System Specification, Verification and Synthesis (SSVS) – CS 4830/7485, Fall 2019

Parting thoughts

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WHAT WE COVERED

Systems, Specifications, Verification, Synthesis

- Systems: formal system modeling
  - State machines, transition systems, automata
- Specifications: formal requirements
  - Temporal logics, automata
- Verification: check whether the system satisfies the spec
  - We saw model-checking
  - Explicit-state (enumerative) and symbolic methods
- Synthesis: automatic generation of systems from specs

WHAT WE DID NOT COVER

(very partial list)

Abstraction

- Big topic.
- Trace inclusion, **simulation**, **bisimulation**: relations between transition systems. E.g., see Chapter 7 of [Baier and Katoen, 2008].
  - Can help reduce the size (number of states / transitions of a transition system).
  - While preserving some of its properties [Loiseaux et al., 1995].
  - Sometimes infinite-state systems become finite, e.g., timed automata! See Chapter 9 of [Baier and Katoen, 2008] and [Alur and Dill, 1994, Tripakis and Yovine, 2001].
- **Predicate abstraction**: e.g., abstract integer variable n with three predicates: $n < 0$, $n = 0$, $n > 0$ (three abstract states). See [Dams and Grumberg, 2018, Jhala et al., 2018] and [Graf and Saidi, 1997].
- **Abstract interpretation**: a mathematical theory of abstractions, compositions of abstractions, computations of abstractions using fixpoints, etc [Cousot and Cousot, 1977].

Abstraction

- Big problem: how do we come up with the right abstractions? One idea is **Counter-Example Guided Abstraction Refinement** (CEGAR): start with a coarse abstraction and refine to more fine-grain abstractions as necessary, based on **spurious counter-examples**.
- Abstraction is key in **software verification** [Ball et al., 2011]. This is a whole area by itself, with annual tool competitions (e.g., `https://sv-comp.sosy-lab.org/`), etc.
- Many interesting topics in software verification: **invariant generation**, **termination analysis**, **interpolation** [McMillan, 2018], dealing with memory and memory allocation (e.g., **separation logic** [O'Hearn, 2019]), **weak memory models** [Atig et al., 2010], ...

Refinement

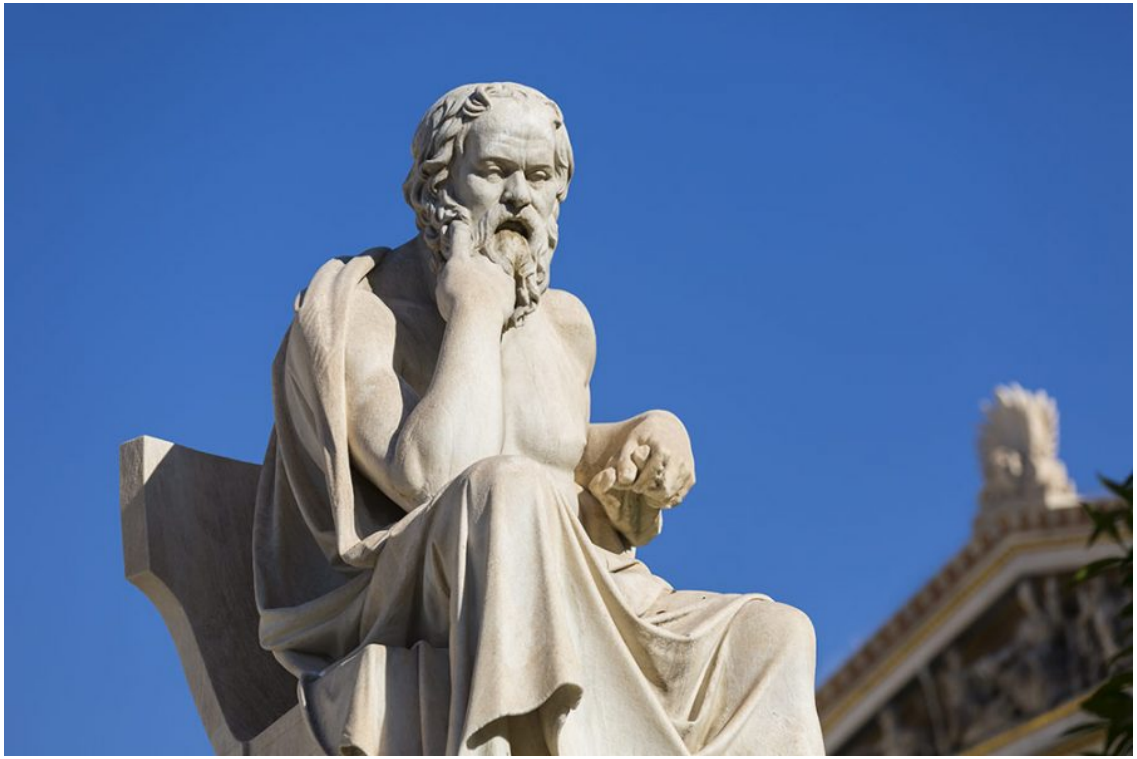
- As a relation, the counter-part to abstraction: if A abstracts B then B refines A, and vice versa.
- **Stepwise program refinement**: a top-down program design methodology: from more abstract programs, to more concrete programs, to finally code (implementations).
  - While preserving properties along the way.
  - And also preserving **compositionality**.
- Some
  references: [Floyd, 1967, Hoare, 1969, Dijkstra, 1972, Wirth, 1971, Back and Wright, 1998, Tripakis, 2016, Dragomir et al., 2018]

