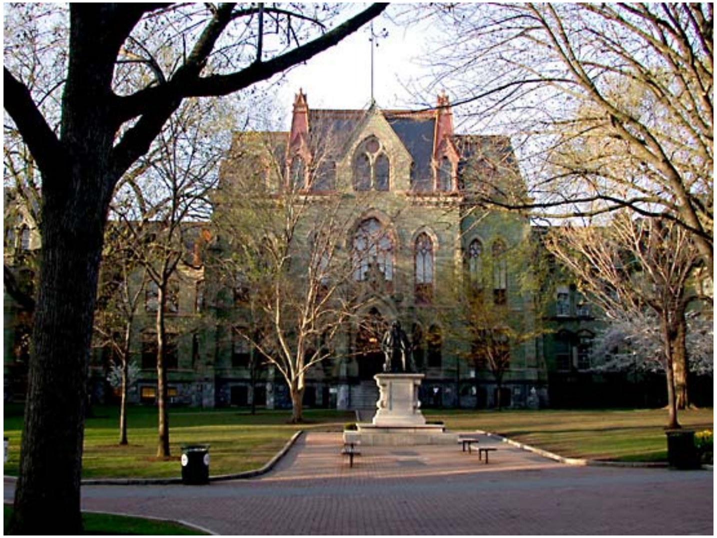
Robust compositions of embedded systems



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Component-based modeling and synthesis

The main (controller) synthesis equation

$$A \,||\, X \cong B$$

or a more relaxed version...

$$A \,||\, X \leq B$$

		Discrete	Continuous	Embedded
Models	:	Finite state automata	Dynamical	Timed/Hybrid
Composition	:	$L(A \,\|\, B) = L(A) \cap L(X)$	Feedback	?
Equivalence	:	$A \cong B$ iff $L(A) = L(X)$	Asymptotic	?
Order	:	$A \leq B$ iff $L(A) \subseteq L(X)$	?	?

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From exact to robust

Exact relationships useful but fragile for binary answers

- Asymptotic relationships are useless for interacting embedded systems

When dealing with the physical world, we need approximations

- Labeled Markov processes (Desharnais et. al., TCS 2004)
- Quantitative transition systems (de Alfaro et. al., ICALP 2004)
- Metric transition systems (Girard and Pappas, 2005)

From exact towards approximate embedded system relationships

- Enable larger system "compression"
- Quantify error/complexity tradeoffs
- Provide measures of robustness

Challenges

- What are the right metrics (industry help is needed) ? Can we compute them ?
- Are approximate relationships compositional ?

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Robust Future

Define metrics for (metric) transition systems*:

$$d_L^{\rightarrow}(S_1,S_2)=0 \quad \text{iff} \quad L(S_1)\subseteq L(S_2)$$
$$d_L(S_1,S_2)=0 \quad \text{iff} \quad L(S_1)=L(S_2)$$
$$d_S^{\rightarrow}(S_1,S_2)=0 \quad \text{iff} \quad S_1 \leq S_2$$
$$d_B(S_1,S_2)=0 \quad \text{iff} \quad S_1 \cong S_2$$

How can we define such metrics and how are they related ?

$A\,\|\|\,X \cong B$	Compute $d(A\,\|\|\,X, B)$
$S_1 \cong S_2 \Rightarrow S\,\|\|\,S_1 \cong S\,\|\|\,S_2$	$d(S_1,S_2)<\varepsilon \Rightarrow d(S\,\|\|\,S_1, S\,\|\|\,S_2)<\varepsilon$

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*A. Girard and G.J. Pappas, Approximation metrics for discrete and continuous systems, 2005. Submitted.