PLCverif: a tool to formally verify critical PLC programs

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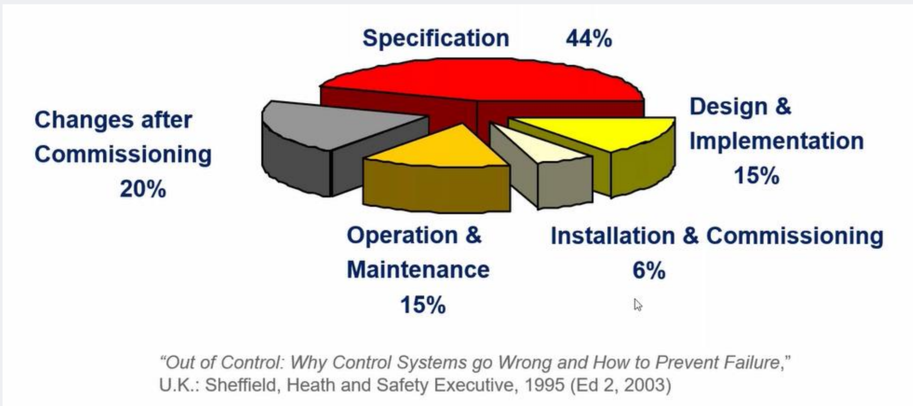
ACCELERATOR RELIABILITY WORKSHOP ARW 2022

Software defects can be fatal and extremely costly

- Errors in the design, specification and software implementation are very common



- E.g. Ariane 5 accident (more than 500 million US$)

- In the **particle accelerators domain**, a software failure may have very serious consequences:
  - **Safety of the personnel** (risks related to radiation, electrical systems, cryogenics, etc.)
  - **High cost** (**damage** of machines and industrial facilities **or unavailability** of particle accelerator)

In industry, **the most common software verification techniques** are **peer reviews and testing**.
But they have **some limitations** (e.g. how to catch corner cases? all combinations of the program cannot be tested).

How to guarantee that critical software is compliant with the functional specifications?
Formal methods

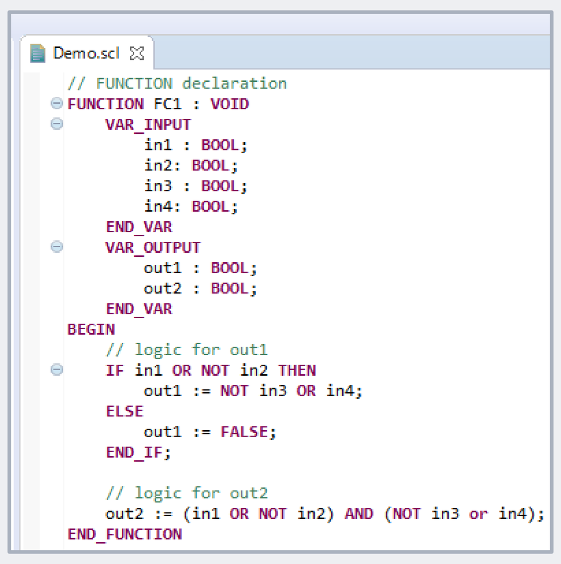
- **Formal methods** are techniques based on **mathematics and formal logic** (e.g. petri nets, automata, temporal logic, B-method, etc.)
- They can be used for **specification** and modelling, simulation, **formal verification** (e.g. **model checking**), etc.
- They provide **more effective** verification techniques (**more combinations** are explored)
- They are **popular** techniques **in critical industries** (e.g. aerospace, aircraft and railway industries)

PLCverif: Model checking for PLC programs

What is model checking? given a global **model of the system** and a **formal property**, the model checking algorithm **explores exhaustively** that the model meets the property

