Think About

How can this be applied in your work environment?

What did you hear that will influence your thinking?

What is your take away from this presentation?

Speaker Bio

Dr. Cihan H. Dagli is a Professor of Engineering Management and Systems Engineering (EMSE) at Missouri S&T.

He is the Director of the EMSE Smart Engineering System Laboratory, and is the founder and current Director of the Systems Engineering MS and PhD programs at Missouri S&T.

His research interests are in systems engineering and systems architecting, cyber physical systems, and computational intelligence: neural networks, fuzzy logic, and evolutionary programming.

Dr. Dagli has been a PI, co-PI, or director of 56 research projects and grants totaling over $25 million from federal, state, industrial funding agencies, and distance tuition revenue. Approximately $21 million of this total has been generated through the Systems Engineering Graduate Program during his tenure as program director (2000-Present).

His new edited book Complex Adaptive Systems Volume 6, “Engineering Cyber Physical Systems: Applying Theory to Practice” will be published on November 2, 2016 by Elsevier, SciVerse ScienceDirect (www.sciencedirct.com) in Procedia Computer Sciences.

Architecting Cyber Physical Systems

Cihan H. Dagli

Founder and Director of Systems Engineering Graduate Program

Missouri University of Science and Technology, Rolla, Missouri, U.S.A.

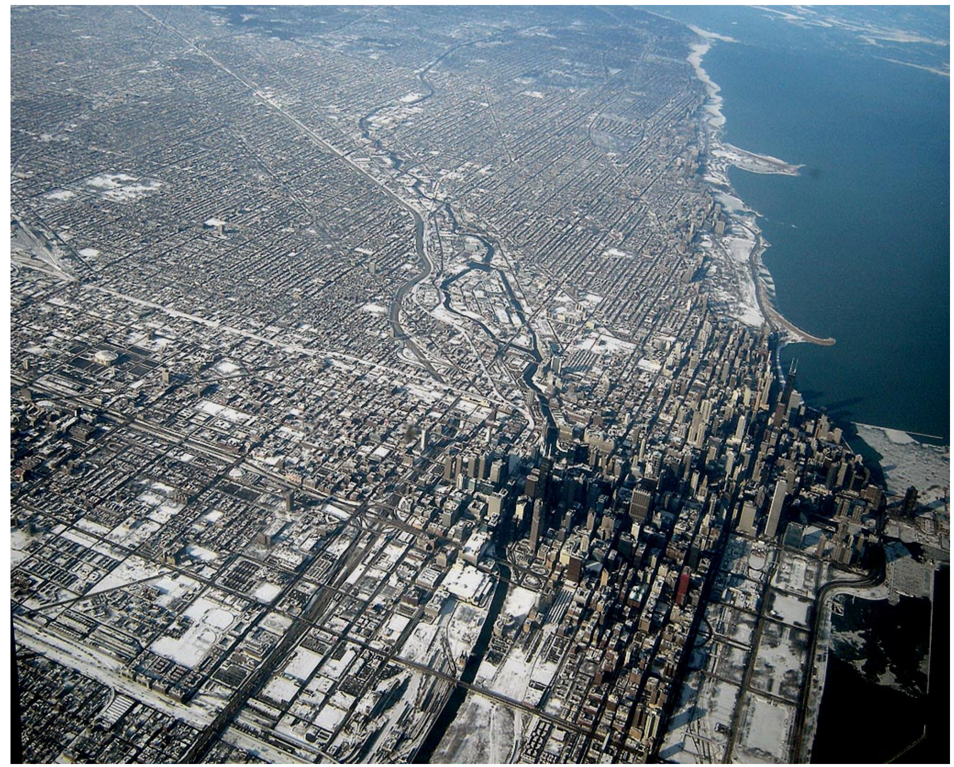
dagli@mst.edu

INCOSE New Mexico Enchantment Chapter

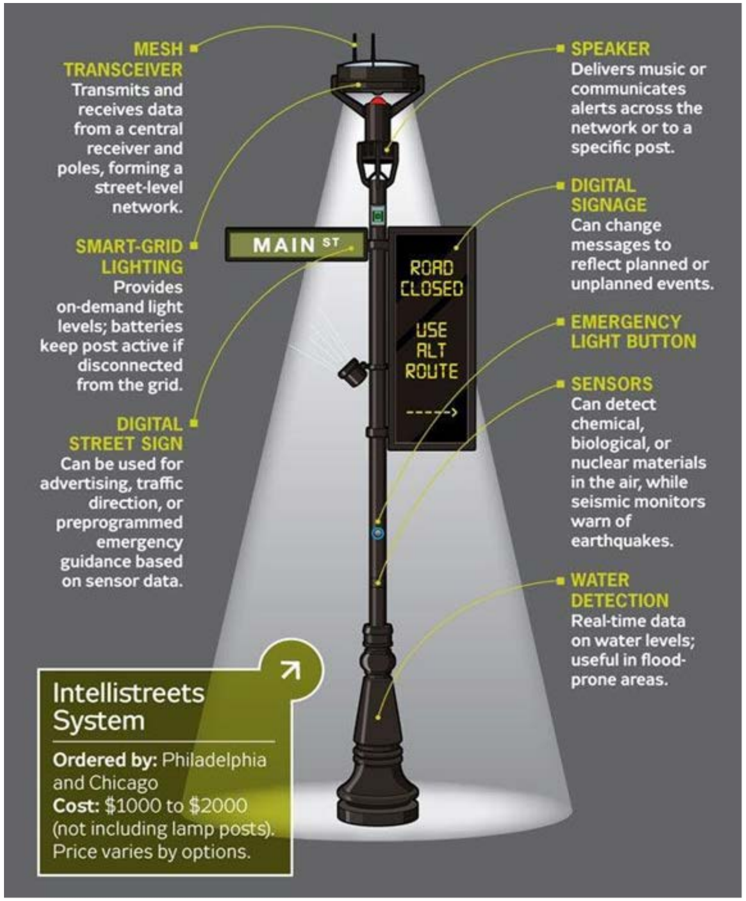
November 9, 2017

Cyber Physical Systems


Istanbul, Turkey


Chicago Illinois , U.S.A.

