Static Analysis by Abstract Interpretation of Embedded Critical Software

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SÃ©mantics and Abstract Interpreation team

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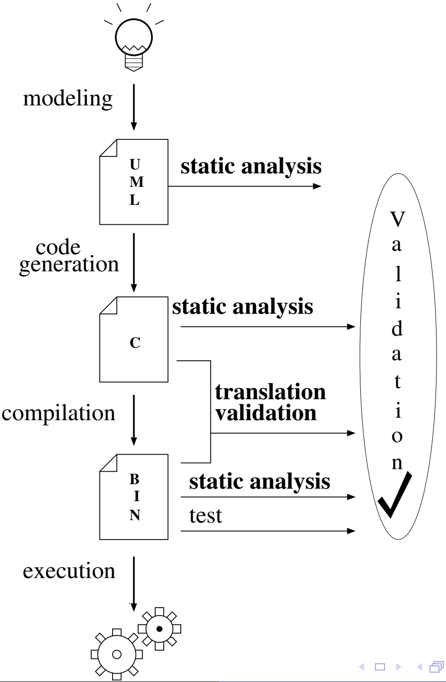
modeling
UML
static analysis
code generation
C
static analysis
translation validation
compilation
BIN
static analysis
test
execution
Validation

Which level should be statically analyzed ?

- Static Analysis can be applied at many levels :
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    - numeric overflows analysis (made at C level)
    - precision of floating-point computations analysis (made at C level)
    - worst case execution time analysis (made at binary level)

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Difficulties :

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Abstract Interpretation framework :

- an analyzer focuses on a subset of properties and programs
- growing library of abstraction domains
- modularity of domains or close cooperation between them

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- So $\mathbf{lfp}^{T} \cap \varepsilon = \emptyset$

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- Concretization function $\gamma_i([\ell, h]) \triangleq \{z \in \mathbb{Z} \mid \ell \leqslant z \leqslant h\}$.
- $\forall V \in \wp(\mathbb{Z}) : \forall [\ell, h] \in V_i^\sharp : \alpha_i(V) \subseteq [\ell, h] \Longleftrightarrow V \subseteq \gamma_i([\ell, h])$ and so, by definition, the pair $\langle \alpha, \gamma \rangle$ is a Galois connection

$$\langle \wp(\mathbb{Z}), \subseteq \rangle \underset{\alpha_i}{\overset{\gamma_i}{\leftrightarrows}} \langle V_i^\sharp, \subseteq \rangle$$

Fixpoint Abstraction

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- convergence has to be accelerated using a widening $\triangledown$
- A naïve example of widening for intervals is

$$[\ell^i, h^i] \triangledown [\ell^{i+1}, h^{i+1}]$$

$$\triangleq [\text{if } \ell^{i+1} < \ell^i \text{ then } -\infty \text{ else } \ell^i, \text{if } h^{i+1} > h^i \text{ then } +\infty \text{ else } \ell^i]$$

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- assertion failures (in calls to the `assert` C function).

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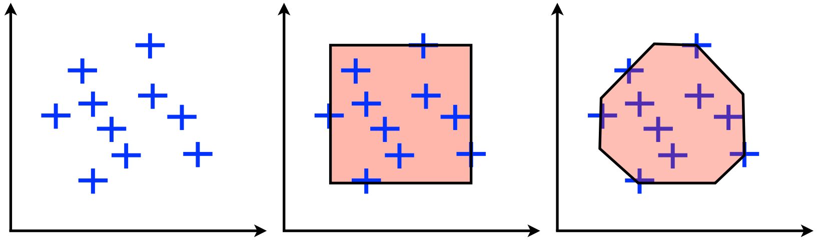
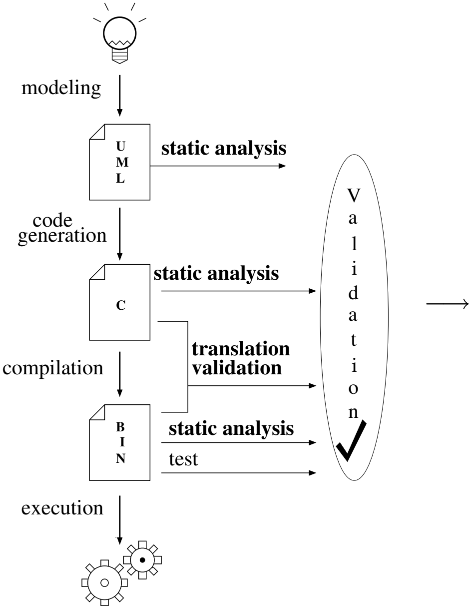
- ASTRÉE now handle code generated by dSPACE TargetLink (code generator for MATLAB, Simulink and Stateflow) (added by AbsInt).

Toward Relational Domains



- relational domains bring fine-tuned preciseness (more precise than intervals)
- at a bounded computational cost.

