Control and Customization of Mobile Systems Under Dynamic Constraints: A Proposal for Collaboration in ARTIST with VERIMAG

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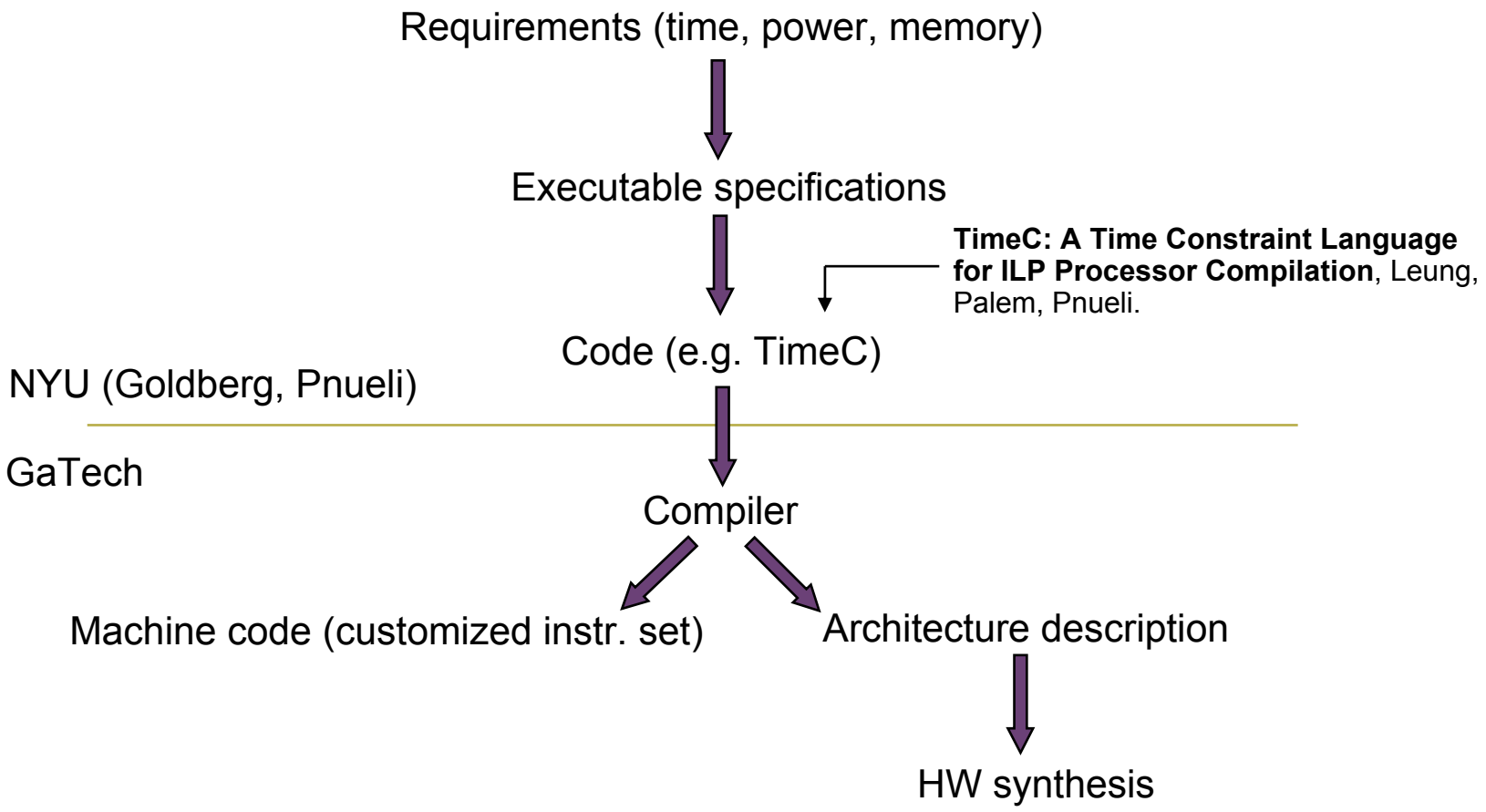
From Specifications to HW/SW Architectures

- Embedded Customization Design Flow:

