Runtime Monitoring for the Diagnosis and Recovery of Complex Physical Systems

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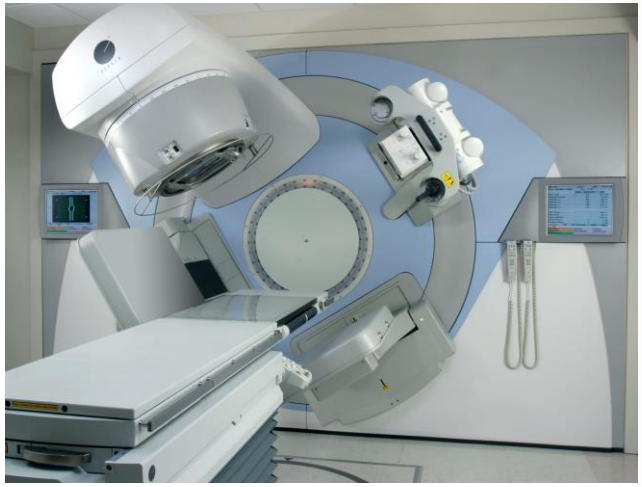
Introduction

- Reliability and fault tolerance in the operation of critical systems is **imperative** to avoid financial setbacks or even loss of lives
- Software engineers try to test their software as much as possible… but very difficult to test huge software products thoroughly to ensure correct functionality.
- Such a system does not work in a vacuum, but in an environment for which it is impossible to simulate **all possible variations**.

Murphy's Law:

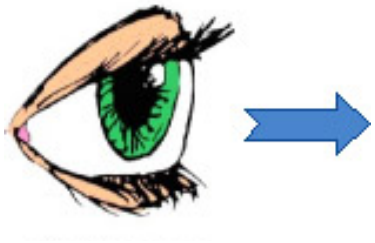
- **Therac-25:** a radiation therapy machine involved in 6 accidents in the 1980s.
- Patients given massive overdoses of radiation due to failure of software interlocks to protect against high-power beams.
- A 1-byte counter in a routine frequently overflowed, and if the operator provided an input at that moment, the interlock would fail.

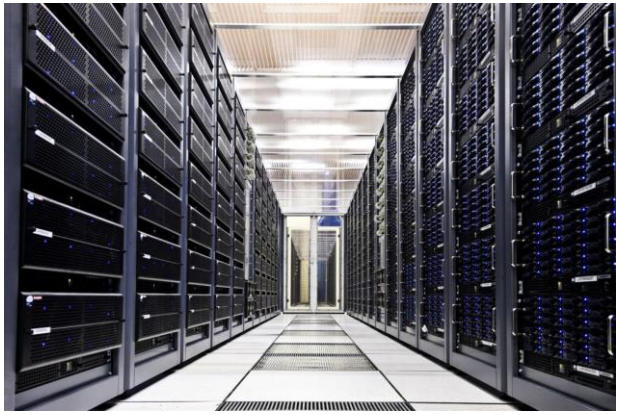


Typical software analysis

- Many automated tools in or outside Integrated Development Environment (IDE) for code coverage, profiling, benchmarking..
- Done at development phase, when bugs are cheaper to fix.
- **Static testing:** code reviews, walkthroughs, inspections.
- **Dynamic testing:** executing code for a given set of test cases.

What is Runtime Verification?

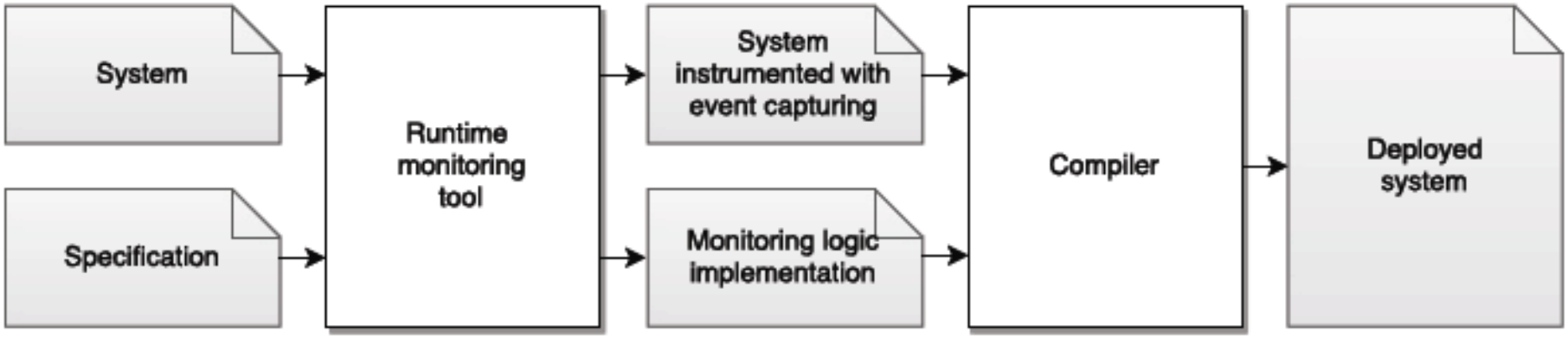




- The extraction of information from a **running** system, to **detect and react** to observed behaviours violating certain properties.

- Rather than **inlining** property checks via e.g. assertions, which **interweaves** the program with the specification of the properties to be satisfied, the two are **separated**.

How does Runtime Verification work?



1. Runtime monitoring tool: modifies the system code to capture points of interest during execution.

2. The specification is automatically converted into a monitor, which checks that the system behaviour does not violate the specification.

How does Runtime Verification work?

- Separation of the system and specification aspects allows for:
  - Different teams working on the different aspects
  - The use of the same specification across different versions, instances or systems
  - Avoids possibility to introduce new bugs as complexity of inline checks increases
  - E.g. *isGasLeak* variable should not have been true for more than 1 minute in the last 30 minutes just before *induceSpark* function is called..

Detector Control System: A use case for RV

- The ALICE High Momentum Particle Identification (HMPID) detector and ALICE-LHC interface control systems are based on the WinCC OA platform.

- Both are critical systems:
  - issues with the detector (e.g. pressure, cooling, HV trips) could result in downtime or even damage
  - issues with ALICE-LHC interface (e.g. DIP server status, disk space, manager status) could result errors in the production of parameter files for the physics runs.

- WinCC OA provides an event-driven platform for controlling and monitoring distributed physical devices and software services.

- These systems are modelled using state machines (SMI++) and the human end-user interacts with them through a GUI.

Detector Control System: A use case for RV

- In both cases, some degree of automatic problem diagnosis already exists through raising of alarms which are visible in the GUI.

- However, typically the recovery from single or multiple failures needs to rely on some form of human intervention, which costs time.

- Runtime monitoring is well-suited to ensuring, using the same specification input, that:

  - the distributed WinCC system does not enter into any critical conditions that could be harmful for the detector or accelerator.
  - the recovery from conditions which occur from time to time is performed automatically.

Our expertise in RV and DCS

- The Semantics and Verification Research Group (SVRG) at the University of Malta has been active in RV since 2005.
- RV applications that we worked on:
  - Industrial financial transactions
  - Telescope signal processing
  - Computer vision (airport security)
- Already involved in various European projects e.g. Open Payments Ecosystem (Horizon 2020), ARVI COST Action.
- Many years of experience in the design, implementation and operation of detector control systems (HMPID & LHC_IF)