Cyber Physical Systems



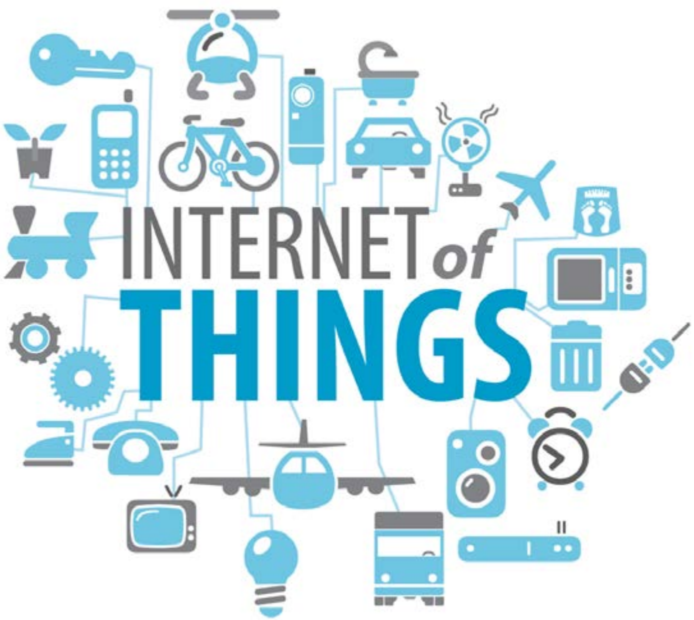
http://www.popularmechanics.com/technology/infrastructure/a7437/smart-everything-even-lamp-posts-are-now-connected/

Cyber Physical Systems

Paris (France)

Singapore, - Singapore

Engineering Cyber Physical Systems



"The network of physical objects that contain embedded technology to communicate and interact with their internal states or the external environment."

This is a complex adaptive systems that can have emergent behavior and requires systems integration and engineering in their design and operation.

Complex Systems

A system with a large collection of interacting elements is said to be complex if there exists emergent global dynamics resulting from the actions of its parts rather than being imposed by a central controller.

- A complex system exhibits properties that do not obviously follow from the properties of the individual agents. These properties are said to be "emergent".

Complex Systems

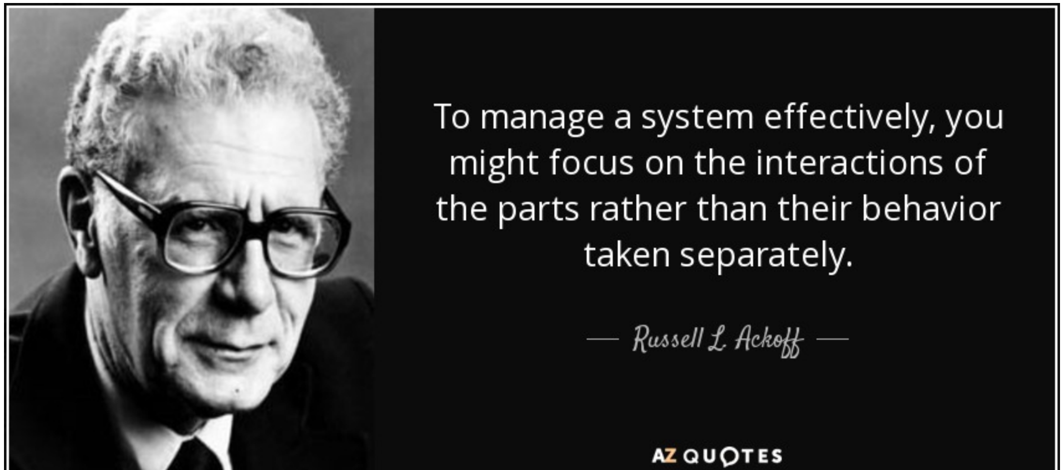
A system with a large number of elements maybe complicated but not complex. The distinguishing characteristics of a complex system are:

- Large number of interacting agents
- Self-organizing collective behavior, i.e., *emergent* behavior
- Emergent behavior does not result from the existence of a central controller
- Open systems
- System boundaries are difficult to determine
- Exhibit nonlinear input-output relationships

Complex Systems

- Universal laws and phenomena are essential to our inquiry and to our understanding
- Qualitatively, to understand the behavior of a complex system we must understand not only the behavior of the parts but how they act together to form the behavior of the whole

Cyber Physical Systems



MANAGEMENT SCIENCE
Vol. 17, No. 11, July, 1971
Printed in U.S.A.

TOWARDS A SYSTEM OF SYSTEMS CONCEPTS*

RUSSELL L. ACKOFF

University of Pennsylvania

The concepts and terms commonly used to talk about systems have not themselves been organized into a system. An attempt to do so is made here. *System* and the most important types of system are defined so that differences and similarities are made explicit. Particular attention is given to that type of system of most interest to management scientists: *organizations*. The relationship between a system and its parts is considered and a proposition is put forward that all systems are either variety-increasing or variety-decreasing relative to the behavior of its parts.

Order and Chaos

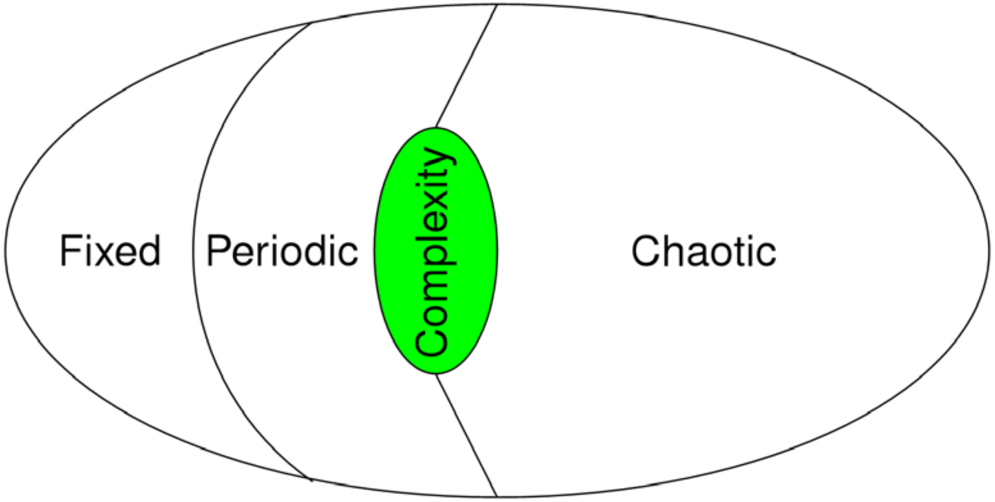
- Order and structure are vital to life
- Patterns are ubiquitous both in natural and man-made systems
- Order ensures consistency and predictability
- Order makes the creation of systems possible
- However, too much order leads to rigidity
- Inflexibility suppresses creativity

- Chaos leads to disorder and unpredictable behavior
- Chaos constantly changes the rules and the environment creating instability
- However, Chaos leads to emergent behavior
- Chaos allows novelty and creativity

Chaos and order are two complementary states of our world. A dynamic balance exists between the two states. Sufficient order is necessary for a system to maintain an ongoing identity, along with enough chaos to ensure growth and development.

The Edge of Chaos

- Complex systems are systems at the edge of chaos.
- Systems are just short of being random.
- Chaos provides the creativity, diversity, and complexity.
- Organized complexity allows system to achieve its goals.
- The edge of chaos is the point of emergence.
- Dynamic stability is maintained through constant self-adjustment.



