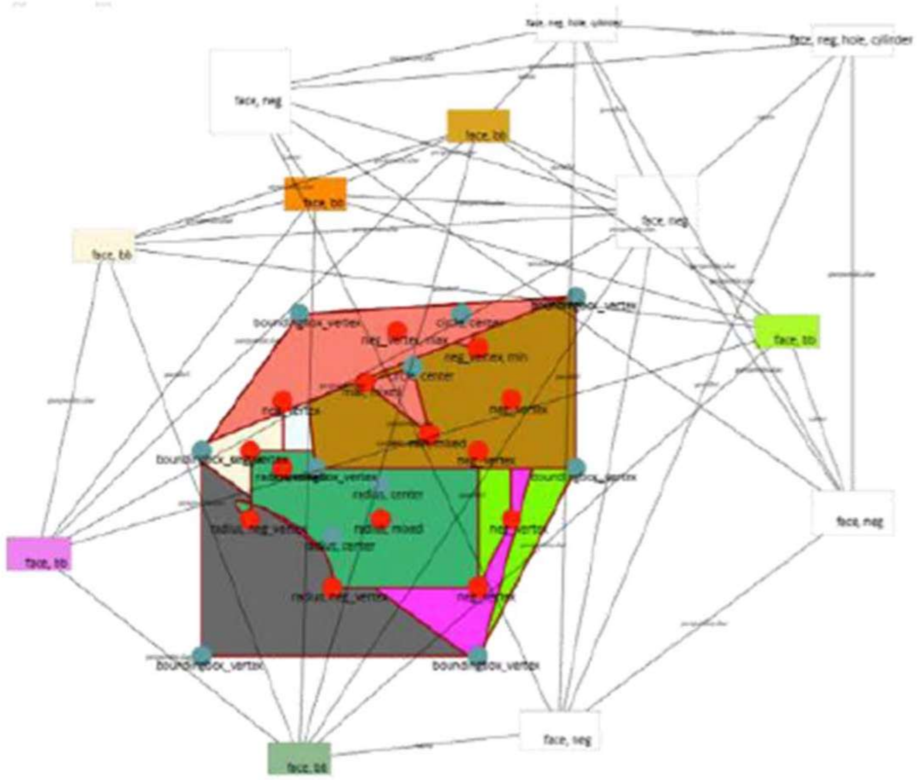
META – iFAB – AVM: Design Decomposition

Topological Decomposition

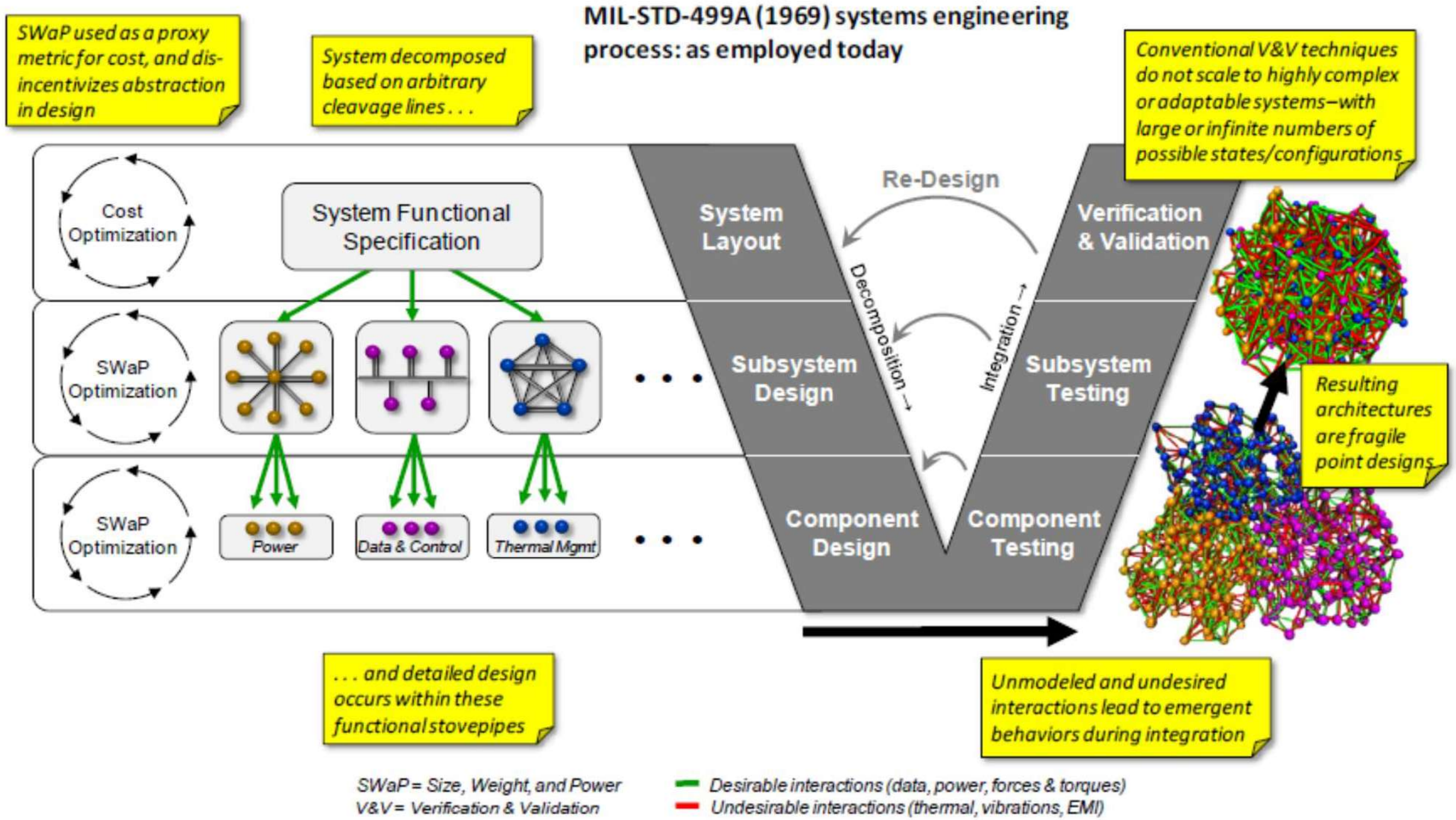


"Reverse Composition"

Source: Xerox PARC

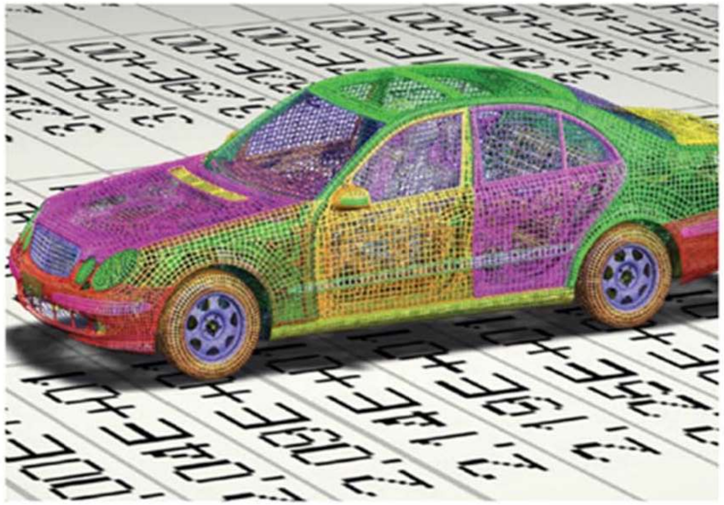
The Institute for Systems Research

Need to Improve Systems Engineering Methods and Tools Dramatically



Source: Paul Eremenko, DARPA/TTO

Integrating in Hubs Siemens PLM Tools: Automotive



SIEMENS

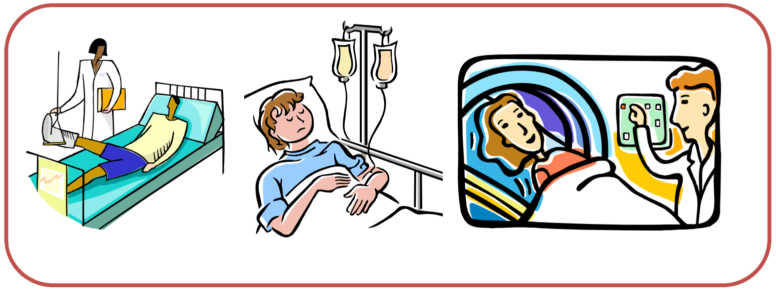
Convergence = new home health platform

- Digital home entertainment infrastructure can be used for health
- Everyday health through everyday devices
- Personalized, proactive health info/reminders/agents