Other not covered topics

- **Probabilistic Model Checking** [Baier et al., 2018]
- **Hybrid Systems** [Doyen et al., 2018]
- **Process Algebras** [Cleaveland et al., 2018]
- **Model Checking Security Protocols** [Basin et al., 2018]
- **Conformance Testing** and combinations of model-checking and testing [Broy et al., 2005, Godefroid and Sen, 2018]
- **Static Program Analysis** [Nielson et al., 1999]
- **Debugging** [Zeller, 2005]
- Software engineering
- Theorem proving
- ...

PHILOSOPHY

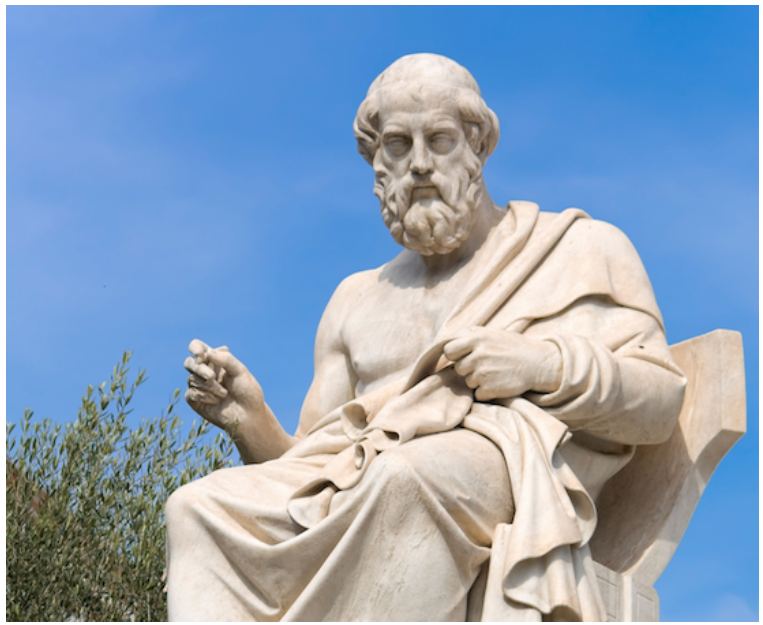
Corrupting young minds



Socrates

Language

- And logic, and reason.
- Definitions matter.
- Human language typically very poor to express complex concepts.
  - C.f. Plato's dialogues.
- A lesson we mostly forget these days, with catastrophic consequences.



Plato

Systems

- Everything is a system.
- Beautifully complex, even when small: c.f., Collatz.

Democracy

- Political systems are systems.
- Anarchy, Monarchy, Oligarchy, Democracy.
- Like all systems, they satisfy some properties, and violate other properties.
- For example, none of anarchy, monarchy, nor oligarchy, can guarantee human rights.
- Can democracy guarantee human rights?

Freedom and human rights

- What exactly does freedom mean?
- Which are our rights, exactly?
- The law.
- The justice system.

Predictions

- About the future.
- Science.
- Intelligence.
- About the past.
- Simulation and verification.

Causality

- We ask *Why ... ?* questions all the time.
- Correlation vs. causation is still an unsolved problem in science.
- Many questions beginning with *Why* are ill-defined.
- *Why am I angry?*
- *Why does my stomach hurt?*
- *Why did Nokia fail?*
- *Why did Greece go bankrupt?*
- *What caused the financial crisis in 20XX?*
- *Why is this state machine in state X?*

Nature vs nurture

- Another famous question that has been bothering mankind for centuries.
  - Famous professors still publish best-sellers on it.
- Yet from a system-theoretic point of view the question makes little sense.
- When a state machine exhibits a certain behavior, is that due to the structure of the state machine, or due to the inputs that the machine has been given?

Time

- What is time?
- Isn't it just the change of state?
- Is it possible to "travel back in time"?
- Does it mean "roll back your state" (like "undo")?
- Or roll back the state of the universe, while maintaining your state (age, memories, etc.) unchanged?

Don't forget to answer the course evaluation survey!

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