9th UCAAT User Conference on Advanced Automated Testing

ML-Based Test Prioritization "to-fail-first" as a Service

Alexandre Vernotte Aymeric Cretin

femto-st SCIENCES & TECHNOLOGIES Smartesting®

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Outline

- Test case prioritization: state of the art
- Fail-first ML based prioritization
- ML experimentation results
- Implementation
- Conclusion

Test Case Prioritization: State of the Art

Execute test cases in an order that satisfies a prioritization objective:

- Business requirements criticality
- Usage patterns frequency
- Test case failure probability (*Fail First*)
- …

Fail first TCP (Test Case Prioritization) aims at executing failing test cases **as early as possible**

- Faster bug discoveries means faster bug fixes
- Combined with test selection, reduces regression test costs (time & resources)

Test Case Prioritization: State of the Art

Many Fail first TCP techniques were created over the last 20 years:

- Prioritization by promoting test cases diversity
  - E.g., compute string distance between test cases

    Y. Ledru et al. **Prioritizing test cases with string distances.** *Autom. Soft. Eng. 19, pp. 65–95.* 2012

- Prioritization by predicting the test cases' result, which may rely on:
  - Code coverage — JS. Elbaum et al. **Test case prioritization: a family of empirical studies.** IEEE Trans.on Softw. Eng., vol. 28, no. 2, pp. 159-182, Feb. 2002
  - Code changes — R. K. Saha et al. **An IR Approach for Regression Test Prioritization Based on Program Changes.** *IEEE/ACM Int. Conf. on Softw. Eng., pp. 268-279.* 2015.
  - Past verdicts — Marijan et al. **Test Case Prioritization for Continuous Regression Testing: An Industrial Case Study.** *IEEE Int. Conf. on Soft. Maintenance, pp. 540-543.* 2013
  - Code & test complexity, customer-assigned costs, severity of detected faults, etc.

Test Case Prioritization: State of the Art

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Recently, ML (Machine Learning) approaches emerged to tackle TCP

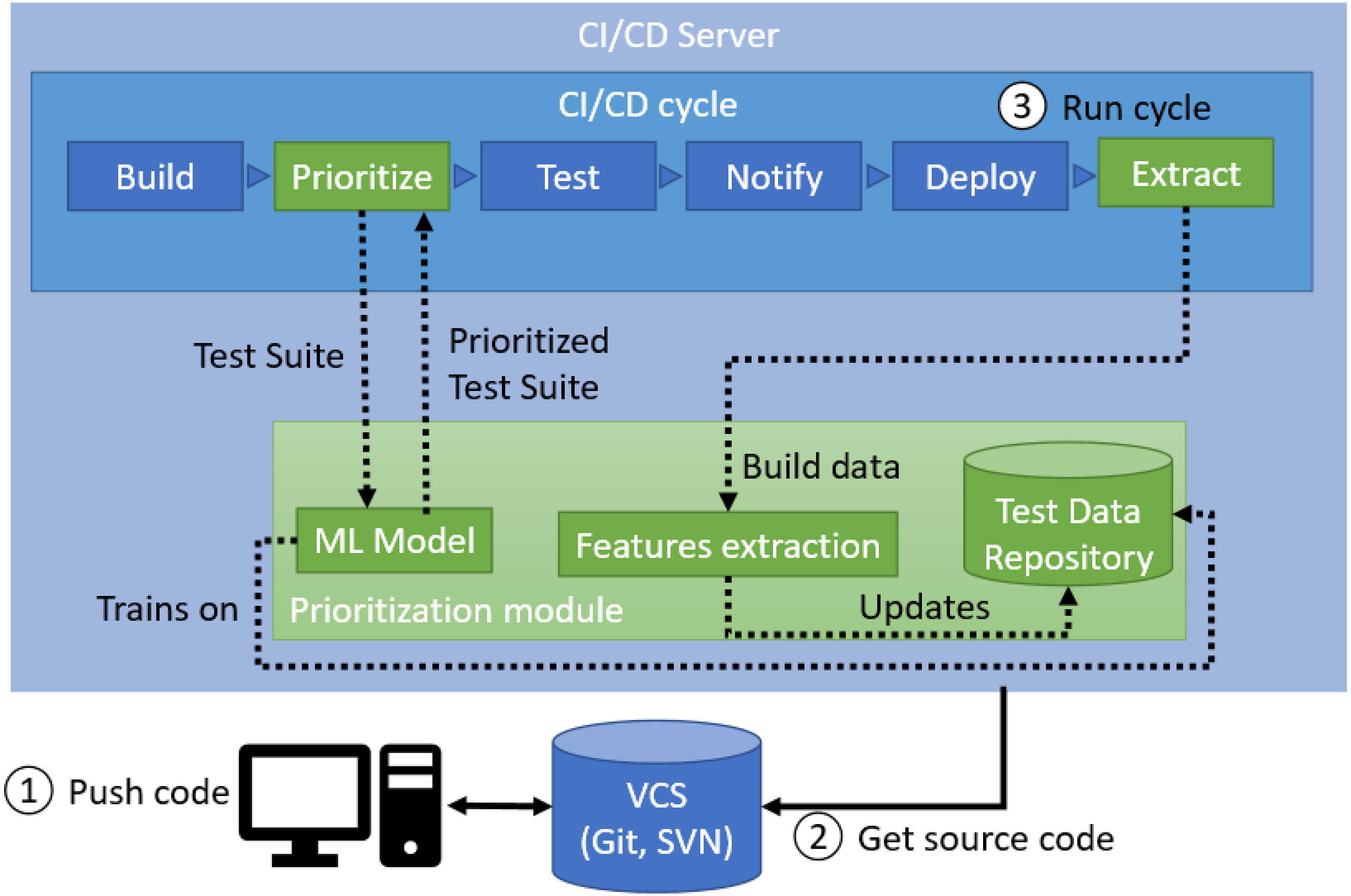
- Fail first TCP is a verdict prediction problem = typical ML problem
- Capability to combine multiple data sources (e.g. code coverage data + historical data)