INTEL

Intel's Proactive Health Lab

Model-Based Systems Engineering for ITU Management

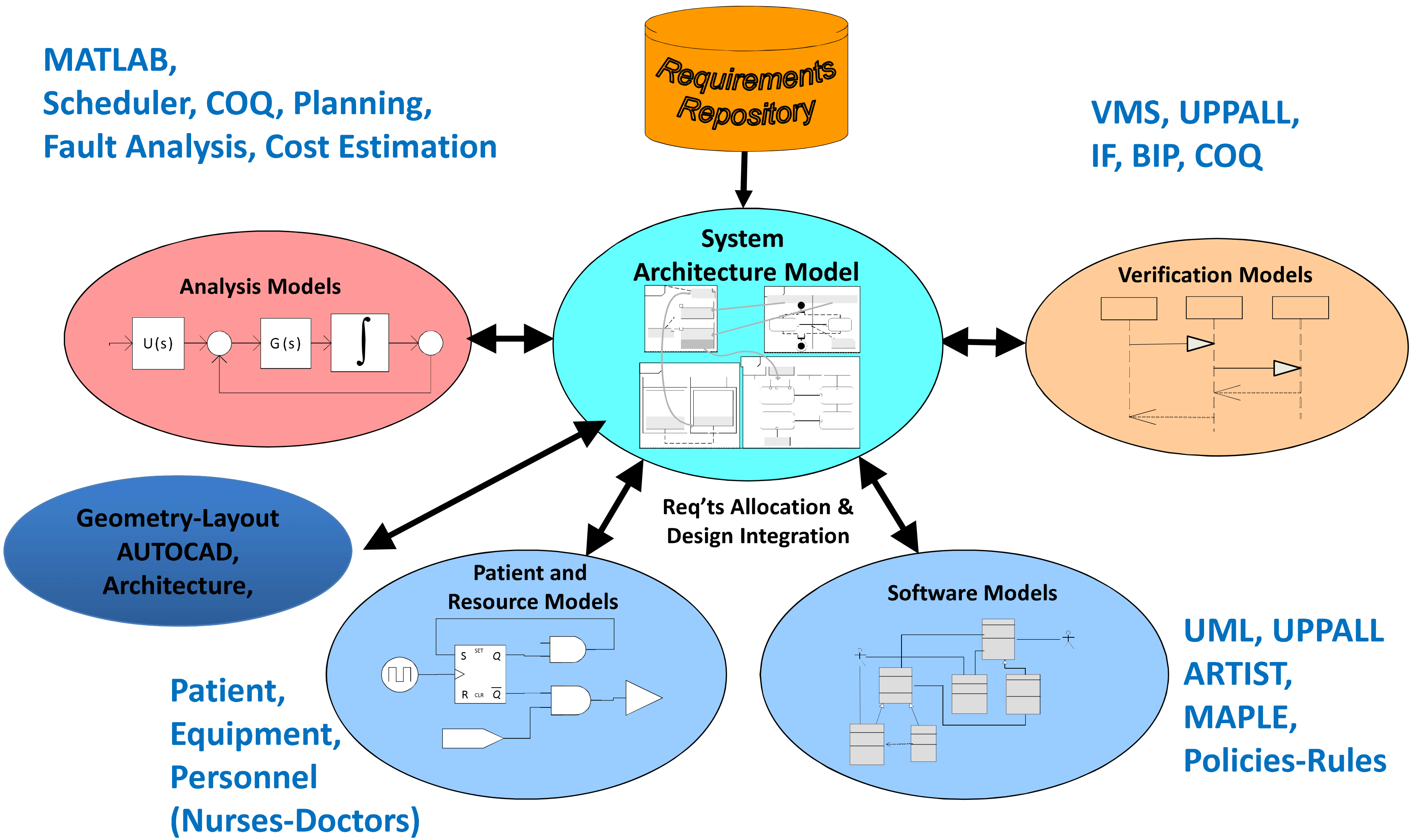


Healthcare operations

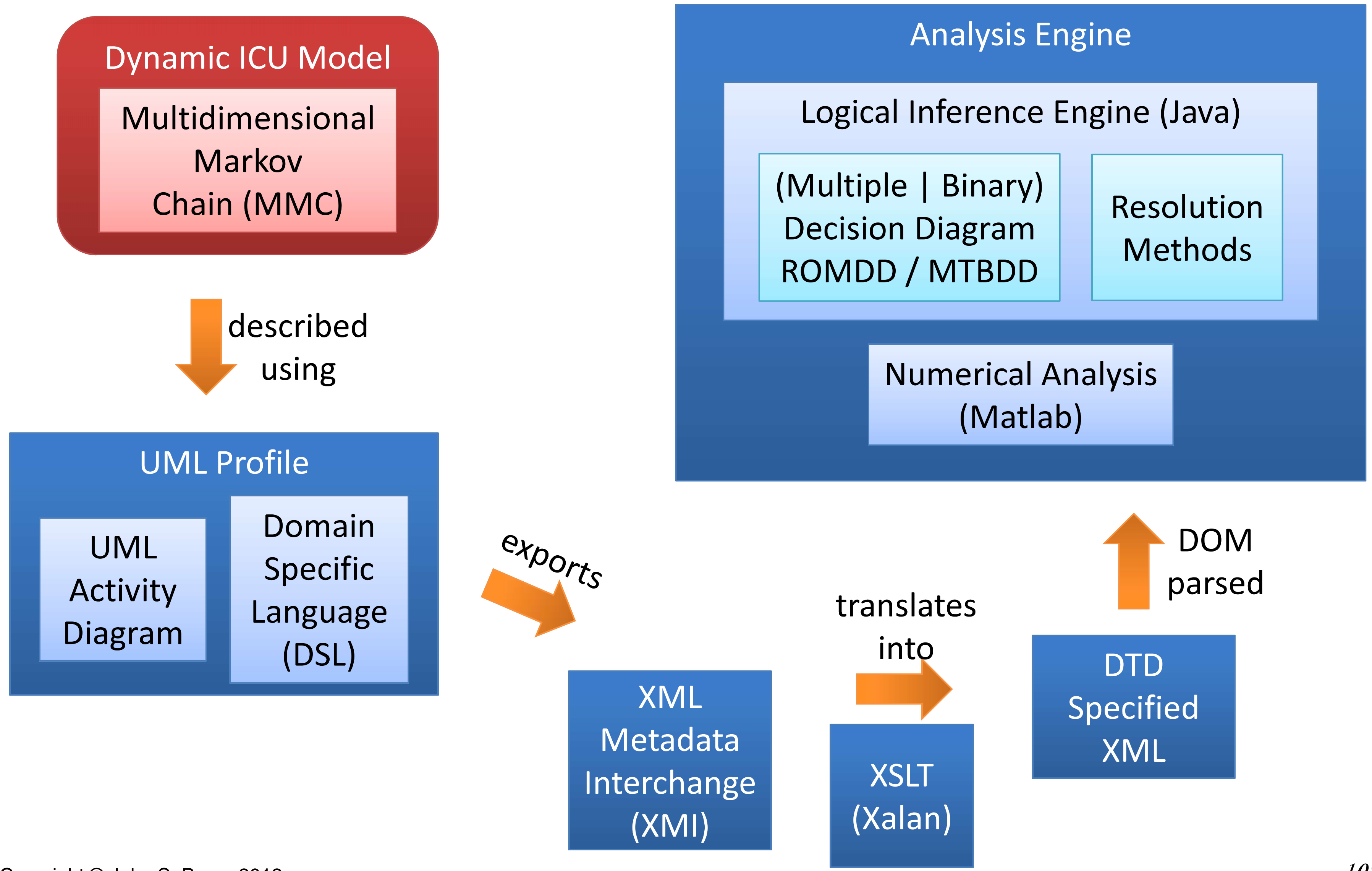
Monitor performance, generate ideas, implement changes

Build models, analyze operations, predict changes

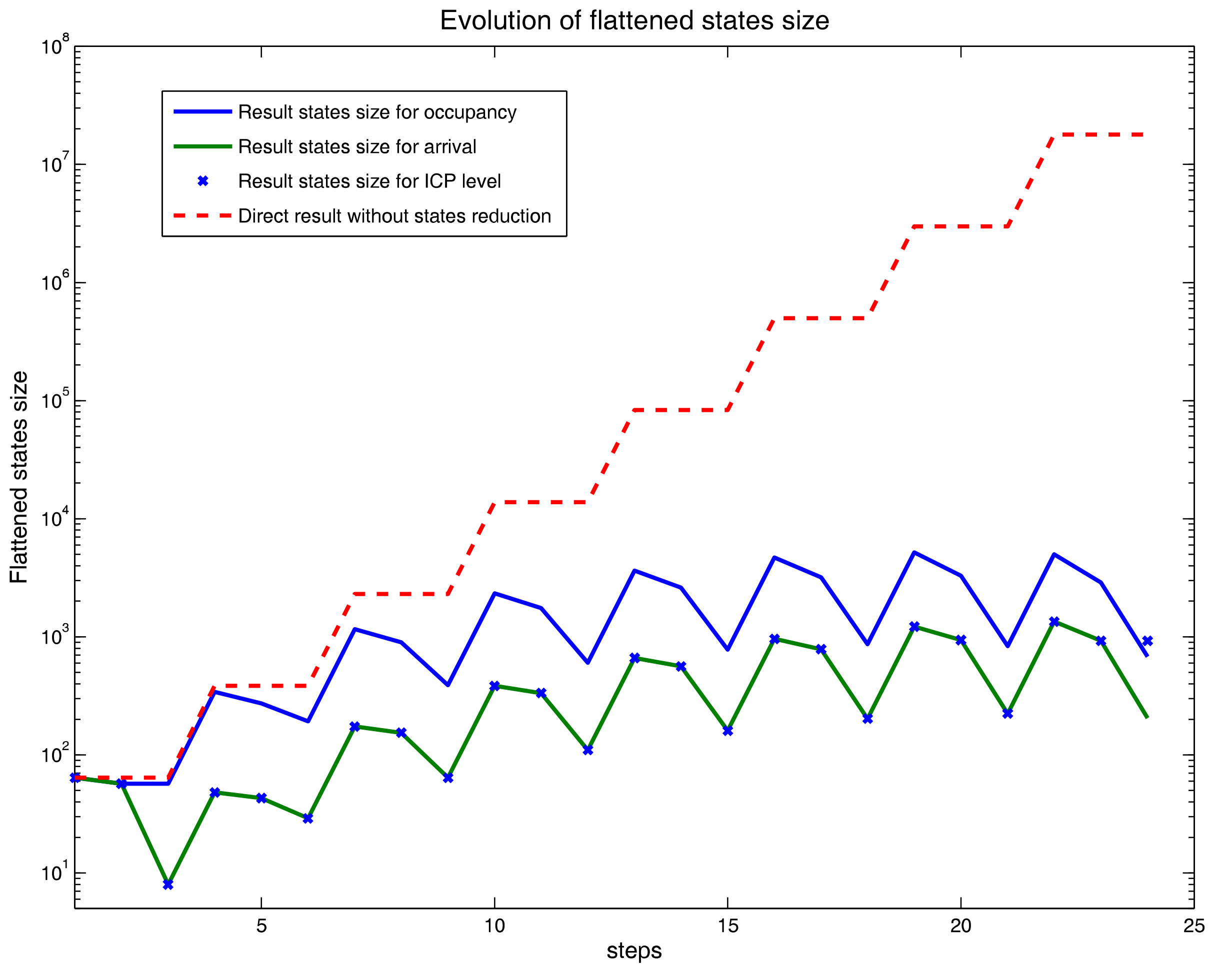
Using *System Architecture Model* as a MODEL Integration Framework