Langton's schematic representation of cellular automata rule space characterized by the λ parameter

Complex Systems as Networks

A complex system can be represented as a network where,

Elements ↔ vertices

Interactions ↔ edges

An edge between 2 vertices means they interact.

System	Vertex	Edge
Facebook	Person	Friendship
Brain	Neuron	Synapse
Air Traffic Network	Airports	Routes
Net-centric System of systems	System	Communication channels
World Wide Web	Websites	Hyperlinks

Axiomatic Basis for Emergence in SoS and CPS

- *Holism* suggests that we cannot understand a complex system through reduction to the component or entity level.
- The concept of *system purpose* suggests that the purpose of a system is "what it does".
  - Distinction between intention and results
  - system purpose must be derived from the SoS-as-performed.
  - The implications of system purpose for emergence suggest that (1) differential between the "as-designed" and "as-performed" SoS is a function of the emergence inherent in deployment of the SoS, and (2) purpose is subject to interpretation and might "shift" over time as the SoS operates.
- *Pluralism* is a systems concept that recognizes there may be multiple purposes/objectives in play at the individual, entity, and enterprise levels
  - In relationship to emergence, pluralism suggests that there may be differences in objectives pursued in response to patterns and properties that manifest through SoS operation.
- The knowledge of a complex SoS and CPS is always *incomplete* and *speculative*. *System darkness* is a systems concept that recognizes there can never be complete knowledge of a system.
- *Boundaries* in an SoS/CPS are ambiguous, fluid, and negotiable.

Axiomatic Basis for Emergence in SoS and CPS

- The *metasystem* provides the structure of relationships that integrates the SoS.
  - It structures the appropriate balance to relieve tensions between (1) the autonomy of subsystems and the integration of the SoS/CPS as a whole, (2) purposeful design and self-organization, and (3) focus on maintaining stability or pursuing change .
  - Emergence will produce those patterns/properties that are necessary to resolve structural tensions and maintain SoS/CPS viability.
- *Context* is the circumstances, factors, conditions, and patterns that both enable and constrain a complex system solution, deployment of that solution, and interpretation of the results of solution deployment
  - For SoS, the context can dominate the solution space and may be more important than technical aspects of a solution.
- *Dynamic stability* holds that a system remains stable as long as it can continue to produce required performance during environmental turbulence and changing conditions. Maintenance of stability, or dynamic equilibrium
  - As the SOS environment and context change, commensurate patterns/properties emerge to make the appropriate compensations necessary for maintenance of stability.

Cyber Physical Systems

My vision for CPS technology in the next 10 years

- There will be *multi-faceted systems* in different levels of implementation that entail complex logic with many levels of reasoning in intricate arrangement, organized by web of connections and demonstrating self-driven adaptability which are designed for autonomy and exhibiting emergent behavior that can be visualized. They will impact manufacturing industry, defense, healthcare, energy, transportation, emergency response, agriculture and society overall.
- The success will come how the current challenges related to cybersecurity, interoperability, privacy, safety and socio-technical aspects mainly interaction of human behavior and complex adaptive systems are handled.

Cyber Physical Systems

Highlights of current research and innovation in system design, modelling and virtual engineering for CPS include;

Cyber Security Analytics
Cyber Fractology
Socio-technical Systems
Service & Distributed Systems
Computational Complexity
Complex Analytics
Resilience & Self Organization
Emergence of Functionality
Systems Modeling & Design
Formal Methods for Systems Architecting
Multi-Scale Modeling

Graphical Methods for Designing Programs & Systems
Systems Behavior Modeling
Emergent System Behavior
Interacting Systems, Collective Dynamics
Models of Interactions between Complex Systems
Structure & Dynamics of Complex Networks
Evolutionary Dynamics on Networks
Networks of Networks
Social & Information Networks
Graph Theory Algorithms

Cyber Physical Systems

Strengths in the US R&D community in system design, modelling and virtual engineering for CPS include

Cyber Physical Manufacturing
Smart Grid and Cities
Big data and Data Interoperability
Cyber Security
Complex Adaptive Systems Architecting and Engineering
Timing in Complex Adaptive Systems
Modeling and Simulation of Cyber Physical Systems
Internet of Things
CPS Virtual Organization
NSF Breakthrough, Synergy, and Frontier projects

Opportunities

TAMS CPS

Trans-Atlantic Modelling and Simulation
for Cyber-Physical Systems

Modelling

- Model scarcity along the abstraction hierarchy
- Interaction of software models with multiple physics models
- Modeling to predict emerging behavior
- Composable and meta- programmable tools components in highly domain specific design tool suites
- Abstractions modularity and composability
- Systems Engineering (rare events challenge and prediction)

Autonomy and Adaptation

- Adaptive and hierarchical control
- Deep neural networks in creating adaptive behavior
- Self-organizing systems ensembles
  - Architectures and meta architectures
- Conformance (adaptive systems)
  - Qualification and certification
  - Validation and verification
  - Probabilistic methods in evidence based assurance
  - Validation and testing

Humans

- Socio-technical aspects, interaction between people and technology, emerging behavior and human interaction reactive systems

General Topics

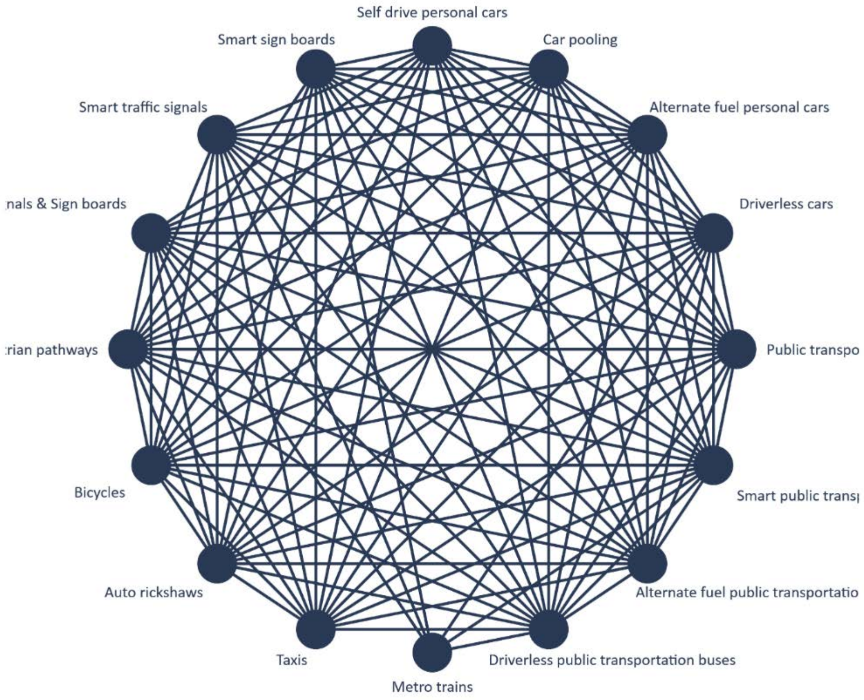
- Safety, security, and privacy integration in design and tools
- Infrastructure (changes and updates)
- Shared open technology with global R&D communities
- Large scale testbeds

Research Needed

- Smart systems architecting, data analytics and machine learning tools can help in responding autonomy and adaptation
- This research can be build on Flexible and Intelligent Learning Architectures for SoS (FILA-SoS) research completed early 2015.