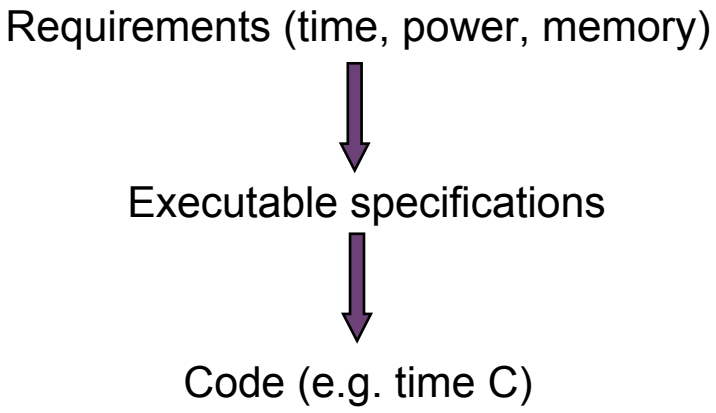


From Specifications to HW/SW Architectures

- Given high-level specifications (including real-time, power, and memory constraints) can the customization process be automated?
  - Design automation via innovative, architecture-level design space exploration
  - Using compiler optimizations as a tool for designing workload-specific architectures
  - Integration with front-end system specification & verification flows and back-end HW/SW design activities
- *For mobile, reactive systems what are the special constraints associated with multi-modal control strategies?*
- *Can dynamical constraints such as memory and power resources be modeled in a similar manner as temporal constraints?*

From Specifications to HW/SW Architectures: An Approach to Collaborationg with VERIMAG

- Embedded Customization Design Flow:



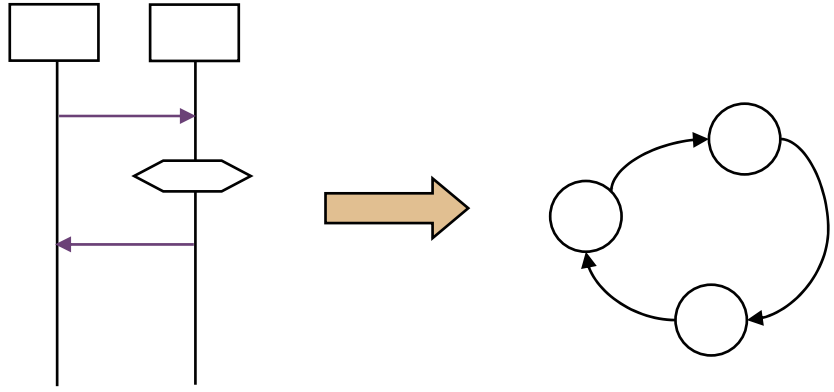
- Tools are needed in order to achieve correctness in each step
- Languages, verification, testing, and modeling?

From Specifications to HW/SW Architectures

- At each step, the resulting objects must be provably correct in the sense that the required properties are preserved
- Customization tools are necessary for achieving this
  - Formal methods for going from high-level specifications to executable code
  - Compiler optimization tools for designing/exploring the architectures
  - VLSI tools for HW synthesis
- It is of key importance that the initial specifications are expressive enough to capture not just timing considerations, but also other physical design constraints

