1. Goal: Compositional Reasoning for Simulink

- Compositional Static Analysis: detect inconsistencies, compute preconditions, eliminate internal variables, check substitutability (when can a block replace another?), etc., at compile-time, without flattening!

2. The RCRS Framework (Refinement Calculus of Reactive Systems)

3. The Algebra of Hierarchical Block Diagrams (HBDs)

Challenge 1: How to represent graphical diagrams in a textual notation with formal semantics?

- Basic block: represented as atomic monotonic predicate transformers (MPTs). Some examples:
  - Basic block: is defined as $\text{Constant} \circ \lambda x \to \{\}
  - discrete state's basic block: is defined as $\text{State} \circ \lambda x \to \{x\}
  - continuous state's basic block: is defined as $\text{State} \circ \lambda x \to \{(x, x)\}
  - Block diagram: is defined as $\text{State} \circ \lambda x \to \{x \circ x\}

Challenge 2: How many possible translations?

4. Three Strategies for Translating HBDs to Algebraic Terms

- Feedback-parallel translation strategy
- Incremental translation strategy
- Feedbackless translation strategy

5. Formal Analyzer: Expansion and Simplification

- Expansion
- Simplification

6. RCRS: A Contract-Based Framework with Refinement

- Horizontal contract: allows to replace a component with another while preserving all properties.
- Vertical contract: allows to replace a component with another while preserving all properties.
- Refinement: allows to replace a component with another while preserving all properties.

7. Case Study: A Fuel Control System (FCS)

- Benchmark provided by Toyota. Publicly available at http://racs-vu.org/group/AM21/benchmark
- Toyota model:
  - 3-level hierarchy
  - 104 blocks: 97 atomic blocks and 7 subsystems
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8. Further Reading