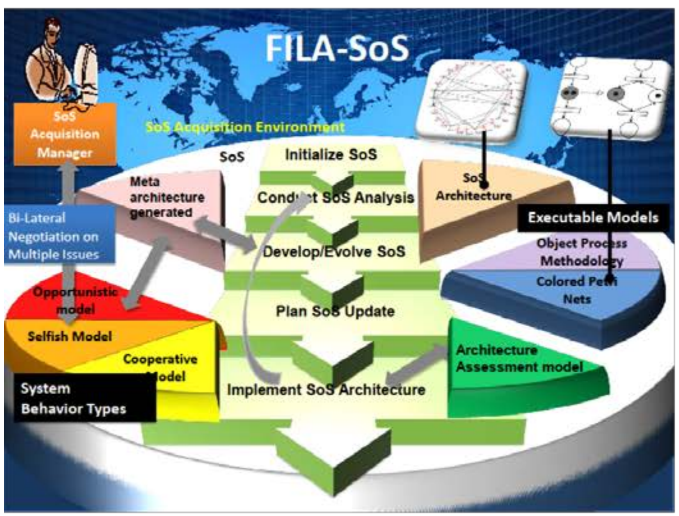
Meta-Architecture

Meta-architecture generated for the identified 16 systems and their interfaces are shown below.



Flexible and Intelligent Learning Architectures for SoS (FILA-SoS)

FILA-SoS Capabilities: Integrated model for modeling and simulating SoS systems with evolution for multiple waves. Models can be run independently and in conjunction with each other. Two model types represent SoS behavior and various individual system behavior. Study of negotiation dynamics between SoS and individual systems



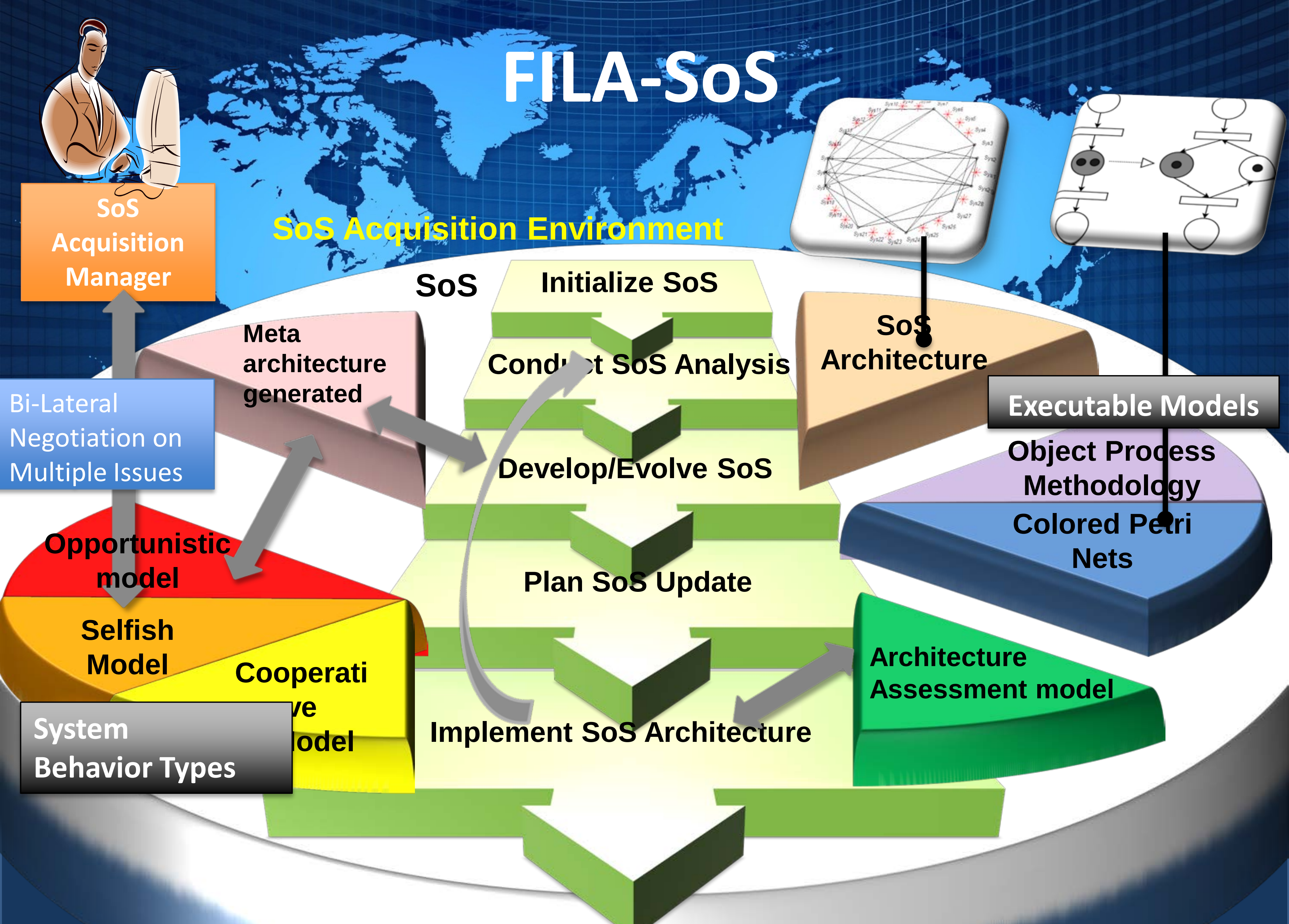
Integrated Quantitative Decision Making Model with seven independent modules

- Meta-Architecture Generation Fuzzy Genetic model
- Meta-Architecture Generation Multi-Level model
- Architecture Assessment Model
- SoS Negotiation Model
- System Negotiation Model: Selfish
- System Negotiation Model: Cooperative
- System Negotiation Model: Opportunistic
- Architecture Executable Model
- Overall Negotiation Framework

Flexible and Intelligent Learning Architectures for SoS (FILA-SoS)

FILA-SoS Value: Aiding the SoS manager in future decision making. Understand emergent behavior of systems in the acquisition environment and impact on SoS architecture quality Study the dynamic behavior of different type of systems (selfish, opportunistic, cooperative). Identify intra and interdependencies among SoS elements and the acquisition environment

FILA-SoS "What-if" Analysis; Model Modularity: Variables such as SoS funding and capability priority can be changed as the acquisition progresses though wave cycles. Simulation of any architecture through colored petri nets. Simulate rules of engagement & behavior settings: all systems are selfish, all systems are opportunistic, all systems are cooperative or a combination.


