

Computational Modeling and Analysis For Complex Systems NSF Expedition in Computing



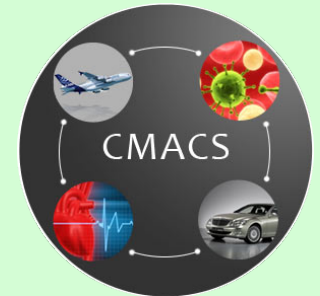
CMACS: Wrap-Up

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2nd Year Review Meeting, Carnegie Mellon University

November 3, 2011

Carnegie Mellon



STONY
BROOK
STATE UNIVERSITY OF NEW YORK

UNIVERSITY OF
MARYLAND



LEHMAN
COLLEGE

NYU
New York University



University of Pittsburgh

Our Goals

- **Scientific:** Develop Next-Generation Model Checking and Abstract Interpretation – MCAI 2.0
- **Societal:** Apply MCAI 2.0 to Challenge Problems in complex biological and embedded systems
- **Education & Outreach:** Build a program that
 - supports CMACS' vision of research and knowledge transfer
 - serves as a primary recruitment mechanism for students, especially those from under-represented groups

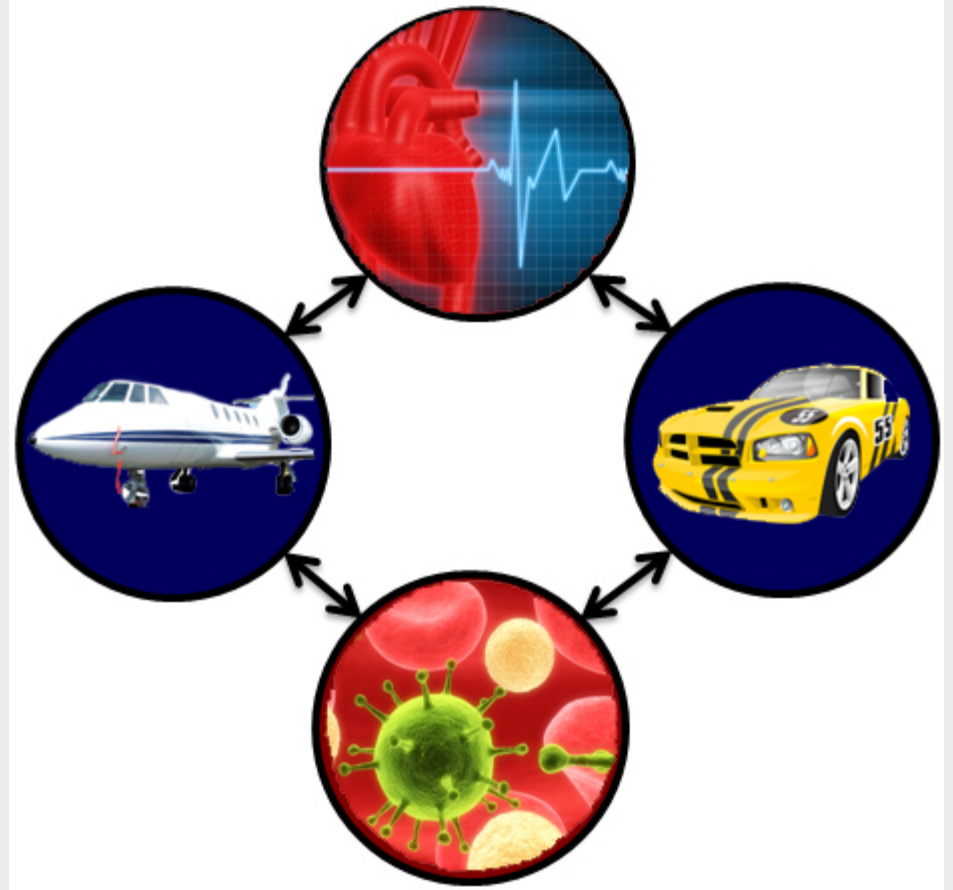
Challenge Problems

Systems Biology

- Pancreatic Cancer
- Atrial Fibrillation

Embedded Systems

- Distributed Automotive Control
- Aerospace Flight Software



Uniqueness, Synergies, and Impact

- Unique in bringing together MCAI with controls, embedded systems, systems biology, medicine
- A very strong team of researchers with diverse backgrounds, working closely and learning from each other
→ unique and promising approaches to these major societal problems
 - Important: real, ongoing, and deep interactions, across fields and across institutions: ECE/CS, CMU/NYU, CMU/UMD, SB/JPL, SB/Cornell, CMU/Pitt

