Scaling up with abstract interpretation

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Usable Verification
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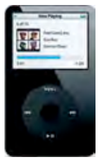
Bugs are also everywhere


"The Australian Transport Safety Bureau (ATSB) found that the main probable cause of this incident was a *latent software error* which allowed the ADIRU to use data from a failed accelerometer"

http://www.atsb.gov.au/newsroom/2008/release/2008_43.aspx,
http://en.wikipedia.org/wiki/Qantas_Flight_72

Safety/mission critical software is everywhere

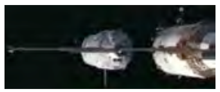










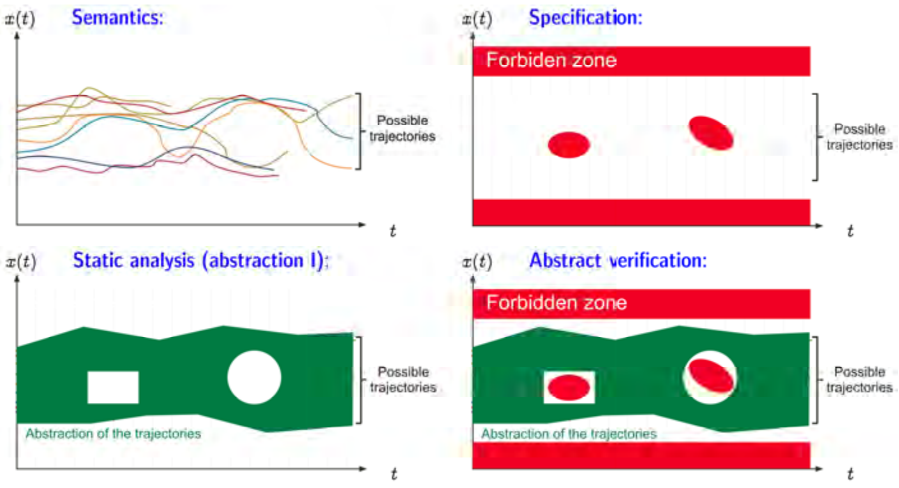


etc...

Verification versus debugging

- Unsound debugging: testing, bug-pattern finding, bounded model-checking,...
  - not difficult, useful, and so popular
  - scales up easily
- Sound verification: deductive methods, exhaustive abstract model-checking of safety properties, static analysis,...
  - useful, difficult, and so rare
  - ultimately indispensable for safety/mission criticality
- [Un]soundness should be clearly stated

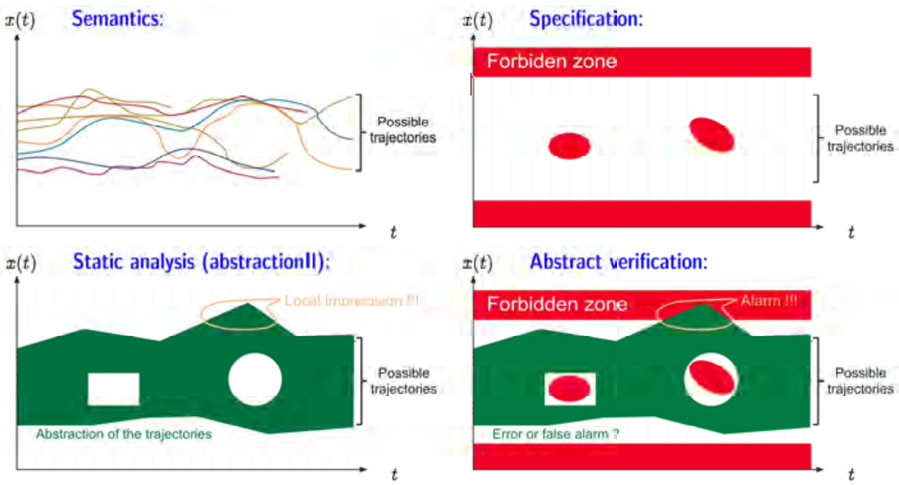
Principle of abstraction-based verification



COUSOT, P., AND COUSOT, R. Abstract interpretation: a unified lattice model for static analysis of programs by construction or approximation of fixpoints. 4^{th} *POPL* (Los Angeles, 1977), 238–252.