FILA-SoS
SoS Acquisition Manager
SoS Acquisition Environment
Bi-Lateral Negotiation on Multiple Issues
SoS
Meta architecture generated
Initialize SoS
Conduct SoS Analysis
Develop/Evolve SoS
Plan SoS Update
Implement SoS Architecture
SoS Architecture
Executable Models
Object Process Methodology
Colored Petri Nets
Opportunistic model
Selfish Model
Cooperative Model
System Behavior Types
Architecture Assessment model

Meta-Architecture Generation Multi-Level Model

Before starting the negotiations between the systems and the SoS architect, the SoS architect can initially select a set of systems that, when negotiated, will result in efficient SoS architecture. The multi level meta-architecture generation model provides an SoS architecture such that each capability is provided by at least one system in the SoS while optimizing SoS three key performance attributes.

$$
\begin{aligned}
\text{(SoS-A)}: \quad & \min \quad TC(\mathbf{S},\mathbf{Y},\mathbf{F}) \\
& \min \quad DL(\mathbf{S}) \\
& \max \quad TP(\mathbf{S},\mathbf{F}) \\
& \text{s.t.} \quad \textstyle\sum_{j\in J} a_{ij} S_j \geq 1 \;\forall i \in I && (4)\\
& \quad y_{jk} + y_{kj} \geq S_j + S_k - 1 \;\forall j \in J, \forall k \in J && (5)\\
& \quad S_j \in \{0,1\} \;\forall j \in J && (6)\\
& \quad y_{jk} \in \{0,1\} \;\forall j \in J, \forall k \in J && (7)\\
& \quad F_j \geq 0 \;\forall j \in J && (8)
\end{aligned}
$$

$$TC(\mathbf{S},\mathbf{Y},\mathbf{F}) = \sum_{i\in I}\sum_{j\in J} S_j a_{ij} c_{ij} + \sum_{j_1\in J}\sum_{j_2\in J} h_{j_1 j_2} y_{j_1 j_2} + \sum_{j\in J} F_j$$

Minimize total cost

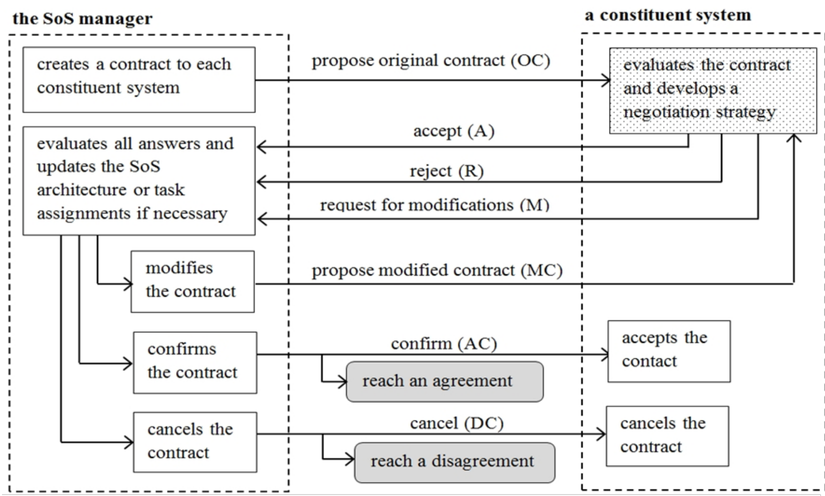
$$DL(\mathbf{S}) = \max_{j\in J}\left\{\max_{i\in I}\{S_j a_{ij} d_{ij}\}\right\}$$

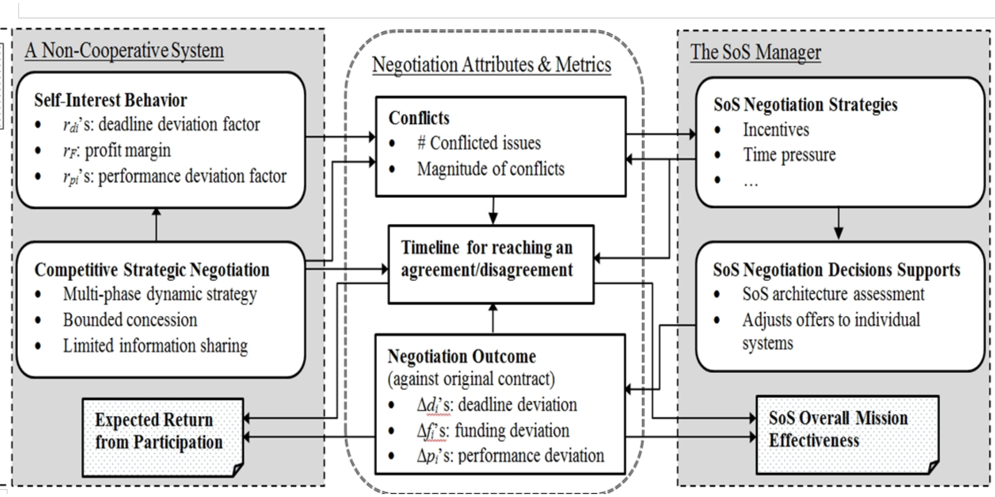
Minimize the deadline

$$TP(\mathbf{S},\mathbf{F}) = \sum_{i\in I}\sum_{j\in J} S_j a_{ij} p_{ij}(F_j)$$

Maximize the performance

System Negotiation Model: Selfish





SoS Explorer

ARCHITECTING

- Improving System-of-Systems means improving System-of-Systems architectures.
- System-of-Systems architectures must make trade-offs between many competing objectives, for example:
  - Affordability
  - Reliability
  - Sustainability
  - Flexibility
  - Performance
- Choosing a best architecture is a multi-Objective optimization problem.

OBSTACLES

Multi-objective optimization problems are difficult for a number of reasons:

- Finding optimal solutions requires careful modeling and advanced optimization methods.
- The number of optimal solutions is usually too large to be comprehended.
- Creating a final architecture from a subset of optimal solutions can easily become arbitrary and sub-optimal.

REMOVING OBSTACLES

- System-of-Systems architecting could be improved by
  - Structuring the modeling effort
  - Optimization methods yielding targeted solution sets
  - Visualization of architectures
  - Interactive architectures allowing "what-if" experimentation

SOS EXPLORER

- SoS Explorer is our solution to the previously identified
- architecting difficulties. It provides Structure for the modeling effort
- A novel optimization method called "MOEA-DM" tailored to the needs of SoS architects:
  - Many-objective optimization
  - Use of clustering to cultivate a limited set of solutions of interest
- Visualization of architectures
- Interactive "what-if" experimentation

OVERALL APPROACH

- The SoS architecture is comprised of systems and their interfaces.
- Systems are modeled using the following attributes:
  - Characteristics: Real-valued attributes such as cost and MTBF.
  - Capabilities: Boolean attributes that a system either has or doesn't
    - have such as a VHF radio or ground-mapping radar.
  - Interfaces: Boolean attributes describing whether a system can support an interface with another system.
- The models output key performance metrics that are used as the objectives in the provided optimization algorithms.