Implementation



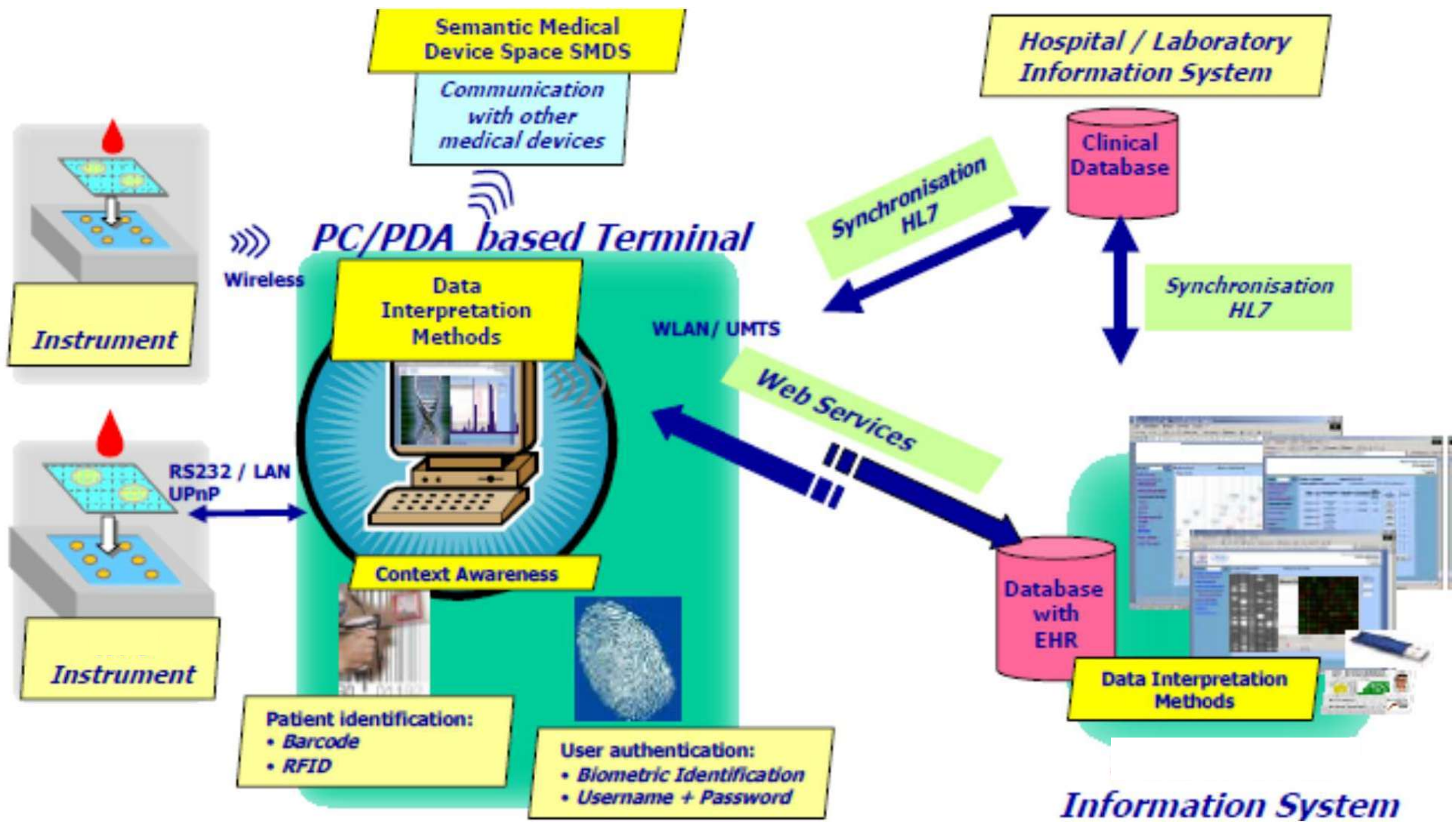
State Reduction Achieved



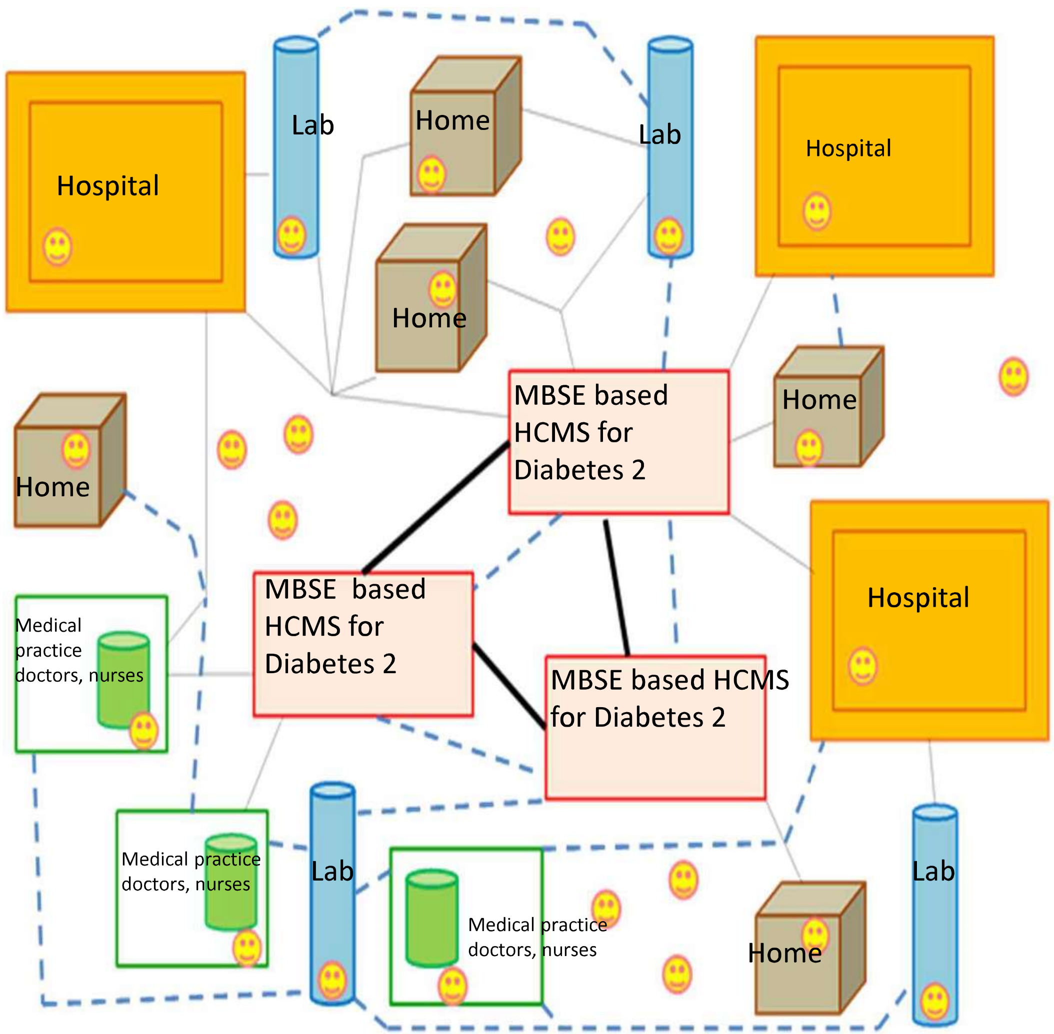
Number of states as a fcn of number of steps in inference

Sawtooth pattern is the result of the project-compose pattern

"Smart" Health ICT Platform (Ambient Health Information Management)



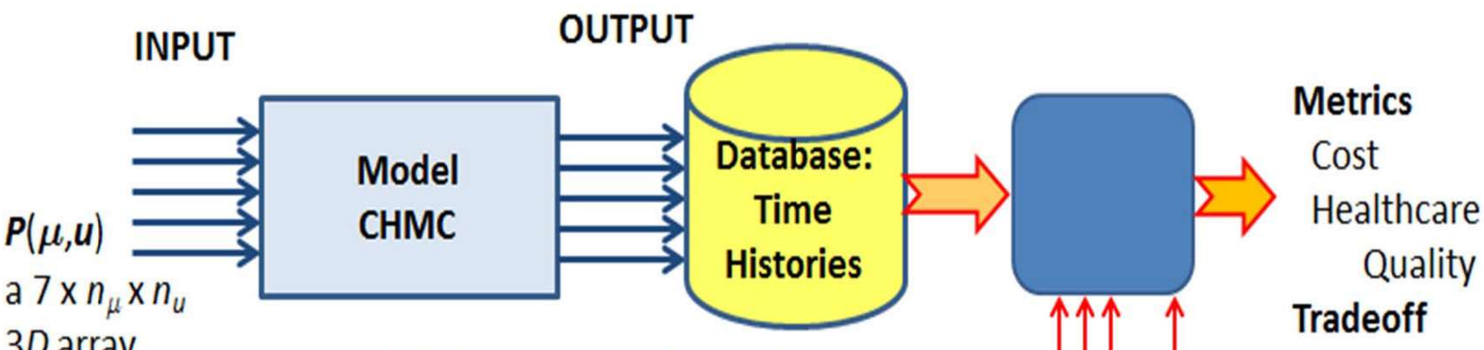
MBSE based HCMS for Diabetes II and its functional connectivity



