Symbolic Systems Technology Group

Using formal systems and logic to understand
• How things work
• Why things don’t work
• ....
Team (alphabetical order)

- Grit Denker
  - Daniel Elenius
  - Rukman Senyake
  - Ashish Gehani
- Steven Eker
- Ian Mason
- Anupama Panikkar (SV)
- Andy Poggio
- Malabika Sarker (Oklahoma)
- Mark Oliver Stehr
  - Minyoung Kim
Projects (in no particular order)

- Maude Development
- Cyber-physical Systems (CPS)
- Circuit Analysis w Superresolved Infrared Optics (CASIO)
- Content Based Mobile Edge Networks (CBMEN)
- Biology

A smattering of each
Maude Development (Steven Eker)

w Meseguer@UIUC
Distributed/Concurrent Maude (NSF)

- many optimizations
- new stack based execution engine
- concurrent search
- concurrent objects (eventually)
Unification (NSA)

- Unification is the problem of finding a substitution such that
  - $t_1 = u_1 \ldots t_n = u_n$ (in an equational theory)
- Free theory easy/finite
- Generally may be infinite, undecidable
- AC, ACU doable but challenging
- Key application narrowing
  - rewriting with unification rather than matching
  - backwards narrowing -- finds all initial states leading to target pattern
    - Maude NPA (crypto protocol attacks)
    - Document Logic (business process risks)
Some Maude Applications

- Border Gateway Protocol Analysis (Anduo Wang, Boon Tau Loo, Andre Scedrov UPenn)

- Modeling Regulations for Clinical Trials (Andre Scedrov (UPenn), Vivek Nigam (Munich), ...)

FDA regulations
Requirements implicit in trial protocol
Runtime monitoring
Adaptive plan generation
Post trial inspection

Internet Routing Systems
Share connectivity information across ASes

BGP: Border gateway protocol.
iBGP within AS
eBGP across AS

IGP: Interior Gateway Protocol.
Example: OSPF, RIP

Plan Generation
Execution Monitoring

FDA / Sponsor / P
Cyber-physical Systems Projects
NCPS (NSF), Fractionated (ONR), CYPRESS (NSF)
(PDL, MOS, MK, IAM, AP, GD, ...)

http://ncps.csl.sri.com
Challenges and Objective

• Networked Cyber-Physical Systems (NCPS) consist of networked hard- and software components embedded in the physical world and interacting with it through sensors and actuators.

• Increasingly large numbers of heterogeneous and potentially resource-constrained and unreliable components

• Need to work in challenging environments with unreliable/intermittent connectivity

• Need to operate in the entire spectrum between autonomy and cooperation

• **Objective:** General principles and tools for building robust, effective NCPS using individual cyber-physical devices as building blocks.
NCPS Approach and Contributions

- Partially ordered knowledge-sharing model for loosely coupled distributed computing

- Implemented in new application framework for NCPS

- Distributed logic for declarative control

- Simulation case study:
  - distributed surveillance, collaborating team of mobile robots
Partially ordered knowledge sharing

- Builds on DTN work, minimal assumptions on network connectivity (can be very unreliable)
- Locally each cyber-node uses an event-based model with local time and may have attached cyber-physical devices
- Communication via knowledge sharing rather than message passing
- Partial order allows the network to replace obsolete or subsumed knowledge
- Global consistency is not enforced (impossible in disruptive environments)
- Avoids strong non-implementable primitives, e.g. transactions
Distributed Logic

• **Key Problem**
  - Traditional logics are not designed for distributed reasoning
  - Logics are traditionally closed systems, i.e. not interactive

• **Knowledge is transparently shared**
  - Knowledge = Facts + Goals
  - Facts can represent observations
  - Goals can represent control objectives

• **Distributed logical framework**
  - Integrates forward and backward reasoning
  - Partial order is essential part of the distributed logic
Distributed derivation
Cyber-Application Framework Architecture

- Cyber-framework implements partially ordered knowledge-sharing model
- Logical framework is implemented as a cyber-application
- Applications cannot distinguish between simulation and reality
Principles and Foundations for Fractionated NCPS

- **Problem:** Current models are too abstract by not taking into account fundamental physical limitations and hence are not efficiently implementable or scalable.

- Once explicitly represented, physical limitations can be overcome to some degree (e.g. probabilistically).

- Diversification, redundancy, and randomization can offset many physical limitations.

- Distribution is a source of redundancy and diversification and can be turned from an obstacle into an advantage.
STEM: A Stochastic Task Execution Model for Fractionated Software

- Fractionated software system composed of nodes with partial connectivity (many, small components -- fragments).