MODELING

- The models take as input the system attributes and calculate the values of the KPMs.
- The models are used for two purposes: to display the KPMs for the displayed architecture and for the optimization algorithms.
- Models may be written in any of the following languages:
  - Python,
  - MATLAB,
  - F#

LANGUAGE SELECTION

- The languages can be selected based on the priority of the modeler:
  - Python provides portability and can be run without anything installed other than SoS Explorer.
  - MATLAB provides a rich set of tools but requires MATLAB to be installed.
  - F# is a compiled Microsoft .NET language and is around 100 times faster than MATLAB and Python. However, it requires the F# SDK (free from Microsoft) to be installed.

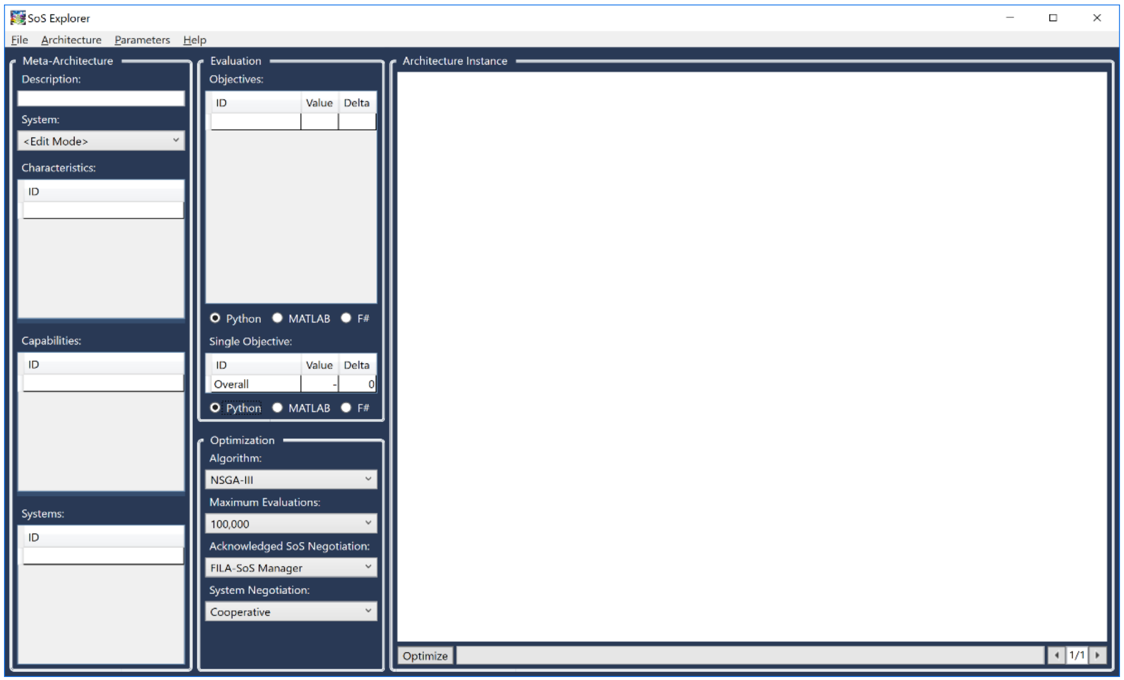
CODE GENERATION

- SoS Explorer can auto-gen source for each KPM in any supported language. The code is a fully functioning template for creating a model:
  - All systems and attributes are fully mapped
  - Sample calculations illustrating scalable methods of using the attributes and given architecture to find a KPM.

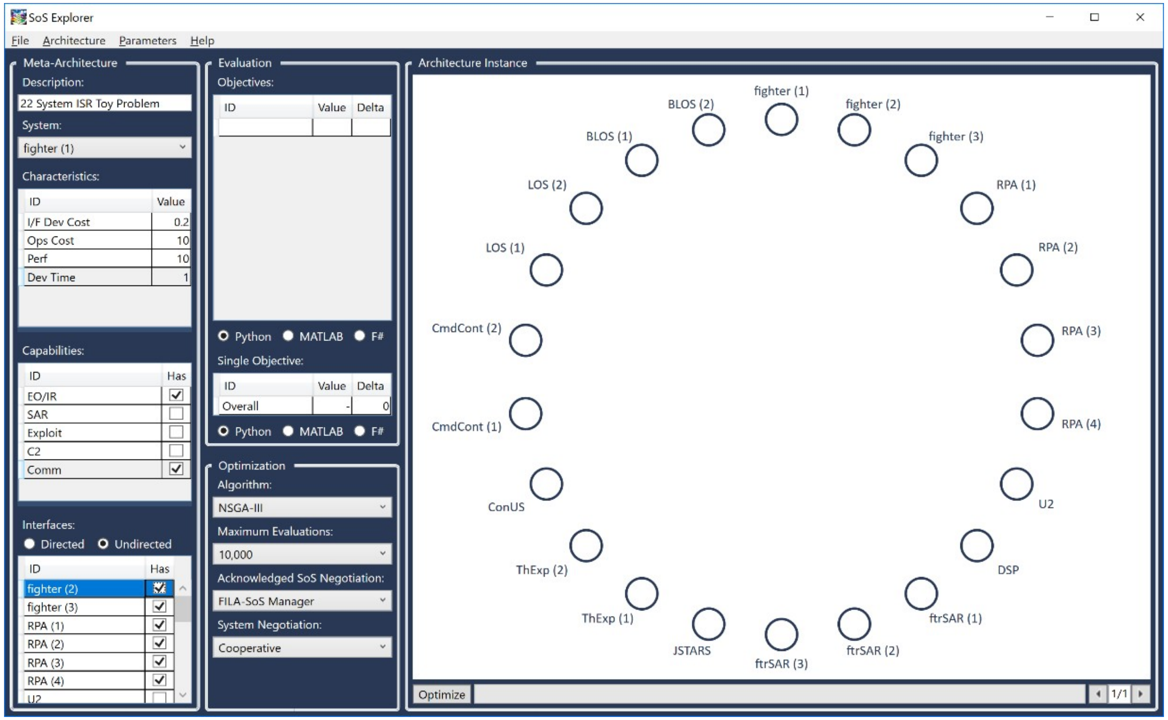
OPTIMIZATION

- SoS Explorer supports
  - Single objective optimization
    - User specifies a function (Python, MATLAB, or F#) to map the objectives to a single overall objective
    - Employs the SOGA genetic algorithm
  - Multiple objective optimization
  - Supports the NSGA-III many objective algorithm
  - Supports the MOEA-DM many objective algorithm