⟹ Indication that ML may outperform heuristics

A wide variety of ML models

- Deep Neural Networks — Sharif et al. **DeepOrder: Deep Learning for Test Case Prioritization in Continuous Integration Testing.** *IEEE Int. Conf. on Soft. Maint. and Evolution, pp. 525-534.* 2021.
- Genetic Algorithms — Khatibsyarbini et al. **Test Case Prioritization Using Firefly Algorithm for Software Testing.** *IEEE Access, vol. 7, pp. 132360-132373.* 2019.
- Decision Trees — J. Chen et al. **Optimizing test prioritization via test distribution analysis.** *EU Soft. Eng. Conf. and Symp. on the Foundations of Soft. Eng., ACM, pp. 656–667*, 2018.
- Reinforcement Learning — Bagherzadeh et al. **Reinforcement Learning for Test Case Prioritization.** *IEEE Trans. on Soft. Eng., vol. 48, no. 8, pp. 2836-2856.* 2022.

Fail-first ML based TCP Architecture



Test and code features for TCP

History-based features

- Last N verdicts (N with range 4 – 10)
- Execution time (mean of the last 3 runs)
- Execution frequency
- Time (number of CI/CD cycles) since last execution

Test case related features

- Age of the test case
- Number of test methods
- Whether the test case was modified
- Text similarity score with modified source code files

Models Experimentation

Experimentation were conducted on 2 classes of ML model:

- Decision Trees (DTs)
- Reinforcement Learning (RL)

