# Using mutation testing to improve test efficiency in embedded systems

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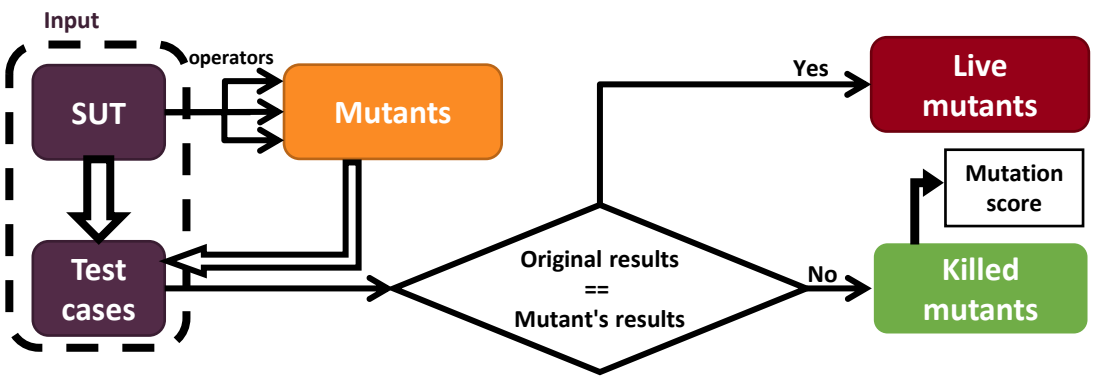
## Mutation Testing




- Uses slightly modified code variants – **mutants** – to simulate faults
- Measures **fault detection** ability of a test suite

### State of the art

- Most efficient mutation operators identified
- Focus shifting from scalability to industrial adoption and test quality improvement
- Large scale case studies: Google [1] , ESA [2]

[1] G. Petrović, M. Ivanković, G. Fraser and R. Just, "Practical Mutation Testing at Scale: A view from Google," in IEEE Transactions on Software Engineering, vol. 48, no. 10, pp. 3900-3912, 1 Oct. 2022, doi: 10.1109/TSE.2021.3107634

[2] O. Cornejo, F. Pastore and L. C. Briand, "Mutation Analysis for Cyber-Physical Systems: Scalable Solutions and Results in the Space Domain," in IEEE Transactions on Software Engineering, vol. 48, no. 10, pp. 3913-3939, 1 Oct. 2022, doi: 10.1109/TSE.2021.3107680

## Embedded software (C)

Lightweight mutation testing tool for railway software test environment

- Successfully introduced in industrial workflow
- Evaluation of tests generated to satisfy code coverage criteria: **SIL2 compliant test suites missing test cases**

Mutation results on automatically generated tests

| Operator set | # of mutants | Killed | Alive | Score |
|---|---|---|---|---|
| Increment invert | 0 | 0 | 0 | |
| Mathematical | 23 | 9 | 14 | 39.13% |
| Conditionals boundary | 2 | 2 | 0 | 100.00% |
| Conditionals negation | 26 | 20 | 6 | 76.92% |
| Boolean invert | 0 | 0 | 0 | |
| Return NULL | 61 | 38 | 23 | 62.30% |
| Remove condition | 109 | 78 | 31 | 71.56% |
| **ALL** | **221** | **147** | **74** | **66.52%** |
| Return NULL without equivalent mutants | 38 | 38 | 0 | 100.00% |
| **Corrected ALL** | **198** | **147** | **36** | **74.22%** |

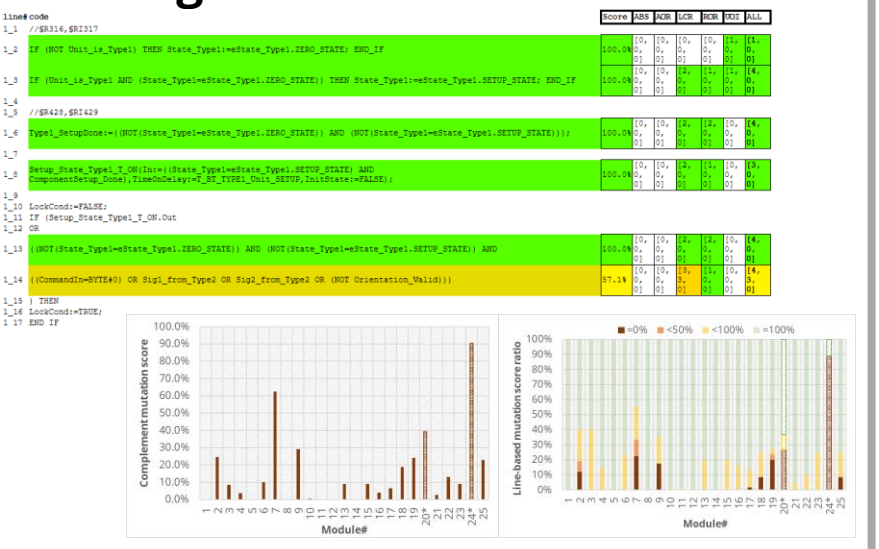
**Future work:** evaluating other industrial test generator tools

https://acta.uni-obuda.hu/Serban_Micskei_148.pdf

## PLC software (ST, FBD)

Case study in railway industry

- **Survey with developers** to identify SW testing challenges
- **New visualization and metrics** for mutation test results
- **Test generation** for live mutants




**Future work**: extended survey & transition to open-source code

https://tdk.bme.hu/conference/VIK/2024/sessions/beagy/paper/Teszthatekonysag-javitasa-mutacios