High-Level Specifications

- We use LSCs (Live Sequence Charts) for modeling temporal orderings

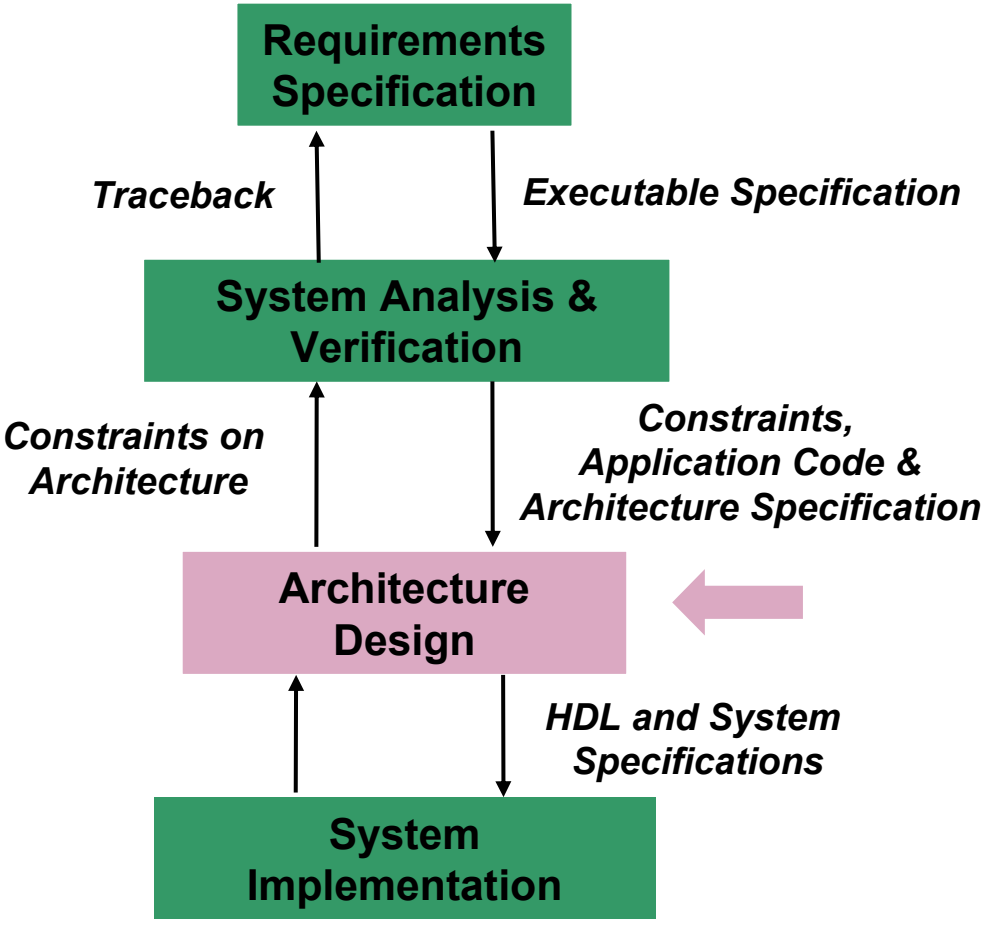


- From these, Timed Automata can be obtained as executable specifications
- However, other physical constraints (e.g. memory and power) must be specifiable as well
- Calls for an extended syntax in the LSCs as well as the introduction of Hybrid Automata rather than Timed Automata at the next specification level
- Team: Egerstedt, Goldberg, Pnueli

High-Level Specifications: Challenges

- Upper bounds on the memory and power consumption available to each component during a given part of the task can be modeled by differential equations
- As the system transitions to different modes of operation, new constraints are in force (e.g. cell phones during dialing, calling, and idling modes)
- This model allows for dynamic, physical implementation constraints to be incorporated already at the high-level specifications
- When the system to be customized is a mobile, reactive system, this provides a unified treatment of the constraints and physical states of the system (described via controlled differential equations).