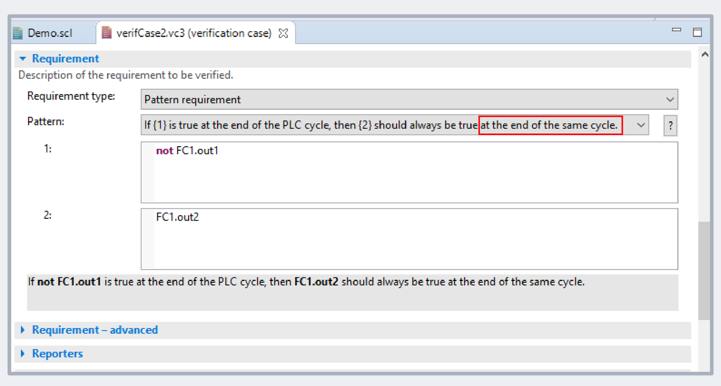
PLCverif user interface (inputs)

1 PLC program



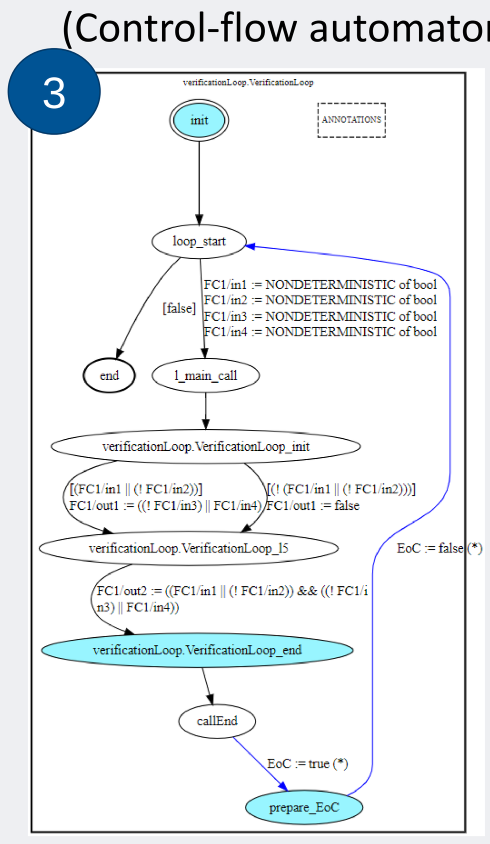
2 Property to verify (specification patterns)

"If Output1 is FALSE, then Output2 should be TRUE at …"



PLCverif internals

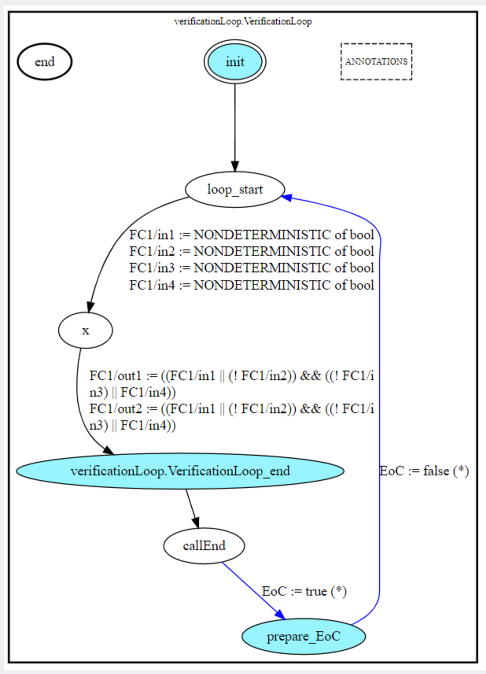
3 Intermediate model generation (Control-flow automaton)