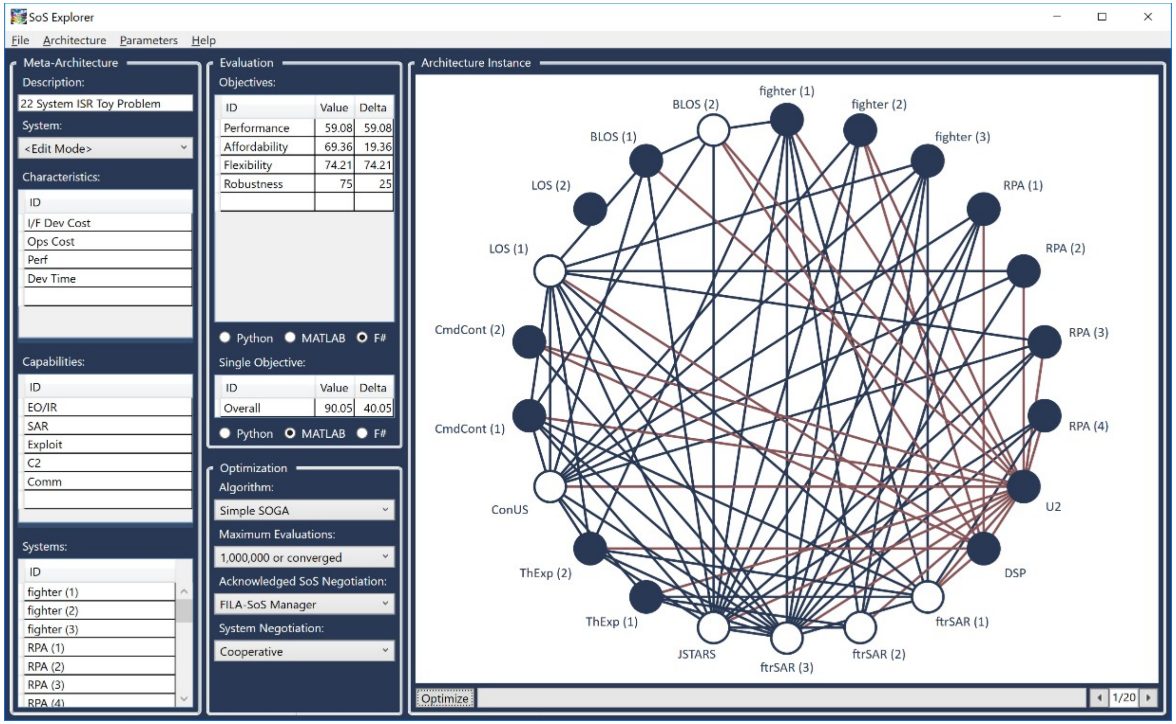
THE GUI


SoS Explorer
File Architecture Parameters Help
Meta-Architecture
Description:
System:
<Edit Mode>
Characteristics:
ID
Capabilities:
ID
Systems:
ID
Evaluation
Objectives:
ID Value Delta
Python MATLAB F#
Single Objective:
ID Value Delta
Overall - 0
Python MATLAB F#
Optimization
Algorithm:
NSGA-III
Maximum Evaluations:
100,000
Acknowledged SoS Negotiation:
FILA-SoS Manager
System Negotiation:
Cooperative
Architecture Instance
Optimize
1/1

THE META-ARCITECTURE



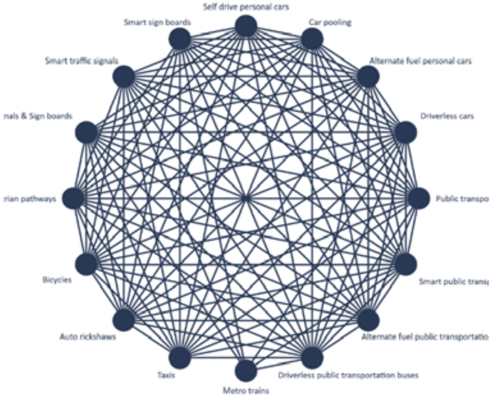
THE RESULT


SoS Explorer
File Architecture Parameters Help
Meta-Architecture
Description:
22 System ISR Toy Problem
System:
<Edit Mode>
Characteristics:
ID
I/F Dev Cost
Ops Cost
Perf
Dev Time
Capabilities:
ID
EO/IR
SAR
Exploit
C2
Comm
Systems:
ID
fighter (1)
fighter (2)
fighter (3)
RPA (1)
RPA (2)
RPA (3)
Evaluation
Objectives:
ID Value Delta
Performance 59.08 59.08
Affordability 69.36 19.36
Flexibility 74.21 74.21
Robustness 75 25
Python MATLAB F#
Single Objective:
ID Value Delta
Overall 90.05 40.05
Python MATLAB F#
Optimization
Algorithm:
Simple SOGA
Maximum Evaluations:
1,000,000 or converged
Acknowledged SoS Negotiation:
FILA-SoS Manager
System Negotiation:
Cooperative
Architecture Instance
fighter (1)
BLOS (2)
fighter (2)
BLOS (1)
fighter (3)
LOS (2)
RPA (1)
LOS (1)
RPA (2)
CmdCont (2)
RPA (3)
CmdCont (1)
RPA (4)
ConUS
U2
ThExp (2)
DSP
ThExp (1)
ftrSAR (1)
JSTARS
ftrSAR (2)
ftrSAR (3)
Optimize
1/20

CMS Technology in the Next Ten Years

There will be multi-faceted systems in different levels of implementation that entail complex logic with many levels of reasoning in intricate arrangement, organized by web of connections and demonstrating self-driven adaptability which are designed for autonomy and exhibiting emergent behavior that can be visualized.

Where are the adaptive architectures for them?



Publications

- Ruwen Qin, Cihan H Dagli and Nnaemeka Amaeshi. “A Contract Negotiation Model for Constituent Systems in the Acquisition of Acknowledged System of Systems” IEEE Transactions on Systems, Man, and Cybernetics: Systems on line publication 2016.
- Konur, Dinçer, Hadi Farhangi, and Cihan H. Dagli. "A multi-objective military system of systems architecting problem with inflexible and flexible systems: formulation and solution methods." OR Spectrum (2016): 1-40.
- Dincer Konur and Cihan H Dagli “Military system of systems architecting with individual system contracts”, Optimization Letters, December 2015, Volume 9, Issue 8, pp 1749-1767 http://link.springer.com/article/10.1007/s11590-014-0821-z
- Kilicay-Ergin, N. and Dagli, C. (2015), “Incentive-Based Negotiation Model for System of Systems Acquisition”. Syst. Engineering., 18: 310–321. doi:10.1002/sys.21305 http://onlinelibrary.wiley.com/doi/10.1002/sys.21305/full
- Paulette Acheson, Cihan Dagli, and Nil Kilicay-Ergin, “Fuzzy Decision Analysis in Negotiation between the System of Systems Agent and the System Agent in an Agent-Based Model,” in International Journal of Soft Computing and Software Engineering[JSCSE], Volume 3, No. 3, Pages 25-29, (www.jscse.com) ISSN 2251-7545, 2013.