Reasoning Engine through MBSE Framework

Health Quality Metric combines patient health risk behavior and patient time history counting

$$J_{hc}(i,m_i) = V_1^i * O_1^i(m_i) + V_2^i * O_2^i(m_i) + V_3^i * O_3^i(m_i)$$



Set of triples of arrays: (s, μ, u)

Cardinality: $N_p \times N_s \times n_x^{(N_{T,\Delta}+1)} \times (n_\mu \times n_u)^{N_{T,\Delta}}$

Each triple size: $3 \times N_{T,\Delta} + 1$

Set of triples O

Cardinality: $N_p \times N_s \times n_x^{(N_{T,\Delta}+1)} \times (n_\mu \times n_u)^{N_{T,\Delta}}$

Reasoning Engine through MBSE Tradeoff Analysis

- Developed Reasoning Engine of the HCMS, based on these disease models and metrics of health state time history: focus in these evaluations are systematic Tradeoffs (Pareto points)
- Three computational methods developed and used
- First method, **Evaluation by Monte Carlo Simulation (EMCS),** uses the model in an exhaustive generation of all possible sample paths (time histories) for any number of patients
- The second method **Fully Observable Multi- Criteria Optimization (FOMCO)** and the third **Partially Observable Multi-Criteria Optimization (POMCO)**, employ multi-criteria optimization to directly compute the Pareto points and associated selection of tests and interventions

  Both use Dynamic Programming for computations

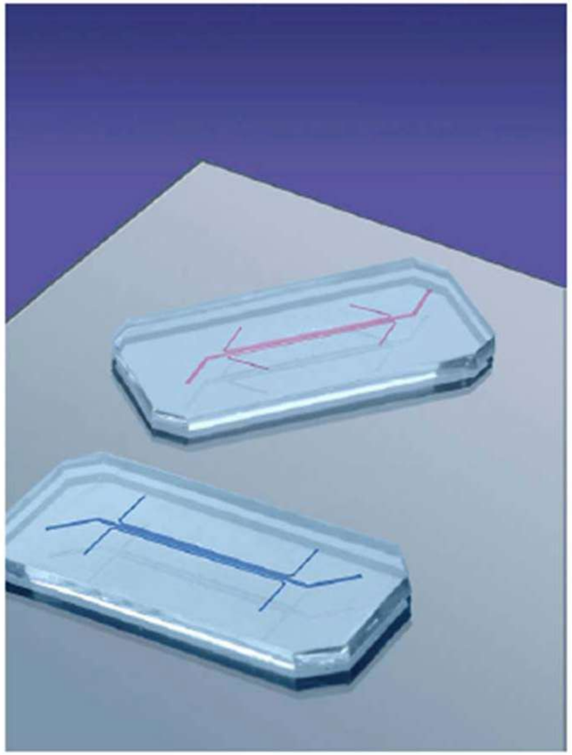
Reasoning Engine: Decision Making & Analytics Capabilities

Can provide answers to many practical questions, queries, problems, from health care management perspective

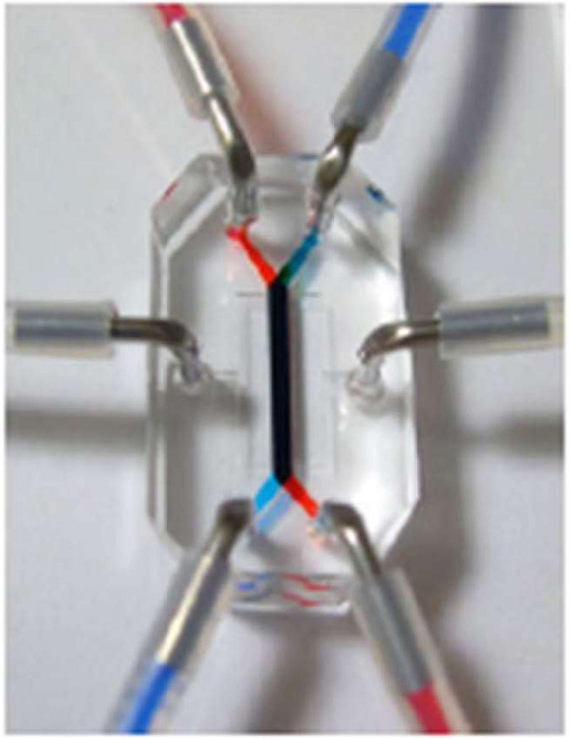
- Evaluate patient risk behavior impact on health care quality
- Evaluate “best” health care achievable
- Can learn from new data, treatment results, improve models
- Evaluate “value” of new proposed tests and interventions
- Provide aggregate statistics for insurance policies calibration
- Find best tests and interventions for patient type, disease state
- Evaluate effects of incentives and rewards for health “maintenance”
- Evaluate sequences of tests and treatments for reversing disease

Revolutionizing Drug Manufacturing: Organ-on-a Chip -- Biochips

Wyss-Lung on a chip -- 2010



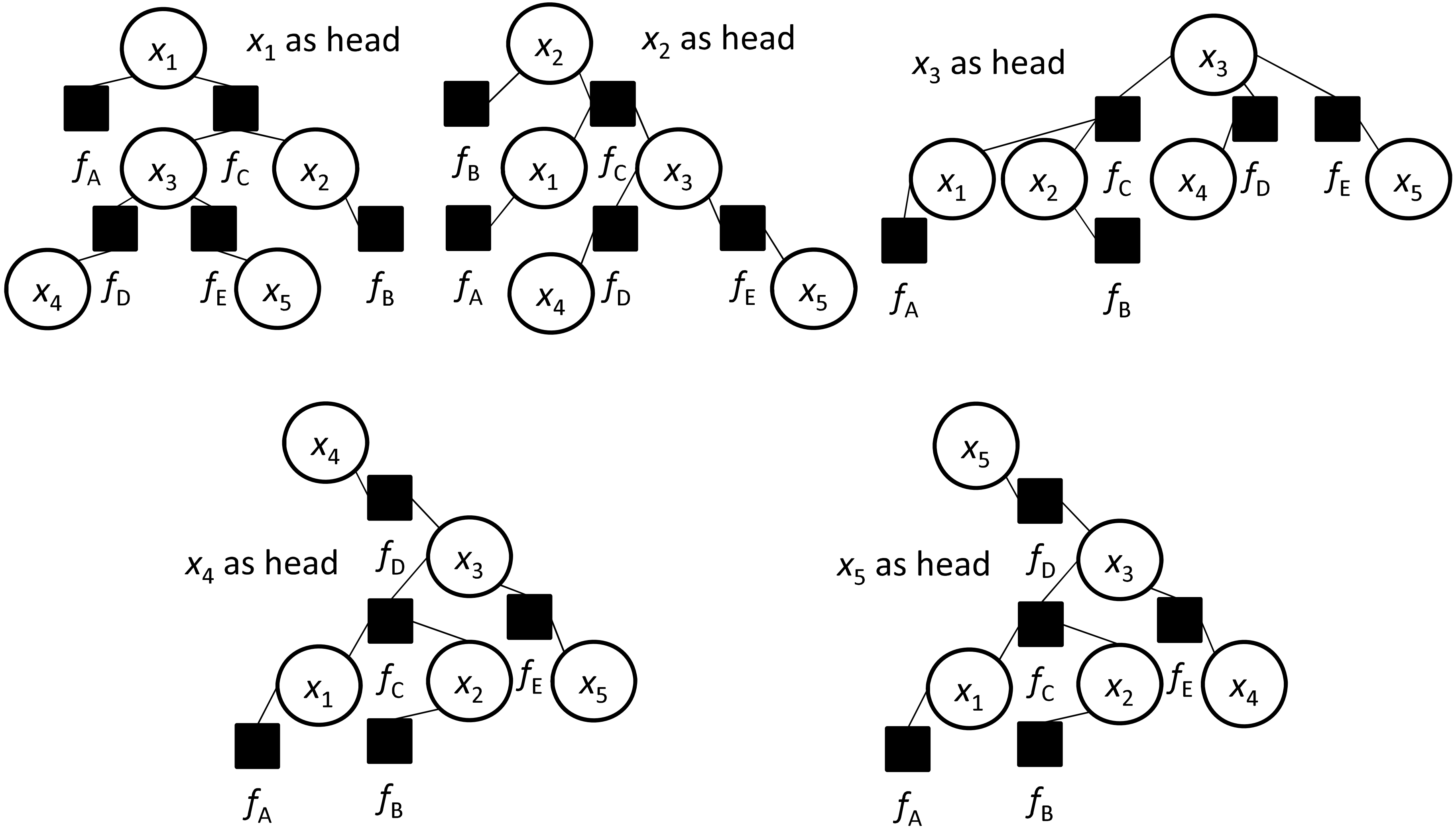
Wyss-Gut on a chip -- 2012



Design Space Exploration: Queries and Complexity

- Large, complex systems have many tunable parameters
- To perform **tradeoff analysis at system level**, a simplified view of the underlying components must be available
- **Challenge**: create an abstract, tractable representation of underlying components.
- **Hypothesis**: Although components are not perfectly decoupled, structure provides useful information for parametric decomposition
- The query itself influences the shape of the resulting graph
- A query that is not local can create links between non-local variables
- The resulting graph and *analysis complexity is dependent on the query*