Impact

- On undergraduates (e.g., workshops)
- On graduate students (e.g., in interdisciplinary research)
- On industry (e.g., industry workshops/input)
- On scientific fields (publications, tutorials)
- On how researchers think about problems (key publications)
- On the challenge problem areas (innovative new approaches and tools)
- On how we teach (new courses)

Significant Achievements & Impacts

- New computational methods for **cancer**
- New computational methods for **cardiac dynamics**
- New automated modeling and verification techniques for **complex embedded systems**
- Highly successful 2010 and 2011 **Undergraduate Workshops** on Pancreatic Cancer and Atrial Fibrillation for students from urban, minority-serving institutions
 - Beautiful examples of integration research and education
- CMACS **Embedded Systems Industry** Workshop (20 Oct. 2011, CMU)

Cross-Cutting Research Themes

- Model Checking
- Abstract Interpretation
- Modeling, Control and Analysis of Hybrid Systems
- Stochastic and Statistical Models

CMACS: Whole >> [Sum of Parts]

- Many breakthroughs due to **new, cross-institutional, cross-disciplinary collaborations**
- Typical example: Atrial Fibrillation Research

Stony Brook

Bartocci (Computer Sci)

Glimm (Applied Math)

Grosu (Computer Sci)

Smolka (Computer Sci)

Cornell/RIT

Cherry (Biomedical)

Fenton (Physics)

Gilmour (Biomedical)

NYU

Le Guernic
(Computer Sci)

CMACS: Whole >> [Sum of Parts]

- Another example: Pancreatic Cancer Research

CMU

Clarke (Computer Sci)

Gong (Computer Sci)

Wang (Computer Sci)

Zuliani (Computer Sci)

Pitt

Faeder (Sys. Biol.)

Miskov-Z. (Sys. Biol.)

UMD

Wu (Public Health)

UPMC

Lotze (Cancer Inst.)

- Translational Genomics Research Institute

- Rich Posner and Daniel Von Hoff

Value-Added as an Expedition

- Deep integration of MC + AI is enabling **fundamental breakthroughs** in modeling, analysis, and verification of **complex systems**
- Unique **societal benefits**
- We are **inspiring new and under-represented groups** of students to choose **careers in computer science and related fields**
- CMACS Research Plan & Challenge Problems require **critical mass** and **visibility** that cannot be achieved with piece-meal efforts
- Our research is inherently **cross-disciplinary**: CPs require large teams involving both domain scientists, computer scientists, and engineers
- **Integration of research, education, and outreach.** New courses. Research and education opportunities for undergraduates as well as graduates.

Looking Forward

- First two years
 - Exciting new discoveries
 - Building strong interdisciplinary foundations
 - Technical
 - Educational
 - Human

Looking Forward (contd.)

- Research
 - Continue, further develop challenge problem areas
 - More realistic cancer models, tight connections to new pancreatic cancer data; e.g., multi-cellular / multi-pathway models
 - MC & AI to developed more reduced order heart models that allow analysis & control
 - Distributed embedded control, using integrated methods
 - Continue, further develop research in cross-cutting areas
 - Stochastic models, analysis
 - Compositional modeling, reasoning
 - Hybrid systems
 - Interplay between model checking, theorem proving

Looking Forward (contd.)

- Research
 - Deepening integration of MC and AI
 - Model approximation / simplification
 - Automatic generation of abstracted models, depending on properties being checked
 - More & wider cross-institutional & cross-disciplinary **collaborations**; e.g.
 - apply UMD classification & dimension-reduction technology to NYU cancer models
 - apply CMU statistical model checking to SB+Cornell 2D & 3D cardiac models

Looking Forward (contd.)

- Educational
 - More winter workshops at Lehman
 - REU experiences at CMU
 - Curricular efforts
 - Further development of course materials and modules for education at all levels
 - Programs of study in complex systems science and engineering
- Outreach and knowledge transfer
 - Specialized workshops for industrialists / scientists
 - Annual advisory-board meetings
 - Special conference sessions / journal volumes