- A goal is posted which is comprised of numerous subgoals

- Stochastically, a free node will take on a new subgoal (if capable)

- Correctness? Measure goal accomplishment quality,
  - e.g. at least 90% subgoal coverage at 95% confidence level
CYPRESS
Cyber-Physical RESilience and Sustainability

Dependability Techniques for Instrumented Cyber-Physical Spaces

Grit Denker, Nikil Dutt, Minyoung Kim, Sharad Mehrotra, Mark-Oliver Stehr, Carolyn Talcott, Nalini Venkatasubramanian, Leila Jalali, Zhijing Qin, Ronen Vaisenberg, Xiujuan Yi, Liyan Zhang

UCI & SRI
Goals & Approach

• Principles / techniques for infrastructure and data resilience

• Formal models and cross-layer tuning

• Middleware services

• Pervasive space testbed

Instrumented UCI Campus
CASIO: Circuit Analysis w Superresolved Infrared Optics (DARPA)
ESD, PSD, CSL, AI, Princeton, Berkeley, ....
The CASIO challenge (DARPA hard^2)

- Identify potential malicious regions in an ASIC
- Chip must work after analysis
- Aim for 45 nm resolution  (currently 150ish)
ENCODERS: Content Based Mobile Edge Network (DARPA) (MOS and many others, in negotiation)
CBMEN ENCODERS
Edge Networking with Content-Oriented Declarative Enhanced Routing and Storage

• **Declarative/Intentional Content-Based Networking:**
  - Vision of network as a distributed cache of content: users/applications state what content is needed, without constraining how to obtain it!
  - Enable fine-grained expression of warfighters’ needs: transition from syntactic (name matching) to semantic networking (predicate resolution)
  - Unified symmetric paradigm where requesters and originators of content express intent (i.e. query and scope)
  - Multidimensional awareness: users, groups, location, mobility, organization, social network, content/interest

• **Disruption-Tolerant and Attack-Resilient Foundation:**
  - Push and pull dissemination for increased robustness
  - Opportunistic caching and proactive replication
  - Polymorphic network layer (morphs like a Chameleon)
  - Spreading trust/responsibility through network coding
  - Decentralized multiauthority security for high availability
  - Fine-grained access control and metadata/query privacy

• **Impact: Focus on the Mission not on the Network!**
  - Warfighter gets the right information at the right time
  - Eliminate content flooding and information overload (for users and network) through fine-grained queries, efficient algorithms and context/interest modeling
  - Zero configuration: self-organizing combination of structured (distributed hashing) and unstructured (information diffusion) approaches

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**SUO Scenario: Content Sharing across MANET Clusters**

**Iterated Pipelined Rapid Prototyping and Integration**

- Translating Research into Prototypes
- Prototype Integration, Enhancement, and Evaluation
- Integration into CBMEN System

**Tasks**
1. Naming
2. Distribution
3. Managing
4. Securing
5. Assessment
6. Integration

**GPC**
- Pi: Mario Gerla (affiliated with UCLA)
- Content-Based Networking
- Automatic Incremental Routing
- Disruption Tolerant Networking
- Network Coding for Caching

**SUN-TECH**
- Pi: J.J. Garcia-Luna-Aceves (affiliated with UCSC and PARC)
- Content-Based Networking
- Automatic Incremental Routing
- Disruption Tolerant Networking
- Network Coding for Caching

**SRI International Computer Science Laboratory**
- Pi: Mark Oliver Stehr
- Declarative Networking
- Efficient Matching Technology
- Disruption-Tolerant Networking
- MANET and Mesh Routing
- Cross-Layer Optimization
- Decentralized Attribute-Based Encryption
- Evaluation under Encryption
- Campus-Wide Wireless Testbed
- Policy-Based Networking

**SET Corp.**
- An SAIC Company
- Pi: David Anhalt
- Information Management for Networking
- Dynamic Traffic Shaping
- Interest Modeling
- Virtual Interest Groups
- Traffic Monitoring
- Agent Based Simulation
- Systems Engineering
Biology

- Pathway Logic
- Combining Pathways and Cheminformatics
- BioMarkers
Pathway Logic (PL)

http://pl.csl.sri.com
Executable models of cellular processes (Maude + Petri Nets)

- Queryable formal knowledge base (DKB) of experimental findings
- Executable network of reaction rules (inferred from DKB)
- Model ~ initial state (experimental setup) + relevant rules
- Analysis using the PL Assistant (PLA)
  - Find subnets (proofs, executions)
  - Find pathways (proofs, executions)
  - In silico knocks
  - Comparing networks
  - Following connections
Signaling response to Egf (AMK)

Predicates

Add a predicate Remove all predicates

50 of 407 Results

Export all results to txt or csv

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Expand All | Collapse All

Erks[Ab]IP IVKA(MBP)[32P-ATP] is increased irt Lps (times) Expand
- cells: mPECs in BMS
- times: 0 7+ 15+ 30 60 90 min
- partially reqs: Irak1 [KO]
- source: 10754329-Fig-3c

Erks[Ab]IP IVKA(Elk1)[32P-ATP] is increased irt Lps (30 min) Expand

Two ways to activate Erk
Multiple synthesis routes

TB-mycolic-acid synthesis
(Malabika)
Combining Cheminformatics Methods and Pathway Analysis
NIH STTR with Collaborative Drug Design (CDD)

• Looking for TB drug candidates

• Phase I: Predicted 30 candidate drugs, tested 20, 3 had activity

• Phase II submitted.
Point-Of-Care Biological Assays for Determining Absorbed Ionizing Radiation Dose (Biodosimetry) (BARDA)

David Cooper PI -- PSD,BSD,ESD,CSL ....
• **Objective**: Biomarkers of irradiation for triage

• **Metric**: find panel of proteins that can distinguish >6gy from <6gy in mouse

• **Experiments**:
  
  • Mouse subjected to irradiation at different levels
  
  • Human (cancer patients undergoing radiotherapy)

• **Data**: Mass Spectra, Elisa of plasma samples

• **Computational analysis**:
  
  • Univariate statistics, multivariate linear classifiers, SVM
The end! (The beginning?)