Query Induced Hierarchies

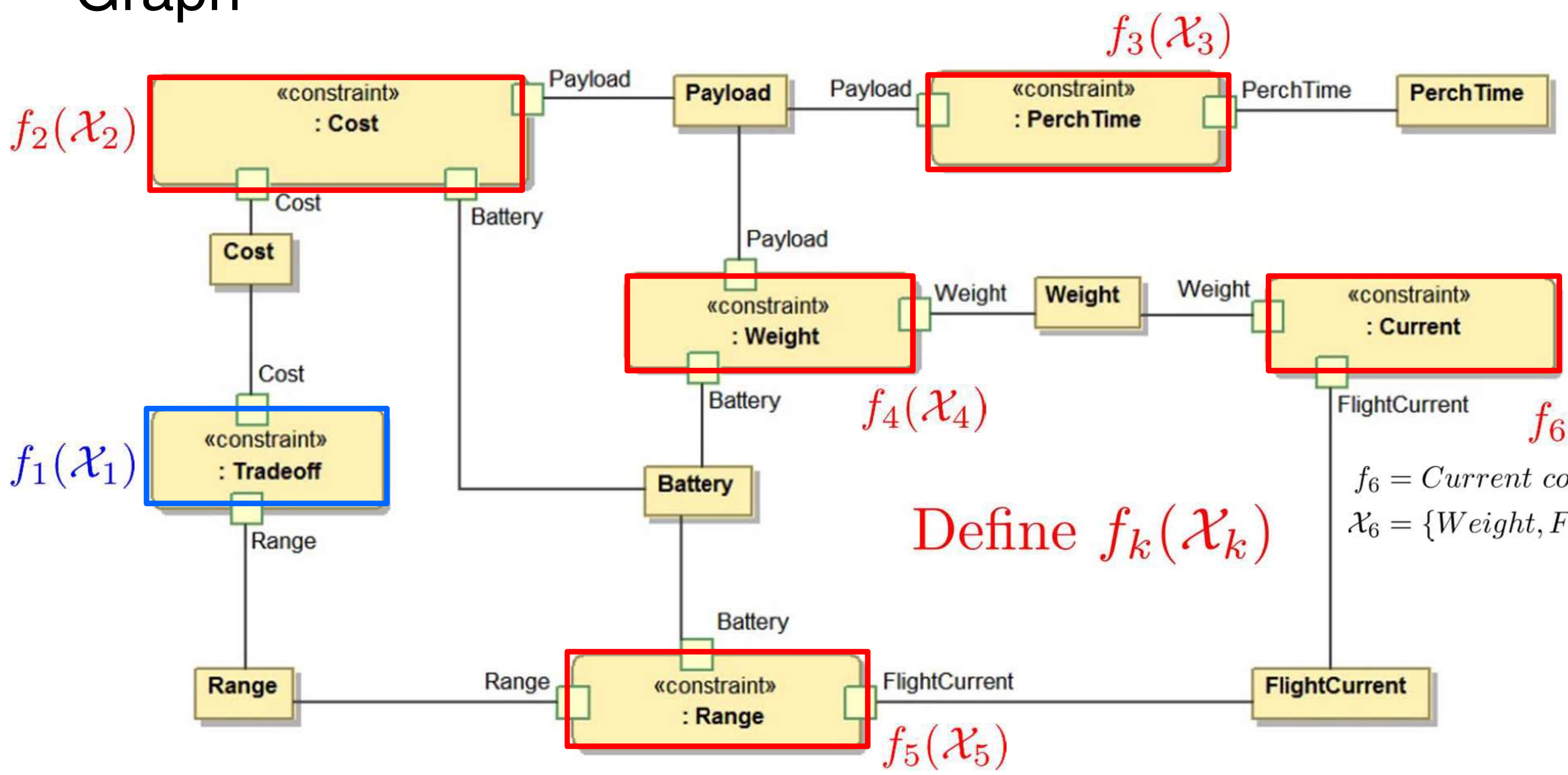


Factor Join Trees in Systems Design Space Exploration and Decomposition

- **Results/Contributions:**
- Starting from an undirected graph representation of the system developed a "divide and conquer" methodology and tool to choose subsets of nodes that completely separate the graph
- Separation produces interfaces -- leads to system decomposition in trees; "width" of a decomposition the size of the largest system component while "treewidth" is the minimum possible width over all tree decompositions
- Decomposition complexity is exponential in treewidth and linear in problem size
- By using novel organization of tradeoff queries for design space exploration, the method leads to chordal systems – decomposition performed in **linear time**

Example: Quadrotor

SysML Parametric Diagram ➔ Functional Dependence Graph



Define $f_k(\mathcal{X}_k)$

$f_6 = Current\ constraint$

$\mathcal{X}_6 = \{Weight, FlighCurrent\}$

Figure: SysML Parametric Diagram (Factor Graph)

Example: Quadrotor

SysML Parametric Diagram ➔ **Functional Dependence Graph** ➔ Join Tree

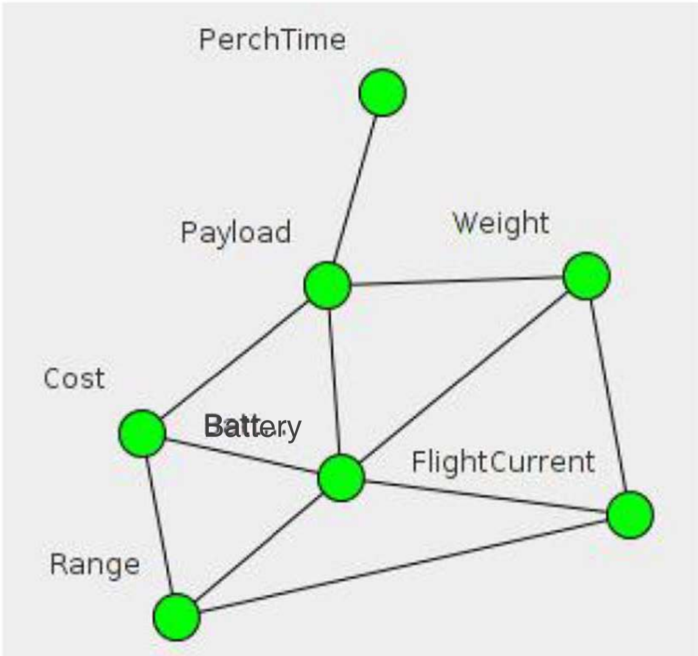


Figure: Functional Dependence Graph (step 1)

Example: Quadrotor

SysML Parametric Diagram ➔ Functional Dependence Graph ➔ **Join Tree** ➔ Factor Join Tree

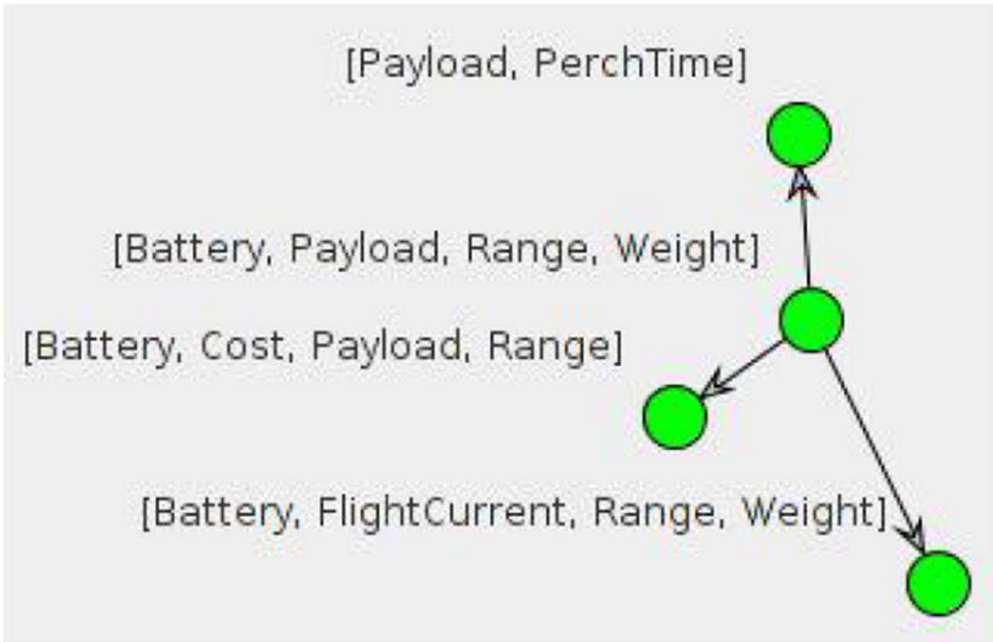


Figure: Join Tree (step 2)

Example: Quadrotor

SysML Parametric Diagram ➔ Functional Dependence Graph ➔ Join Tree ➔ Factor Join Tree ➔ **Summary Propagation**