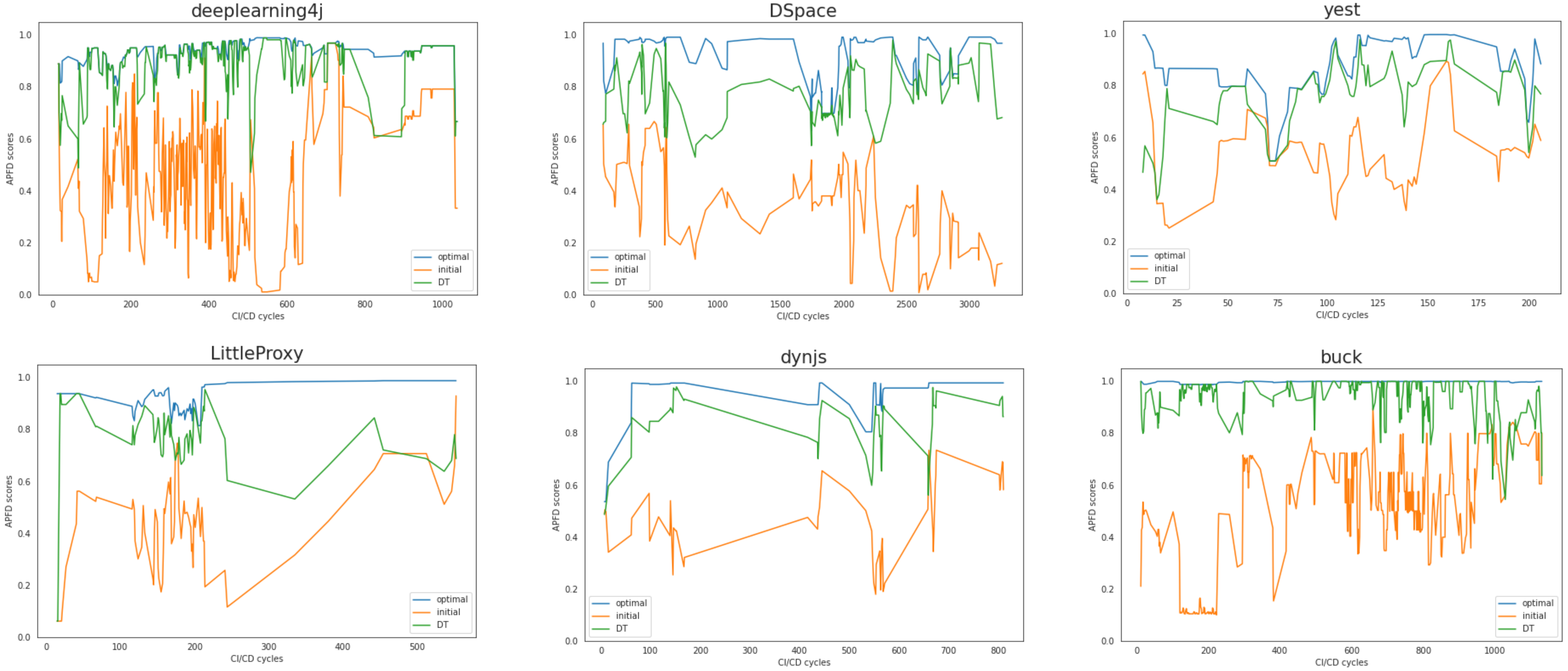
The models were evaluated on 13 software development projects:

- 12 GitHub projects obtained from the RTPTorrent dataset
- 1 live product (Smartesting Yest)