OK

Principle of abstraction-based verification (cont'd)



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False alarm

Abstract interpretation-based static verification is successful in industry

- Polyspace verifier (The MathWorks)
- Stack analyzer (AbsInt)
- AiT (WCET analyzer by AbsInt)
- Astrée:
  - Sound
  - Scales to 10^6 LOCs of C code
  - Effective (5mn to 35h) with no false alarms for control/command applications
  - To be commercialized by AbsInt

The difficulty of program verification

- Relatively "easy" in the small:
  - By exhaustive enumeration (e.g. model-checking)
  - User guided deductive proofs (e.g. proof checkers)
- Very difficult in the large:
  - Safety/mission critical software is routinely millions of lines
  - Approximate abstractions are necessary
  - Bug-finding helpful but unsatisfactory
  - False alarms as a result of undecidability

How to scale up ?

I don’t know (1)

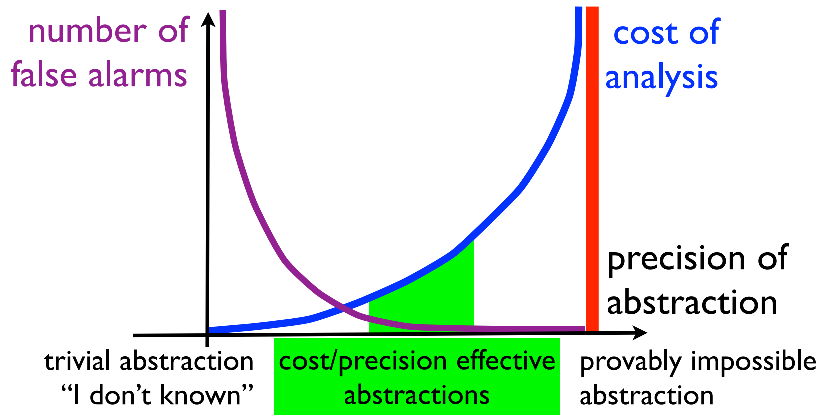
A few modest suggestions only!

(1) typical answer in abstract interpretation

I don’t know (1)

(1) typical answer in abstract interpretation

Choose the right abstraction for the right problem



Consider modularity (of the analysis)

- Analyze programs by parts
  - may be difficult to discover the parts
  - may be difficult to discover the interfaces
  - needs costly relational analyzes
- Analyze program globally
  - simpler abstractions
  - which can be very efficient
- Program parts may unavailable → stubbing & input configuration is necessary

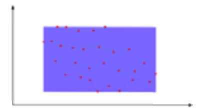
Choose efficient representations of abstract properties

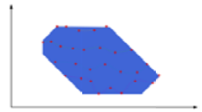
- General representations: formulae in logic/theorem provers, BDDs in model-checking, bit-vectors in dataflow analysis, ...
  - no universal encoding of data does always scale up in algorithmics
- Abstraction specific representations:
  - efficient algorithms require adequate data representations

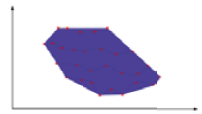
Consider modularity (of the analyzer)

- Can be very hard to guess the right abstraction:
  - experimentation is required to find the appropriate cost/precision balance
  - so easy modifiability of the verifier is indispensable
- Extensible modular verifier:
  - many (parametric) abstractions
  - abstractions are modular with common interfaces
  - abstractions can be inserted/changed/replaced
  - abstractions can be combined

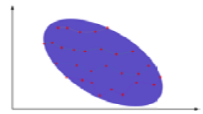
Combine universal & domain-specific abstractions

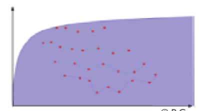






- Universal abstractions:
  - designed once and for all
  - useful as an everywhere usable basis
  - can produce many false alarms (e.g. Polyspace verifier)
  - acceptable when over-approximation is acceptable (compiler optimization, WCET analyzer, etc.)





- Domain/problem-specific abstractions:
  - designed 'on demand'
  - very precise
  - necessary to reach no false alarm

Consider local (better than global) abstractions

- Global abstraction: same abstraction is used everywhere in the program, e.g.
  - Data flow analysis
- Local abstraction: different abstractions are used in different program regions (depending on estimate of required precision) e.g.
  - Manual proof
  - Astrée
- Necessary to balance cost/precision

Refine by adjusting and combining abstractions

- Manuel refinement can be intelligent
- User-guided refinement through directives:
  - Ajust precision of parametric abstractions
  - Hints to analyzer on where to use which abstractions
- Designer refinement:
  - Add new abstractions combined with existing ones to enhance precision
  - The analyzer must be designed to be modular

Understand the sources of imprecisions

- The weaskest inductive argument necessary to make the proof is not expressible within the abstraction
- No way out of a required refinement
- Automatic refinement does not scale
  - Requires to go to the concrete semantics
  - The most abstract refinement is fixpoint computable but not convergent
  - Ultimately equivalent to a fixpoint computation in the concrete

Conclusion

To scale, you must be quasi-linear!

The end, thank you for your attention