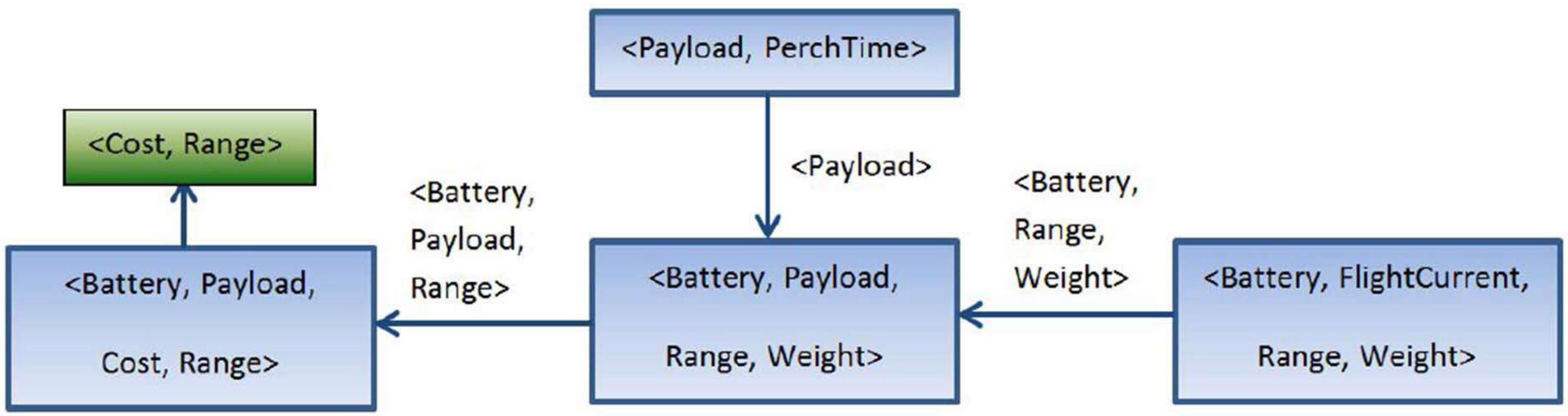
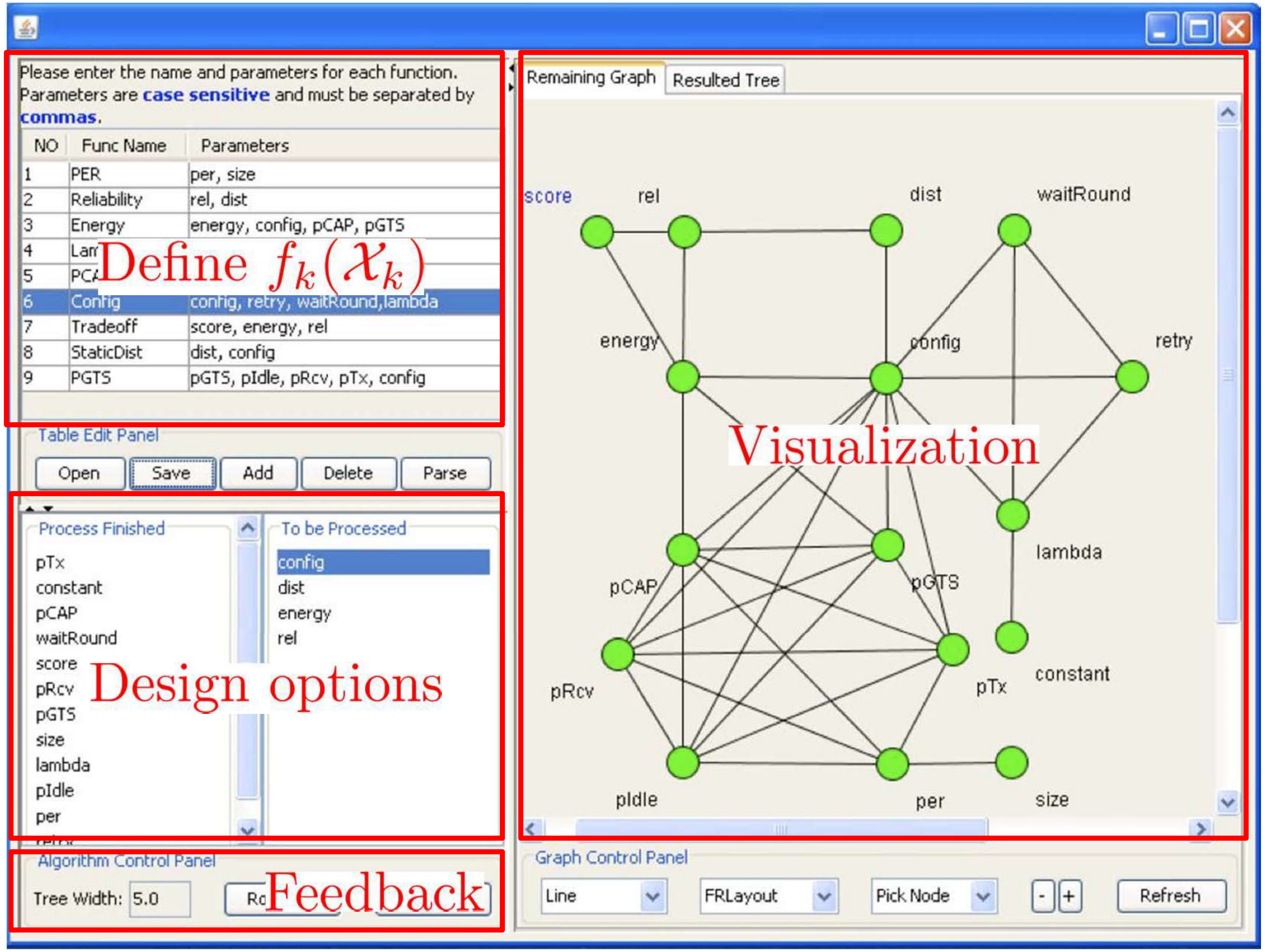


Figure: Summary Propagation (step 4): $\langle \oplus = Projection, \otimes = Intersecion \rangle$

Complexity of system analysis: reduced from D^7 to $3D^4 + D^2$

GUI


Please enter the name and parameters for each function. Parameters are case sensitive and must be separated by commas.
NO Func Name Parameters
1 PER per, size
2 Reliability rel, dist
3 Energy energy, config, pCAP, pGTS
6 Config config, retry, waitRound,lambda
7 Tradeoff score, energy, rel
8 StaticDist dist, config
9 PGTS pGTS, pIdle, pRcv, pTx, config
Define $f_k(\mathcal{X}_k)$
Table Edit Panel
Open
Save
Add
Delete
Parse
Process Finished
pTx
constant
pCAP
waitRound
score
pRcv
pGTS
size
lambda
pIdle
per
To be Processed
config
dist
energy
rel
Design options
Algorithm Control Panel
Tree Width: 5.0
Feedback
Remaining Graph
Resulted Tree
score
rel
dist
waitRound
energy
config
retry
Visualization
lambda
pCAP
pGTS
pRcv
pTx
constant
pIdle
per
size
Graph Control Panel
Line
FRLayout
Pick Node
Refresh

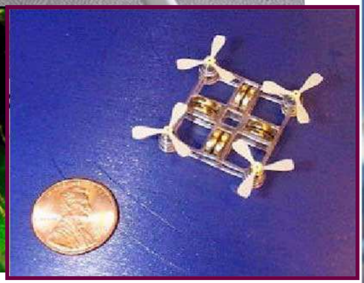
The Institute for Systems Research

How to Use It?

- Input constraints of SysML Parametric Diagrams
- Interact with our tool to generate a factor join tree
- Roll back if necessary
- Create SysML Block Diagrams
- Revise the original SysML Parametric Diagrams
- Analyze the system using summary propagation

Autonomous Swarms – Networked Control

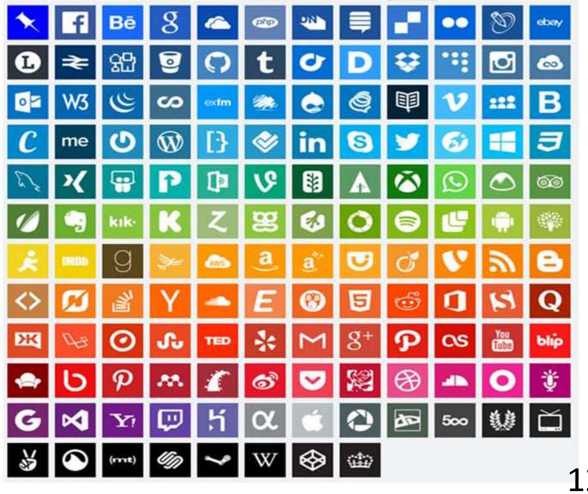


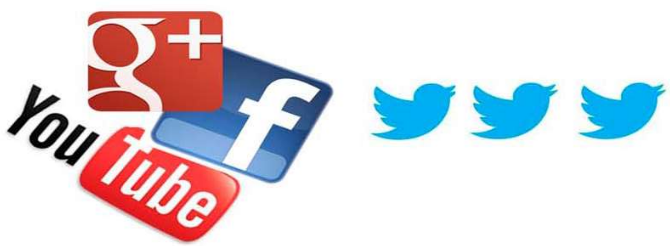


- *Component-based Architectures*
- *Communication vs Performance Tradeoffs*
- *Distributed asynchronous*
- *Fundamental limits*

Social Networks over the Web

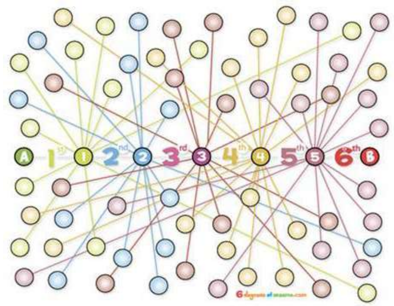
- We are much more “social” than ever before
  - Online social networks (SNS) permeate our lives
  - Such new Life style gives birth to new markets
- Monetize the value of social network
  - Advertising - major source of income for SNS
  - Joining fee, donation etc.
  - …
- Need to know the common features of social networks



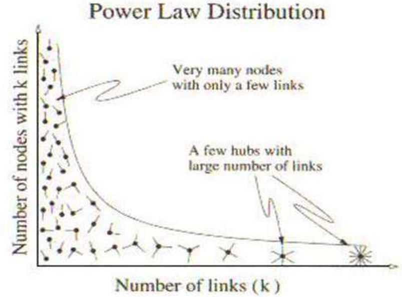


Social Networks -- Challenges

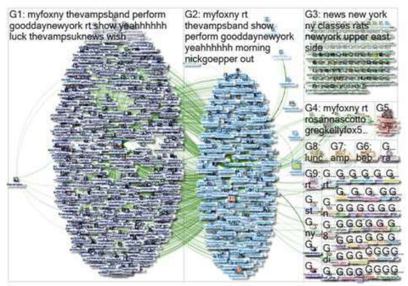
- Major characteristics of social networks
  - The small-world effect (6 degree of separation)
  - Scale-free degree distribution (power-law)
  - Community structure (clustering)
- Statistical models
  - Random Graph (Poisson, exponential)
  - Small-World
  - Preferential Attachment
- SNS applications (e.g. advertising) should consider these properties