Publications

- Agarwal, Siddhartha, Cihan H. Dagli, and Louis E. Pape II. "Computational intelligence based complex adaptive system-of-system architecture evolution strategy." Complex Systems Design & Management. Springer International Publishing, 2016. 119-132.
- Agarwal,S., Wang, R., & Dagli, C., (2015) FILA-SoS, Executable Architectures using Cuckoo Search Optimization coupled with OPM and CPN-A module: A new Meta-Architecture Model for FILA-SoS, in Complex Systems Design & Management (CSD&M) editor, Boulanger, Frédéric, Krob, Daniel, Morel, Gérard, Roussel, Jean-Claude, P 175-192 . Springer International Publishing.
- Cihan H. Dagli and N. Kilicay-Ergin, "Chapter 4: System of Systems Architecting", in System of Systems Engineering, M. Jamshidi (editor), Wiley & Sons Inc., 2009, p. 77-101.
- Gene Lesinski, Steven M Corns, Cihan H Dagli " A fuzzy genetic algorithm approach to generate and assess meta-architectures for non-line of site fires battlefield capability" Evolutionary Computation (CEC), 2016 IEEE Congress on 24-29 July 2016. DOI: 10.1109/CEC.2016.7744085
- Rahul Alaguvelu, David M Curry, Cihan H Dagli " Fuzzy — Genetic algorithm approach to generate an optimal meta-architecture for a smart, safe & efficient city transportation system of systems "System of Systems Engineering Conference (SoSE), 2016 11th IEEE, June 12-16, 2016. DOI: 10.1109/SYSOSE.2016.7542935

Publications

- George Muller, Cihan Dagli "Simulation for a coevolved system-of-systems meta-architecture" System of Systems Engineering Conference (SoSE), 2016 11th IEEE, June 12-16, 2016. DOI: 10.1109/SYSOSE.2016.7542931
- Dagli, Cihan H. "Engineering Cyber Physical Systems: Machine Learning, Data Analytics and Smart Systems Architecting Preface." Procedia Computer Science 61 (2015): 8-9.
- Agarwal, S., Pape, L.E., Dagli, C.H., Ergin, N.K., Enke, D., Gosavi, A., Qin, R., Konur, D., Wang, R. and Gottapu, R.D., 2015. Flexible and Intelligent Learning Architectures for SoS (FILA-SoS): Architectural Evolution in Systems-of-Systems. Procedia Computer Science, 44, pp.76-85.
- Curry, David M., and Cihan H. Dagli. "A Computational Intelligence Approach to System-of-Systems Architecting Incorporating Multi-objective Optimization." Procedia Computer Science 44 (2015): 86-94.

Publications

- Dagli, Cihan H. "Engineering Cyber Physical Systems: Machine Learning, Data Analytics and Smart Systems Architecting Preface." Procedia Computer Science 61 (2015): 8-9.
- Pape, Louis, Siddhartha Agarwal, and Cihan Dagli. "Selecting Attributes, Rules, and Membership Functions for Fuzzy SoS Architecture Evaluation."Procedia Computer Science 61 (2015): 176-182.
- Agarwal, Siddhartha, Louis E. Pape, and Cihan H. Dagli. "A Hybrid Genetic Algorithm and Particle Swarm Optimization with Type-2 Fuzzy Sets for Generating Systems of Systems Architectures." Procedia Computer Science 36 (2014): 57-64.
- Wang, R., Agarwal,S., & Dagli, C. (2014). Executable System of Systems Architecture Using OPM in Conjunction with Colored Petri Net: A Module for Flexible Intelligent & Learning Architectures for System of Systems, In Europe Middle East & Africa Systems Engineering Conference (EMEASEC).
- C. O .Adler, C. H. Dagli “Study of the Use of a Genetic Algorithm to Improve Networked System-of-Systems Resilience”,Procedia Computer Science 36, 49-56, 2014

SoS Videos for FILA-SoS

- Integrated Model Structure (FILA-SoS Version 1.0) Systems Engineering Research Center Presentation on "Integrated Model Structure" by Principal Investigator: Cihan Dagli, Missouri University of Science and ...

- Architecture Assessment Model (FILA-SoS Version 1.0) Systems Engineering Research Center Presentation on "Integrated Model Structure" by Louis Pape II, Doctoral Student under Cihan Dagli, both of Missouri University of ...

- Fuzzy-Genetic Optimization Model (FILA-SoS Version 1.0) Systems Engineering Research Center Presentation on Fuzzy-Genetic Optimization Model for the Systems Engineering Research Center by Louis Pape II on October ...

SoS Videos for FILA-SoS

- Meta-Architecture Generation Multi-Level Model (FILA-SoS Version 1.0) Systems Engineering Research Center Presentation on "Meta-Architecture Generation Multi-Level Model" by Co-Principal Investigator: Dincer Konur, Missouri University ...

- Incentive Based Negotiation Model for System of Systems (FILA-SoS Version 1.0) Systems Engineering Research CenterPresentation on "Incentive Based Negotiation Model for System of Systems" by Co-Principal Investigator: Nil Ergin, Penn State ...

- Non-Cooperative System Negotiation Model (FILA-SoS Version 1.0) Systems Engineering Research Center Presentation on "Non Cooperative System Negotiation Model" by Co-Principal Investigator: Ruwen Qin, Missouri University of ...

SoS Videos for FILA-SoS

- Semi-Cooperative System Negotiation Model (FILA-SoS Version 1.0) Systems Engineering Research Center Presentation on "Semi-Cooperative System Negotiation Model" by Co-Principal Investigator: Abhijit Gosavi, Missouri University of ...

- Cooperative System Negotiation Model (FILA-SoS Version 1.0) Systems Engineering Research Center Presentation on "Cooperative System Negotiation Model" by Co-Principal Investigator: David Enke, Missouri University of Science ...

- Executable Model-Object Process Methodology OPM and Color Petri Nets CPN (FILA-SoS Version 1.0) Systems Engineering Research Center Presentation on "Executable Model-Object Process Methodology OPM and Color Petri Nets CPN FILA-SoS" by Co-Principal ...

Today's Presentation

Things to Think About

How can this be applied in your work environment?

What did you hear that will influence your thinking?

What is your take away from this presentation?

Please

The link for the online survey for this meeting is

www.surveymonkey.com/r/2017_11_MeetingEval

www.surveymonkey.com/r/2017_11_MeetingEval

Look in GlobalMeet chat box for cut & paste link.

Slide presentation can be downloaded now/anytime from:

The library page at: www.incose.org/enchantment.

Recording will be there in the library tomorrow.