Customizing Platforms at CREST



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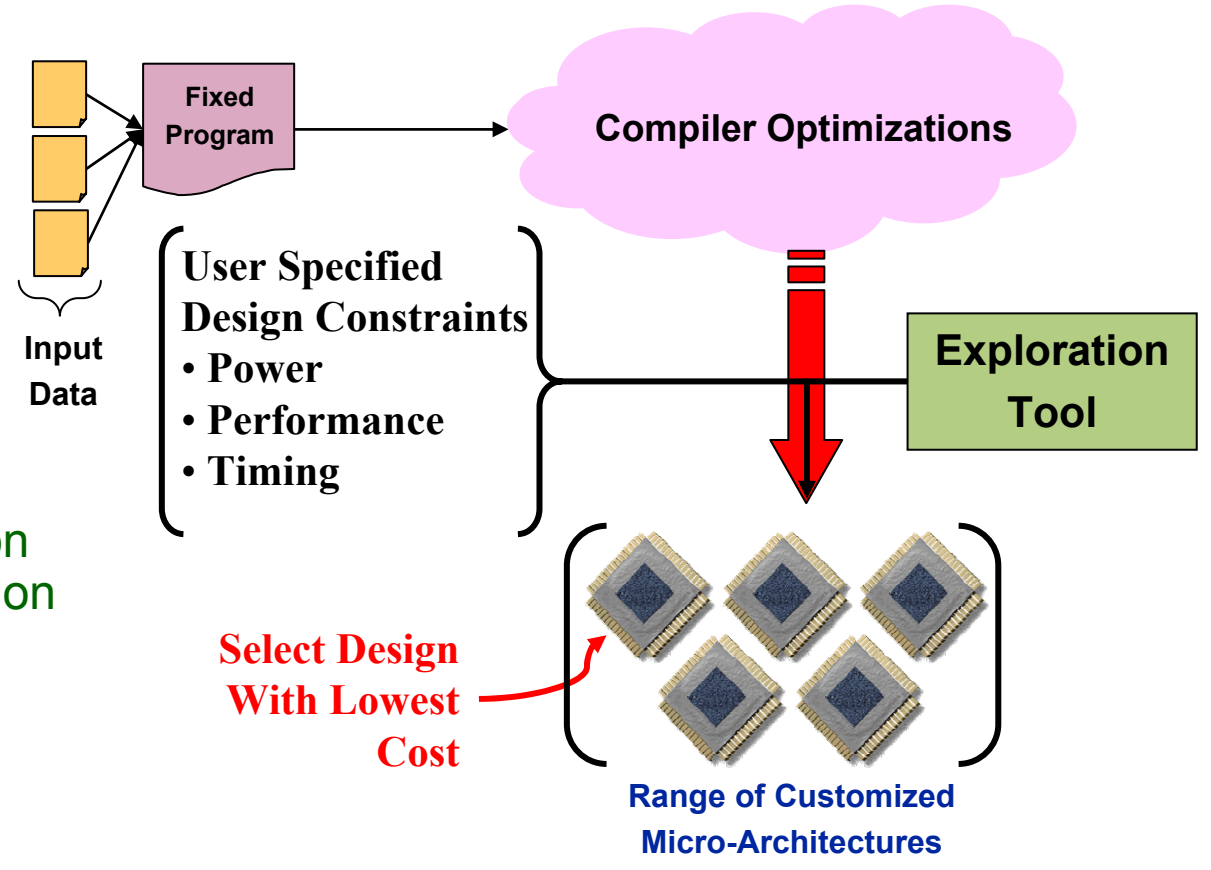
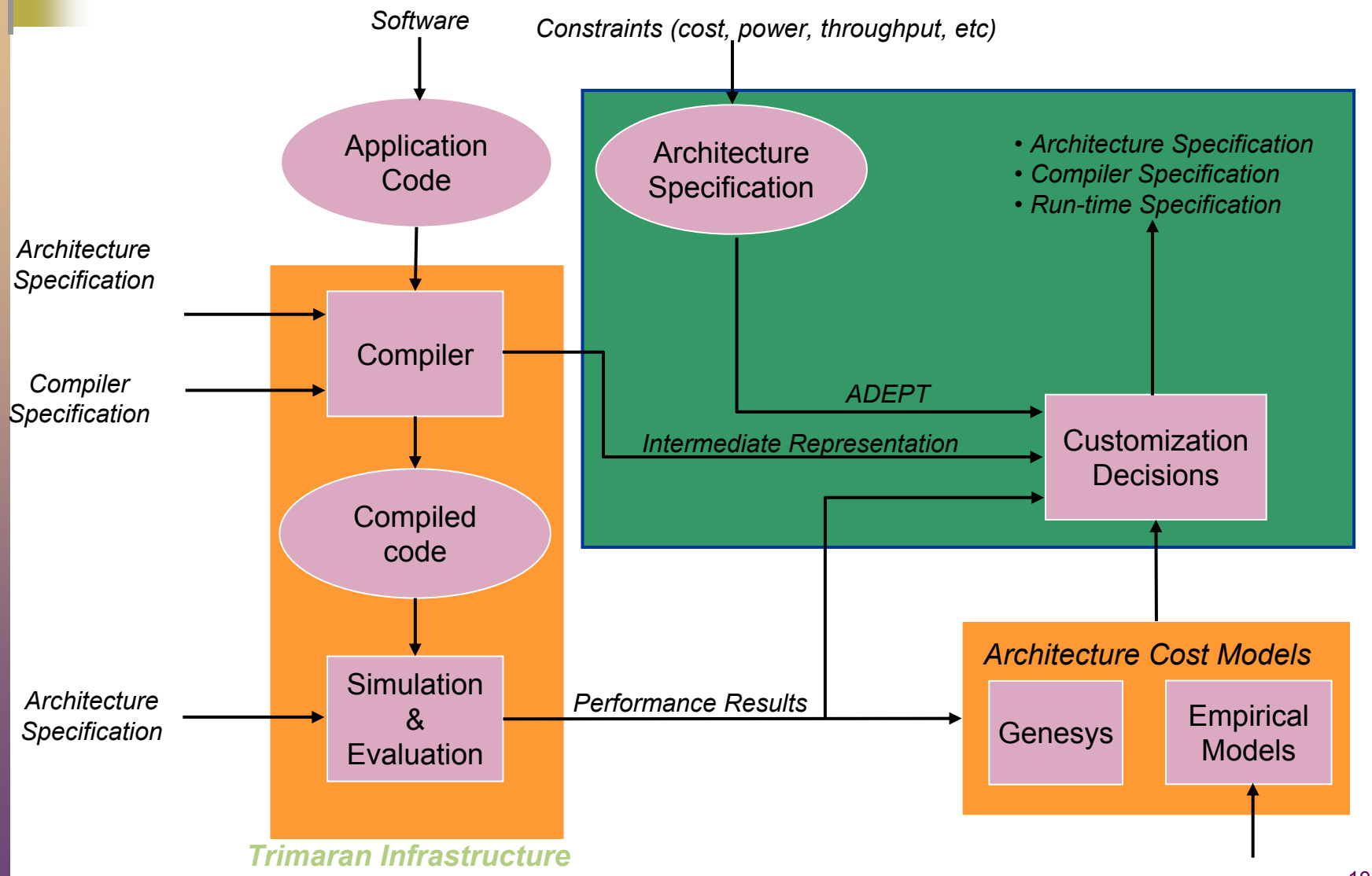
Customization via Design Space Exploration