Imperfectly-Clocked Synchronous Systems



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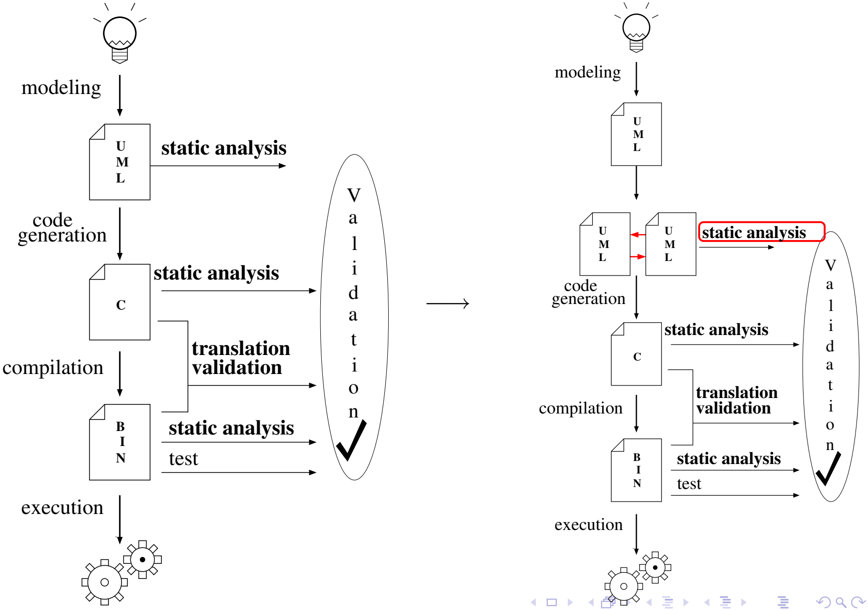
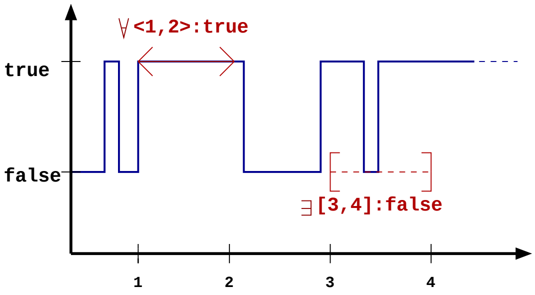


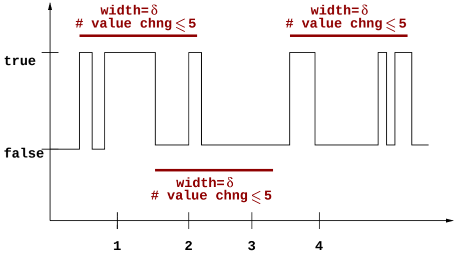
This non-standard semantics : **continuous-time**

- allows a **more precise modeling** of reality
  - imperfect clocks
  - communication channels with unknown latency
- reuses **continuous theories**
  - integral theory
  - directed homology
- allows a **precise and efficient** static analysis



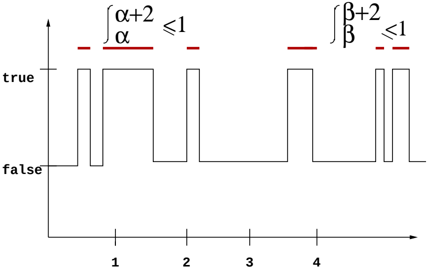
- express many **local temporal properties**
- and **prove** some of these properties

[*VMCAI'05*] J. Bertrane. Static analysis by abstract of the quasi-synchronous composition of synchronous programs. *Paris* value changes counting



- express **stability specifications**.

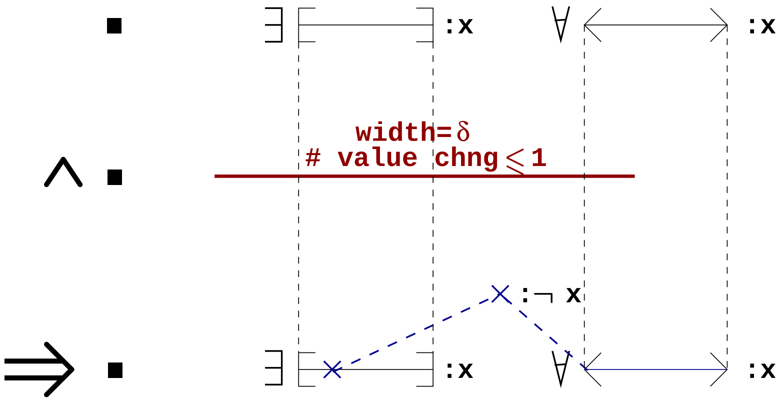
integral boundings



- express **quantitative properties (average value, ...)**

[*SAS'06*] J. Bertrane. Proving the properties of communicating imperfectly-clocked synchronous systems. *Seoul*

Reduce product Constraints - Value changes counting



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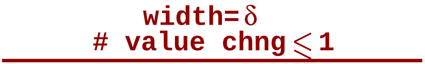
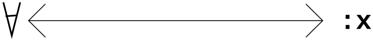
- 

$\wedge$

- 

$\Rightarrow$

- 

Conclusion

- Abstract Interpretation is able to define a static analysis at several levels of the development of embedded systems
- It may help designers from early stages to product shipping
- It may even check that the translation from one level to another is correct
- Static analysis community can only benefit from a better formalization of different layers, as proposed by UML