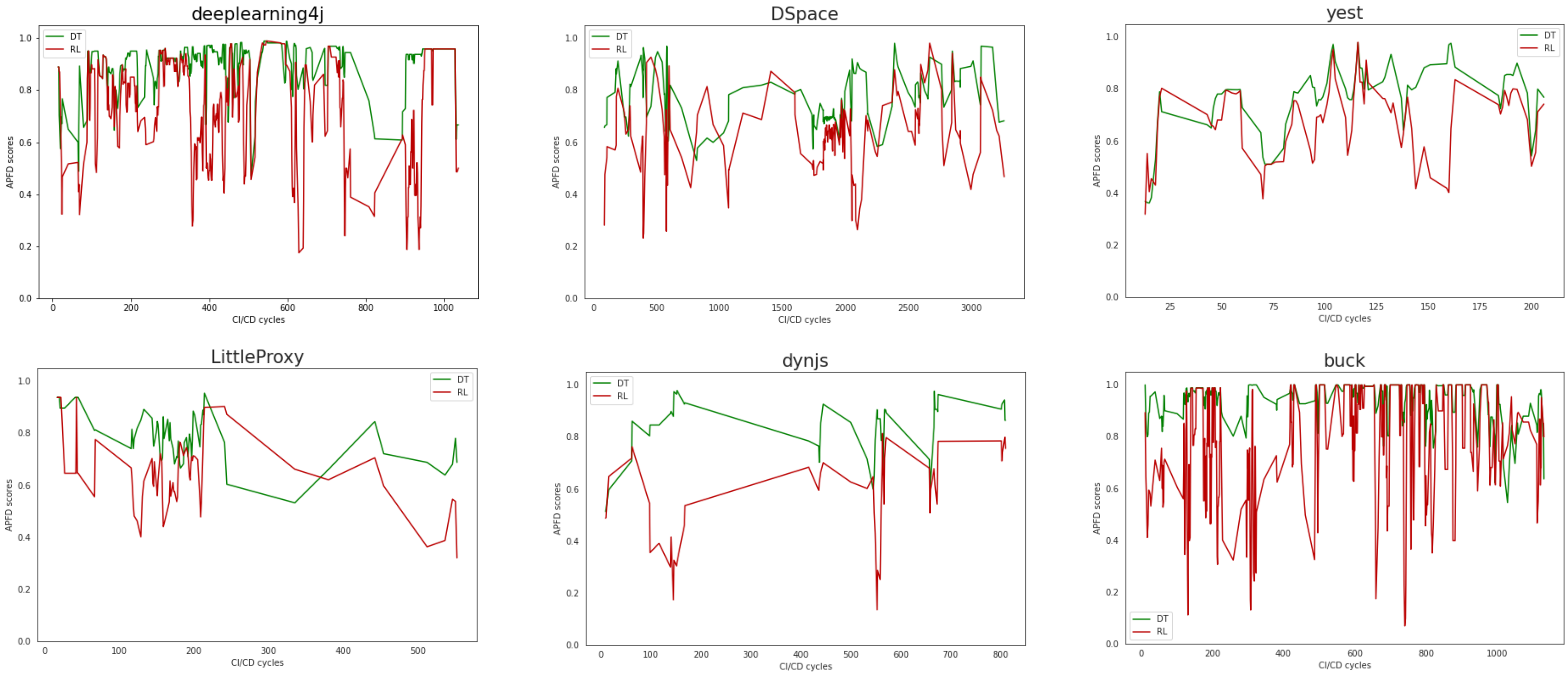
Results consistently showed that DTs are superior to RL models (w.r.t. the feature set)

- Much faster to train (seconds for DTs, several hours for RL at best)
- Better prediction scores (APFD – Average Percentage of Faults Detected)

Experimentation Results: DTs vs baseline



Experimentation Results: DTs vs RL



Implementation: Comet API

Comet API

- Online prioritization requests
- Resources management:
  - Projects
  - Test cycles
  - Tests
  - Test features
- Can be easily integrated to a CI server or a test management tool