- *Fix program*
- *User specifies design constraints*
- *Optimizations and exploration tools search design space*
- *Best design is chosen*



Design space exploration for concurrent optimization an architecture and associated compiler optimizations!

Architecture Design Methodology

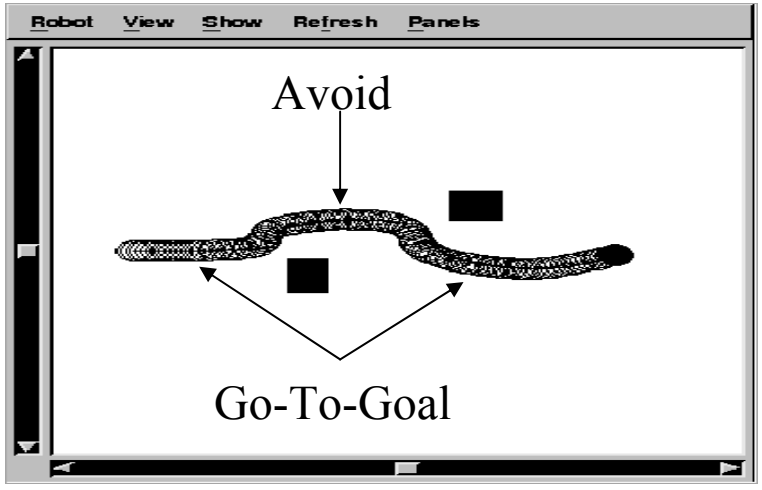


Hardware/Software Customization

- Once code has been produced from the specifications:
  - Compiler optimization tools can be used for determining the workload specific hardware, software architectures
  - Design space exploration allows for optimization based hardware synthesis
  - Compilers provide a unified framework for exploring and finding architectures as well as compile to the appropriate architecture (TRIMARAN)
  - Customized instruction sets should be selected
- Questions
  - Highly accurate cost modeling in the design space exploration?
  - Decomposition of the computations in such a way that the total energy required to perform an algorithm with specified bounds will be met by the best QoS possible?
  - Empirical power models of individual instructions and instruction sequences in terms of supply voltage, technology parameters such as threshold voltage, instruction delay / timing / clock speed and input data values (best-, worst-, avg-cases)?

Reactive, Mobile Systems (SPIDER)

- For mobile systems (e.g. autonomous mobile robots) the executions can be characterized by strings of control modes (so-called hybrid words)



$$\mathcal{S} = \sigma_1\sigma_2\sigma_1$$
or
$$\mathcal{S} \in (\sigma_1\sigma_2)^\star\sigma_1$$

- Each mode consists of a reference to a particular control law, the interrupt condition, and a specification of the temporal sensitivity of that particular mode (unstable modes, safety critical switches,…)
- The interrupts together with the temporal sensitivities can be modeled in LSCs.
- **SPIDER: S**pecifiable and **P**rovable **I**ntegrated **D**esign of **E**mbedded systems for **R**obotics

In Summary: Collaboration Opportunities with VERIMAG

- Tools are needed in order to achieve correctness in each step
- Characterizations of specifications from multi-modal control design?
  - Critical modes and interrupts?
  - Power, memory, and real-time constraints?
- “Hybrid” LSCs to Hybrid Automata?
  - Equivalence?
  - Automatic transition or post model validation?
- From Hybrid Automata to code?
  - Timed languages?
  - Languages for control tasks?
- Languages, verification, testing, and modeling?
- Design space exploration algorithms?