Embedded Systems Education: Vanderbilt

Edited and Presented by
Janos Sztipanovits
ISIS, Vanderbilt University

Chess Review
October 4, 2006
Alexandria, VA
Vanderbilt Engineering School

• Mid-size engineering program (# faculty < 100, ~1200 undergraduate and ~400 graduate students)

• Feasible strategy must build on research strength and effective resource utilization:
  - Large research program in model-based design, tools and networked embedded systems.
  - Strong collaboration with other Universities (UC Berkeley, U. Memphis, CMU, Cornell, GMU, Princeton, Stanford and others).
  - Extensive industry research collaboration (Boeing, GM, Raytheon, BAE Systems, LMCO and others).
Undergraduate Program Development

- Stakeholders: EE, CompE, CS and ME Programs
- Constraints and opportunities in curriculum development:
  - Insertion of only a limited number of new core courses
  - Faculty interest in adjusting content of existing courses
  - Developing new emphasis areas in curriculum is relatively easy
### Undergraduate Curriculum Structure

<table>
<thead>
<tr>
<th>Freshman</th>
<th>Sophomore</th>
<th>Junior</th>
<th>Senior</th>
</tr>
</thead>
<tbody>
<tr>
<td>EECE 116 Digital Logic</td>
<td>EECE 218 Micro-controllers</td>
<td>EECE 276 Embedded Systems</td>
<td>EECE 297 Senior Design</td>
</tr>
<tr>
<td>CS 201 Program Design</td>
<td>CS 231 Computer Organization</td>
<td>EECE 256 Digital Sig. Processing</td>
<td>EECE 258 Control Systems II</td>
</tr>
<tr>
<td>EECE 112 EE Science</td>
<td>EECE 274 Modeling and Simulation</td>
<td>EECE 257 Control Systems I</td>
<td></td>
</tr>
<tr>
<td>EECE 256 Digital Sig. Processing</td>
<td>EECE 277 FPGA Design</td>
<td>EECE 256 Digital Sig. Processing</td>
<td></td>
</tr>
<tr>
<td>EECE 258 Operating Systems</td>
<td>CS 201 Program Design</td>
<td>EECE 274 Modeling and Simulation</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Motivating example: Simple robot</th>
<th>Basic abstractions and their relationship:</th>
<th>Design of heterogeneous systems:</th>
<th>Integrated design experience:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering systems are heterogeneous</td>
<td>- Time in continuous and discrete systems</td>
<td>- Model-based design</td>
<td>- Design process</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Design space and optimization</td>
<td>- System integration</td>
</tr>
</tbody>
</table>

Oct. 4, 2006; Chess Review
EECE 276: Embedded Systems

- Focus on: Embedded System Design

- Topic highlights:
  - Real-time Programming Models
  - Model-based Design
    - Processes, dataflow, finite-state machines
  - Real-time languages
  - Analysis techniques
  - Embedded project
    - Hardware + Software
    - 16bit microcontroller
    - Microkernel RTOS (uCOS-II)
"...I probably wouldn't be working at my current job if it wasn't for getting to participate in the program, since my current job deals with a lot of the technology ideas that we worked with in the SIPHER program.”
- Miguel Taveras, SIPHER 2004

<table>
<thead>
<tr>
<th>Year</th>
<th># Students</th>
<th># In/on the way to Grad School</th>
<th>Industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>10</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>2004</td>
<td>9</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>2005</td>
<td>8</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>2006</td>
<td>10</td>
<td>(n/a)</td>
<td>(n/a)</td>
</tr>
</tbody>
</table>

"The SIPHER program was a great experience which I continue to share with people. It really confirmed my intent to transition into embedded systems in the future.”
- Trevor Brown, SIPHER 2004
SIPHER Projects 2006

• Radio Controlled Car Controller
  Graduate Mentor: Graham Hemingway
  Undergraduates: Jessica Kane and Thao Nguyen

• Hybrid Systems Modeling for Fault Diagnosis
  Graduate Mentor: Wu Jian
  Undergraduates: Nathaniel Allotey and Brian Turnbull

• Controlling Lego Robots Using Synchronous Reactive Model of Computation
  Graduate Mentor: Rthan Jackson
  Undergraduates: Javier Lara and Darren White

• Exploring with Lego Robots
  Graduate Mentor: Daniel Balasubramanian
  Undergraduates: Daniel Limbrick and Emily Sherill
Graduate Curriculum Principles

• Rapid transitioning of research results to education
  - Use of methods and tools produced in research program
  - Course material is available for industrial training

• Opportunity for testing new concepts:
  - Formally specified heterogeneous abstractions are used in design flows
  - The abstractions are also design objectives
## Graduate Curriculum Structure

**Modeling, analysis, and design of hybrid and embedded systems.**
Formal models of computation, modeling and simulation of hybrid systems, properties of hybrid systems, analysis methods based on abstractions, reachability, and verification of hybrid systems.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 376</td>
<td>Foundations for HES</td>
<td>CS 376 Foundations for HES provides the foundation for hybrid and embedded systems.</td>
</tr>
<tr>
<td>CS 379</td>
<td>Topics in Embedded SW</td>
<td>CS 379 focuses on topics in embedded system software, including modeling, design, and implementation.</td>
</tr>
<tr>
<td>CS 388</td>
<td>Model Int. Computing</td>
<td>CS 388 explores compositional specification of domain-specific modeling environments.</td>
</tr>
<tr>
<td>CS 396</td>
<td>Sensor Networks</td>
<td>CS 396 delves into sensor network platforms and models of computation.</td>
</tr>
<tr>
<td>CS 315</td>
<td>Automated Verification</td>
<td>CS 315 covers automated verification techniques.</td>
</tr>
<tr>
<td>CS 390</td>
<td>Sensor Network Platform</td>
<td>CS 390 discusses sensor network platforms and models of computation.</td>
</tr>
</tbody>
</table>

- **Systems verification and validation, industrial case studies.**
- Propositional and predicate logic, syntax and semantics of computational tree and linear time logics. Binary decision diagrams, timed automata model and real-time verification. Model checking using the SMV, SPIN, and UPPAAL tools.

- **Role of domain-specific modeling languages (DSML) in embedded system design.** Designing, creating, and evolving DSML-s and modeling environments using metamodeling. Role of model transformations in the design process. Specification and implementation of model transformers. Transformational specification of DSML semantics.


- **Sensor network platforms and models of computation.** Messaging, routing, and time synchronization protocols. Security issues. Sensor network applications.