Small-world effect



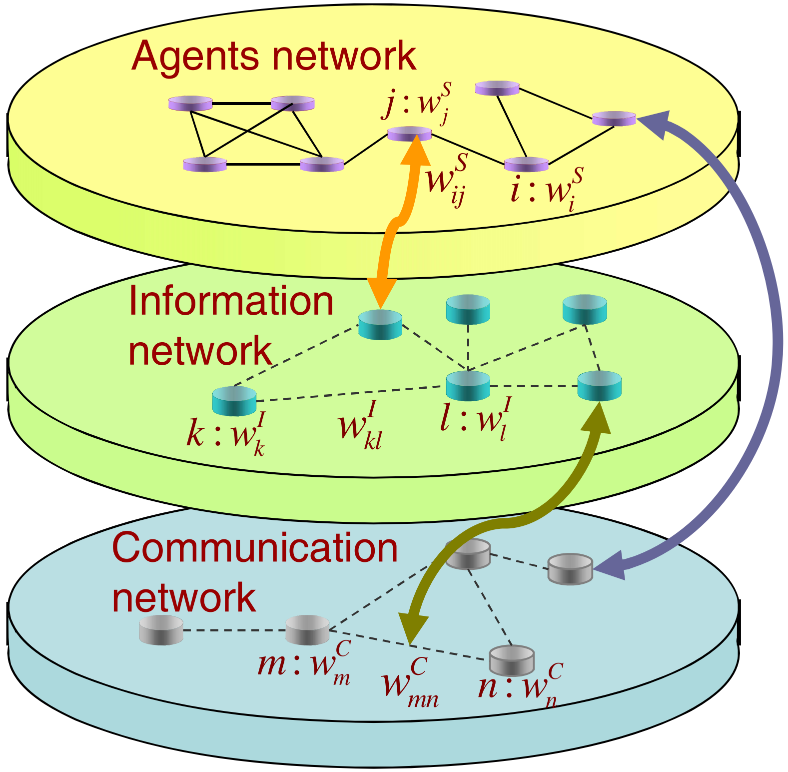
Scale-free distribution

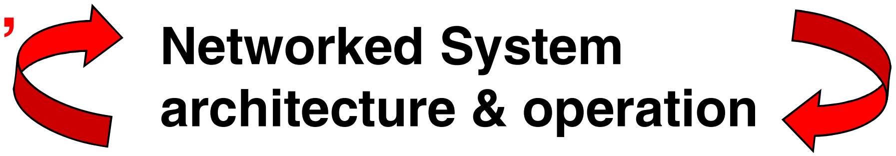


Community structure

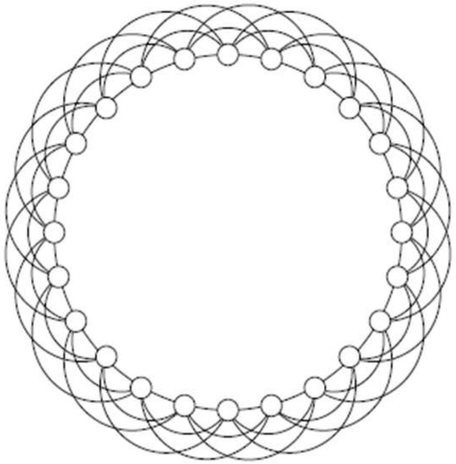
Multiple Coevolving Multigraphs

- Multiple Interacting Graphs
  - *Nodes*: agents, individuals, groups, organizations
  - Directed graphs
  - *Links*: ties, relationships
  - Weights on links : value (strength, significance) of tie
  - Weights on nodes : importance of node (agent)
- **Value directed graphs with weighted nodes**
- **Real-life problems: Dynamic, time varying graphs, relations, weights, policies**

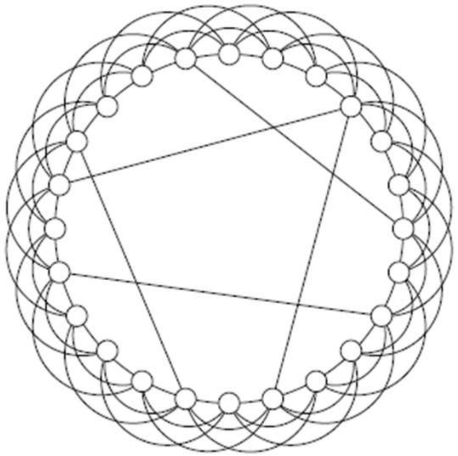




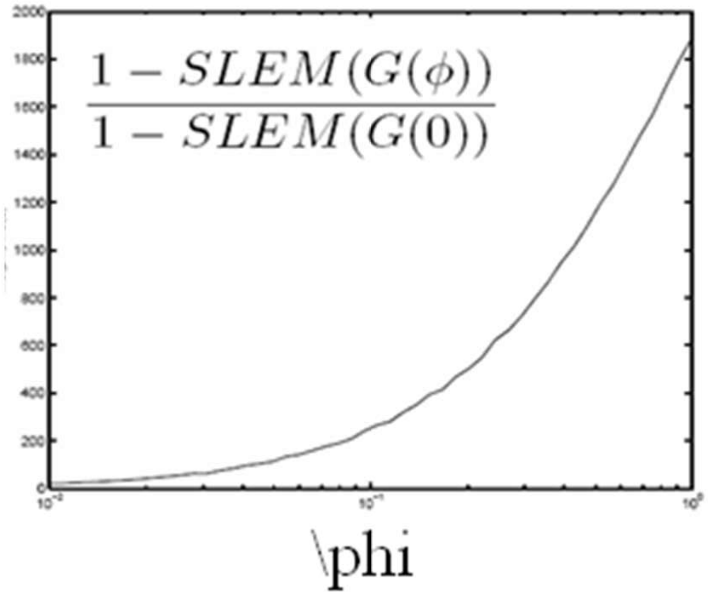
Small World Graphs



Simple Lattice
C(n,k)



Small world: Slight variation adding $nk\Phi$



C(1000,5)

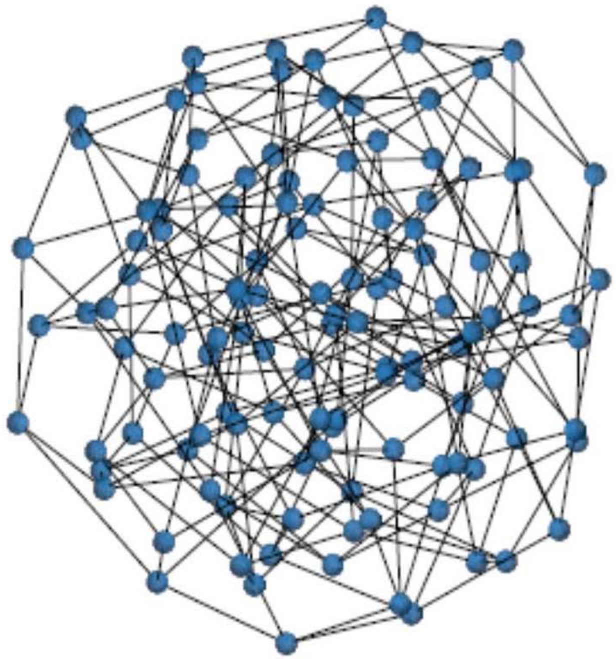
Adding a **small portion** of well-chosen links →
significant increase in convergence rate

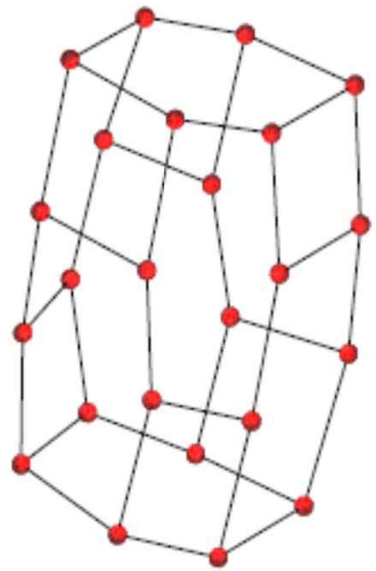
Expander Graphs

- First defined by Bassalygo and Pinsker -- 1973
- Fast synchronization of a network of oscillators
- Network where any node is “nearby” any other
- Fast ‘diffusion’ of information in a network
- Fast convergence of consensus
- Decide connectivity with smallest memory
- Random walks converge rapidly
- Easy to construct, even in a distributed way (ZigZag graph product)
- Graph G, ***Cheeger constant h(G)***
  - All partitions of G to S and S^c ,

    $h(G)$=min (#edges connecting S and S^c) / (#nodes in smallest of S and S^c)
- (k, N, ε) **expander** : $h(G) > \varepsilon$; **sparse but locally well connected** **(1-*SLEM*(*G*) increases as $h(G)^2$)**

Expander Graphs – Ramanujan Graphs





CPS Architectures

- **Architecture** : description of structure and behavior components of a system together with their configuration and interfaces and interconnections.
- **Architecture for CPS** is challenging : account for both the physical and cyber constraints – e.g. physical and material laws as well as geometric laws will guide the physical part
- Various concepts of time and their constraints. Extensions of current distributed architectures for computers at all scales, including both digital and analog components need to be considered
- Interplay between the principles and rules of architectures from the physical and cyber sides need to be considered and brought to harmony