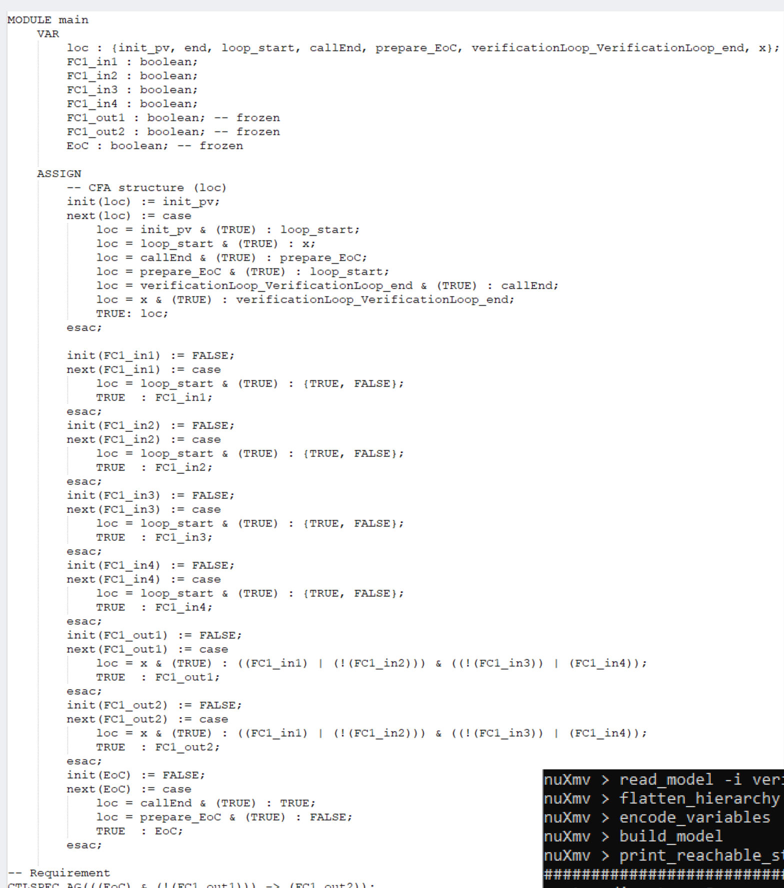
4 Formalized property (Temporal logic)

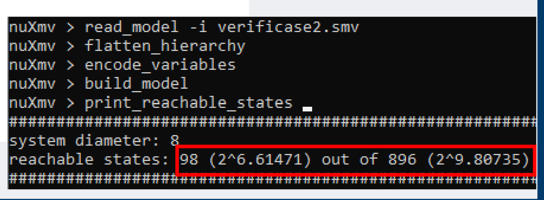
AG ((EoC & !FC1.Out1) → FC1.Out2)

5 Model reduction and abstraction techniques



6 Specific model generation (nuXmv model)





7 Model checking algorithms

Model checker

CBMC

theta

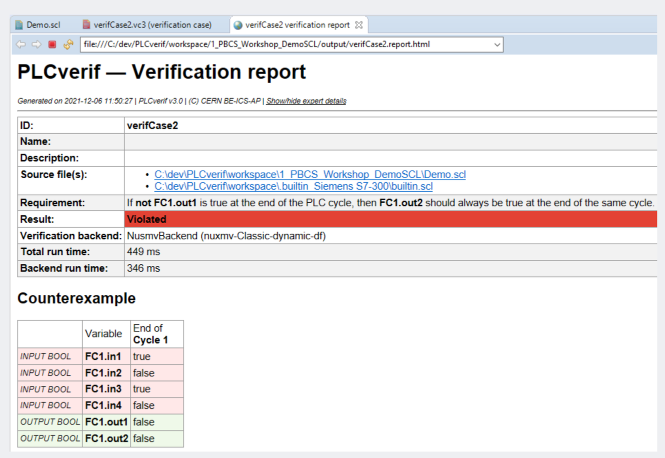
PLCverif user interface (results)

Model checking report

8

✓ Property OK

✗ Property failed
Trace leading to the violation (counterexample)



PLCverif is an **open source** project https://gitlab.com/plcverif-oss (more details in www.cern.ch/plcverif)

PLCverif relevant projects

- **CERN SPS-PPS project:** *B. Fernandez et al. "Applying model checking to highly-configurable safety critical software: The SPS-PPS PLC program" in Proc. of the 18th ICALEPCS* https://accelconf.web.cern.ch/icalepcs2021/papers/wepv042.pdf
- **CERN SM18 project:** *B. Fernandez et al. "Cause-and-Effect Matrix specifications for safety critical systems at CERN" in Proc. of the 17th ICALEPCS* https://accelconf.web.cern.ch/icalepcs2019/papers/mopha041.pdf
- **ITER:** *B. Fernandez et al. "Applying model checking to critical PLC applications: An ITER case study" in Proc. of the 17th ICALEPCS* https://accelconf.web.cern.ch/icalepcs2017/papers/thpha161.pdf
- **GSI:** collaboration to formally verify safety critical PLC programs of the FAIR particle accelerator

CERN Beams Department
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