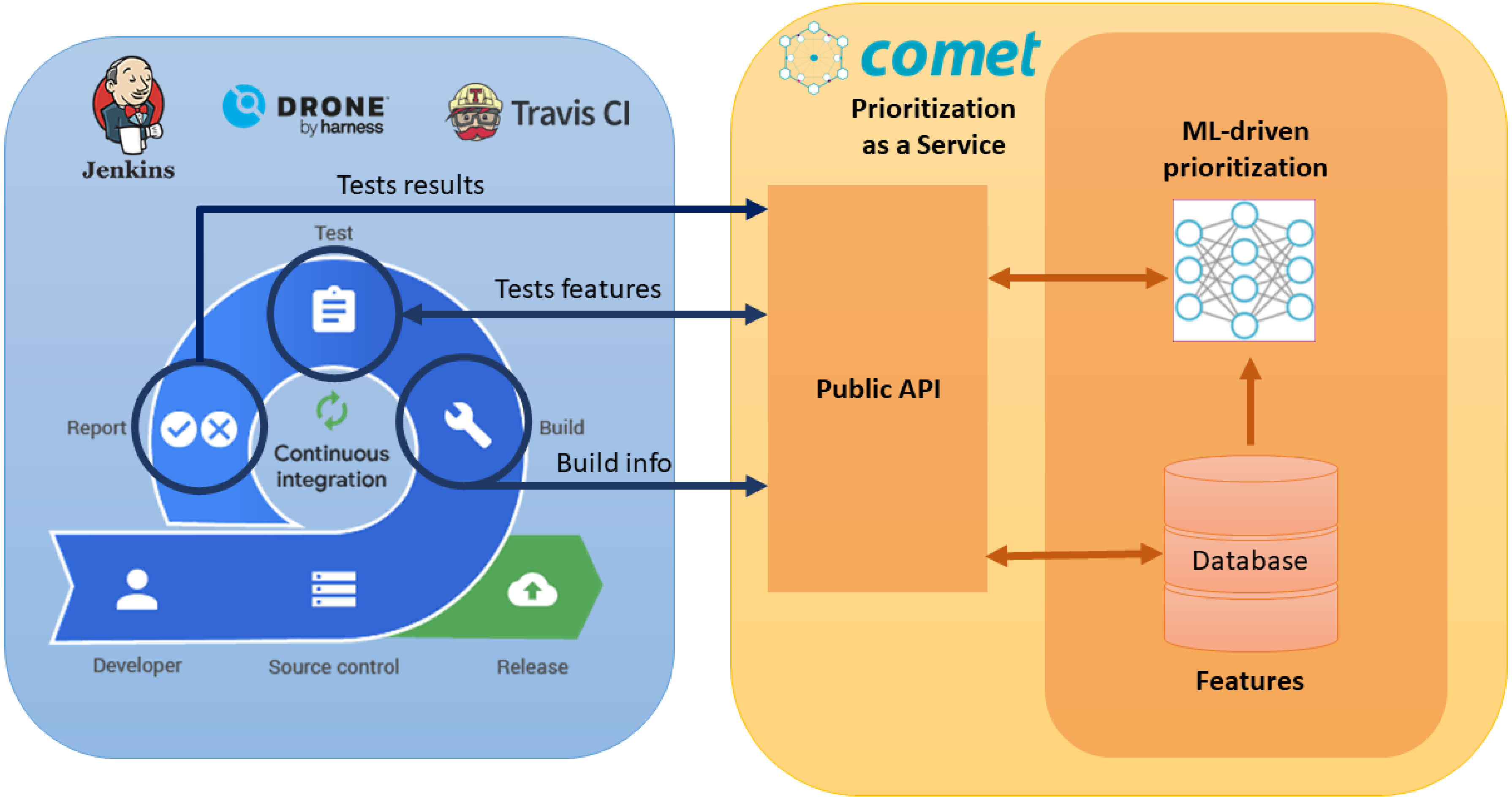
Implementation: CI integration

CI integration

- Targets automated tests
- Jenkins Plugin

Collected data

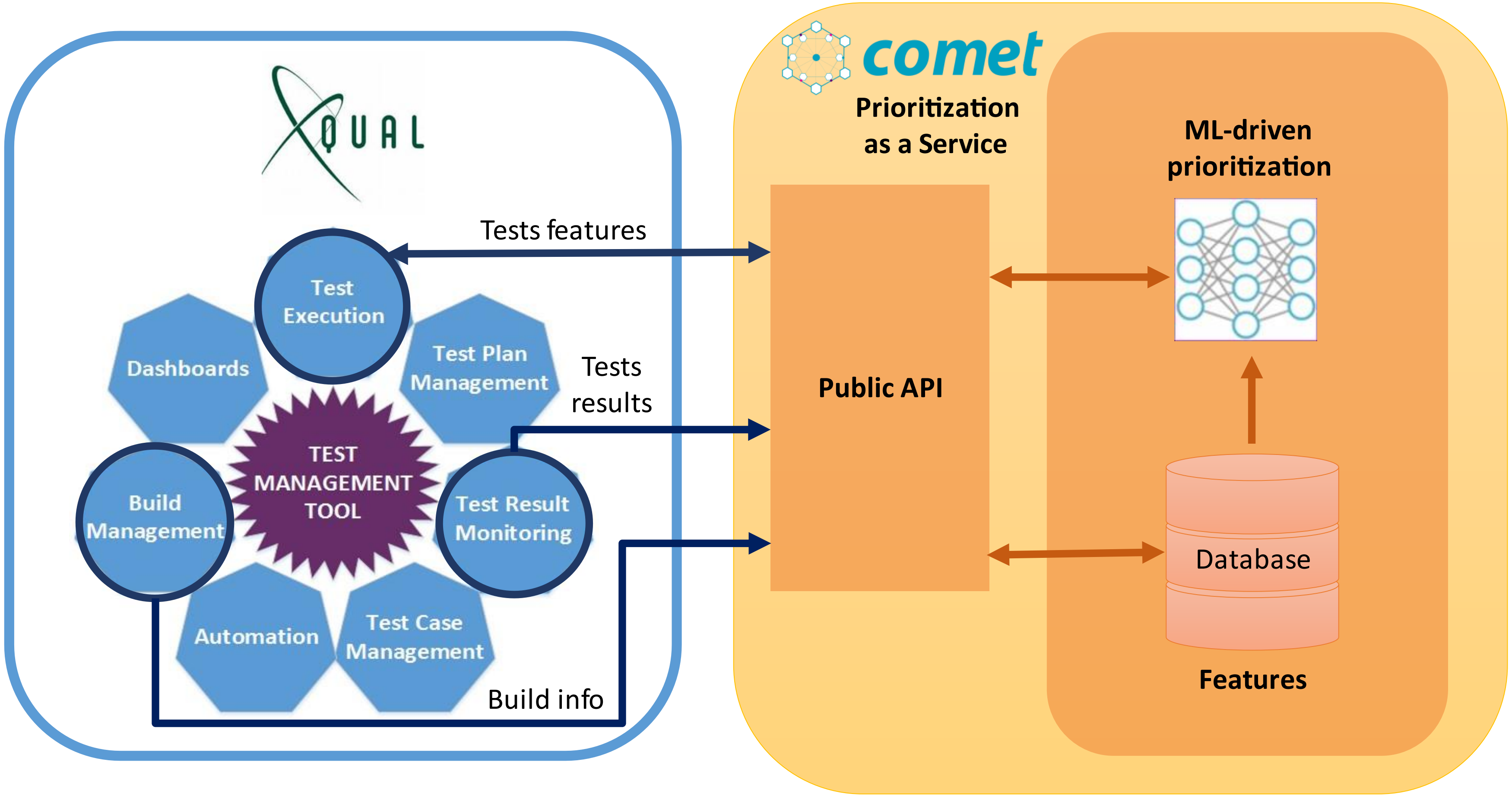
- Build info
- Tests features
- Tests results



Implementation: Test management Tool

Test management tool integration

- Targets automated and manual test
- Java and Python clients



Remaining Barriers for ML-driven TCP

Major features that are too cumbersome to compute

- Per test code coverage can rarely be obtained without hassle
- NLP may be an acceptable lightweight alternative to per test code coverage

Peng et al. **Empirically revisiting and enhancing IR-based test-case prioritization**. *29th ACM SIGSOFT Int. Symp. on Soft. Testing and Analysis (ISSTA). ACM, pp. 324–336*. 2020.

Defining an explicit testcase execution ordering ⟹ A lot harder that it appears to be!

- Most testing tools do not allow this (has to do with test cases having to be independents)
- Multi-module (e.g., maven) projects add another layer of complications

Conclusions

- Regression tests are time-consuming to run, and TCP can help reduce that cost
- SoTA implies that ML models outperform heuristics
- Experimentation suggests that decision trees yield better results than RL models
- Comet is a fail-first TCP API that can integrate CI/CD processes
- Comet can also integrate test management tools to prioritize manual tests

Any further questions?

alexandre.vernotte@femto-st.fr

aymeric.cretin@smartesting.com