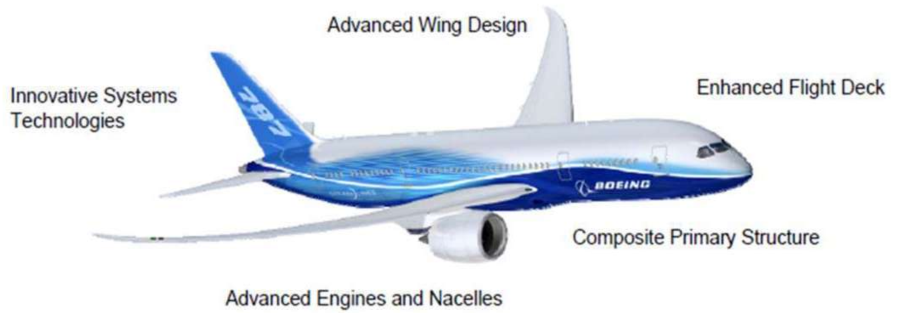
Materials-Geometry-Controls

The Institute for Systems Research

The 787 Dreamliner delivers:

- 20%* reduction in fuel and CO_2
- 28% below 2008 industry limits for NOx
- 60%* smaller noise foot print

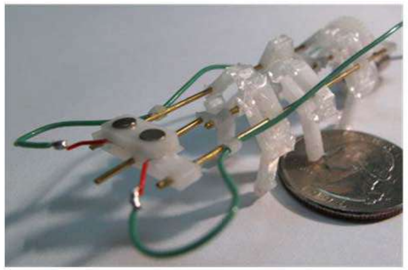
*Relative to the 767

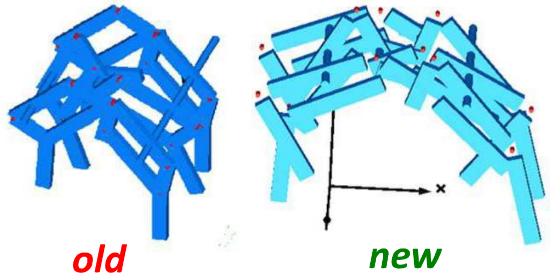


Smart suit – improve physical endurance & energy harvesting

Composite wing – new control algorithms
All-electric platform – new aircraft VMS

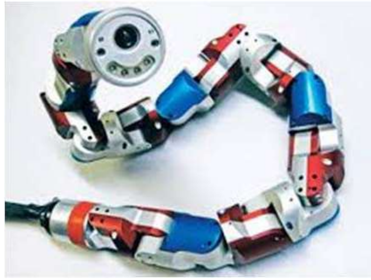
Robotic lizards – new motion-material-geometry

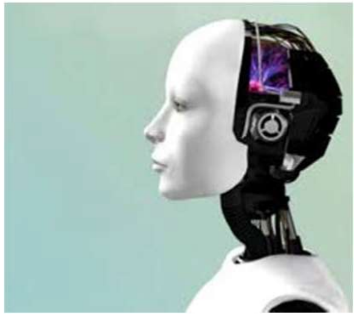
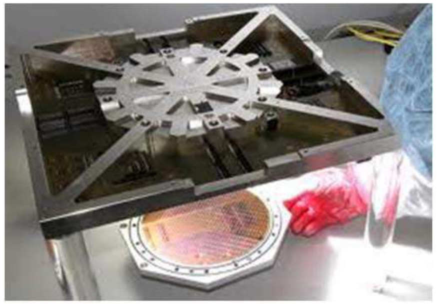




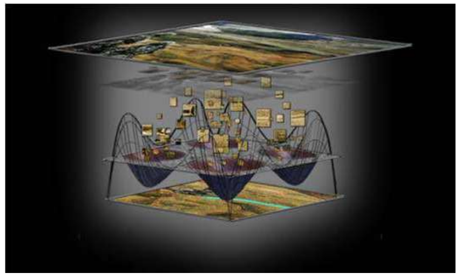
Fast micro-robots – new joint design of geometry-material-controls – More stable and faster running

Perception-Cognition and Co-Robots

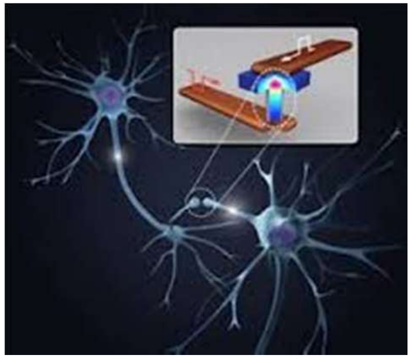


The pressure of P on C
The return of analog computation?
Non-von Neumann Architectures?
Physics of computation?
Beyond Turing?



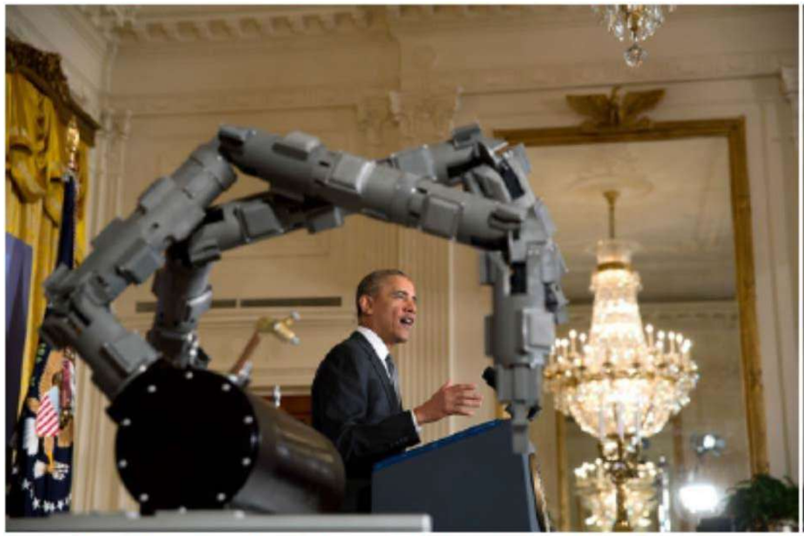




Cognition and knowledge generation from sensory perception – communicating with humans – collaboration
Not just obeying commands – the inverse problem

Digital Manufacturing Design Innovation Institute (DMDII)

- Announced February 25, 2014, 2014 by President Obama
  http://www.whitehouse.gov/the-press-office/2014/02/25/president-obama-announces-two-new-public-private-manufacturing-innovatio



President Barack Obama delivers remarks announcing two new public-private Manufacturing Innovation Institutes, and launches the first of four new Manufacturing Innovation Institute Competitions, in the East Room of the White House, Feb. 25, 2014. (Official White House Photo by Lawrence Jackson)

- Headquartered in Chicago, Illinois
- Academic-Industry-Government "Mega Project" $320M co-funding, 5 years
- **Goal**: Revitalize manufacturing along the lines described in this lecture
- "Infinite number of virtual factories and an open-source manufacturing platform"

Crowdsourcing Manufacturing

- ***Google's Project ARA***: Smartphones are composed of modules (of the owner's choice) assembled into metal frames

- ***Ubundu Edge Project***: crowdsourcing the most radical smartphone yet "Why not look for the best upcoming tech and throw it together to stay ahead of the competition?"
- ***Crowdsourcing*** the development and manufacturing of ***small unmanned aerial vehicles***

"Democratizing" Manufacturing

- **Goal**: Transforming more ordinary people to "makers" of products and services
- Helping small and medium size companies to manufacture products and services – **bridge the "gap"** from innovation, prototyping, to manufacturing

- General Electric (GE) opens manufacturing fab lab to spark ideas and participation in manufacturing through making
- Several companies have also opened up similar "open" labs: Ford etc.

- Several regional manufacturing centers (industry-university-government) are being established in various regions of USA
- "Industrial Internet" (USA) and "Industrie 4.0" (GE-EU) arrive

Comparative Impact of MBSE and MBE on Transforming Life-Work-Society

- Typography
- Microelectronic chips
- The PC
- The Internet
- MBSE and MBE

The ISR SE Programs in Brief

MSSE

DEGREE REQUIREMENTS

The following courses are required:

Systems Engineering Core

ENSE 621 Systems Engineering Principles
ENSE 622 System Modeling and Analysis
ENSE 623 Systems Engineering Design Project
ENSE 624 Human Factors in Systems Engineering

Management Core

ENSE 626 Systems Life Cycle Cost Estimation
ENSE 627 Quality Management in Systems

Those choosing the thesis option also take ENSE 799 Master's Thesis (for six credits) as well as an additional four electives. Those choosing the non-thesis option take an additional six electives.

ENPM-SE

DEGREE REQUIREMENTS

The ENPM Systems Option requires four courses from the systems engineering core, three courses from the management core, and four electives. The courses are identical to the MSSE curriculum.

Systems Engineering Core

ENPM 641 Systems Engineering Principles
ENPM 642 System Modeling and Analysis
ENPM 643 Systems Engineering Design Project
ENPM 644 Human Factors in Systems Engineering

Management Core

ENPM 646 Systems Life Cycle Cost Estimation
ENPM 647 Quality Management in Systems

Both Supplemented by Technical Electives form many Technical Areas

A Bold Experiment

Starting early in the education chain

Undergraduates working with industry and government mentors on SE projects

Concluding Remarks -- Challenges

- Further work on meta-models needed
- Create libraries with patterns of component models annotated by properties and metrics
- Develop a lot more uncertainty models and their composability; deterministic and stochastic
- Integrate multi-criteria optimization, constraint based reasoning, and logic
- Link the above to the integrated modeling hubs that allows return “values”
- Link to query management for design space exploration allowing many views
- Develop requirement representations for automatic verification: constraints, metrics, rules, semirings, soft semirings, automata, timed automata, Petri nets, procss models, contracts, model-checking, automatic theorem proving, include uncertainties
- Develop automatic suggestions for feasibility or improvements
- Integrate all the above, especially composability and compositionality
- Provide users with ability to select “slices of tools” and integrate them
- Address the “front end” to make it affordable and easy to use

The Institute for Systems Research

Thank you!

baras@umd.edu

301-405-6606

http://www.isr.umd.edu/~baras

Questions?