Project Group "CoCoVa"

Compositional and Continuous Validation for Autonomous Driving

Praeambel

"You only have one car." is a statement concerning every team participating in disciplines for autonomous driving in the Formula Student. It is also true for various organizations with small teams, limited resources and high risk in operations, like startups, mining, or aerospace industry. There it is vital to conserve resources and detect failures of the systems as early as possible, to increase the chance of finding a solution.

Idea of CoCoVa

- **Continuous validation** through automation
- Tool supported solution for validating **individual components** isolated or grouped
- **CI/CD** pipelines and cloud-based **simulation** services.
- **Automatic testing** on different data

➡ Combined with our solutions for **physical models** we make testing rapid and usable on many plat-platforms, facilitating elaborate validation at every stage of the development process

A Validation Framework for CPS

Challenges/Risks

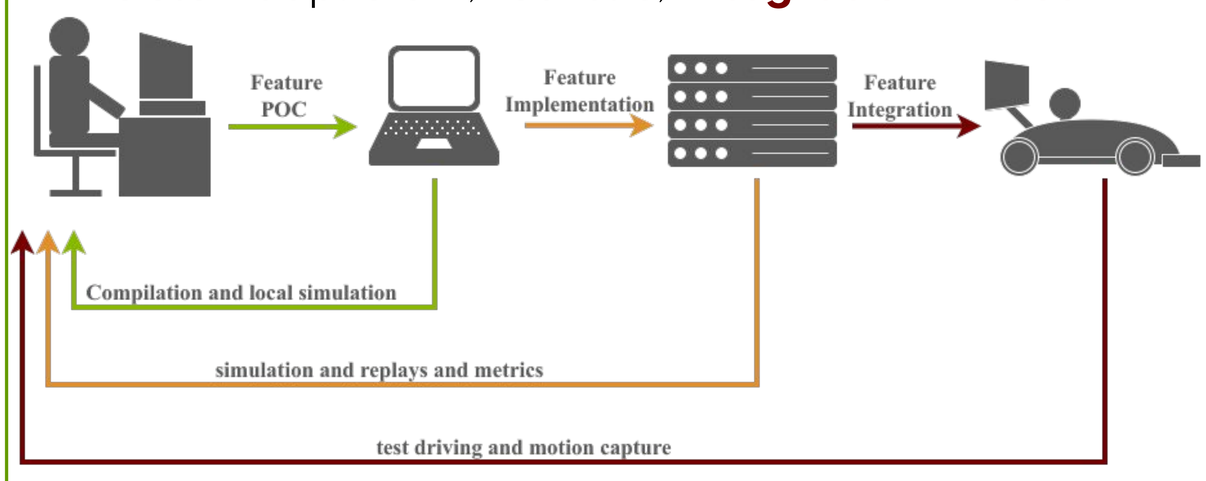
- Risk of **failure** on the target platform (FS223)
- Two weeks **testing time**, before events

Solution

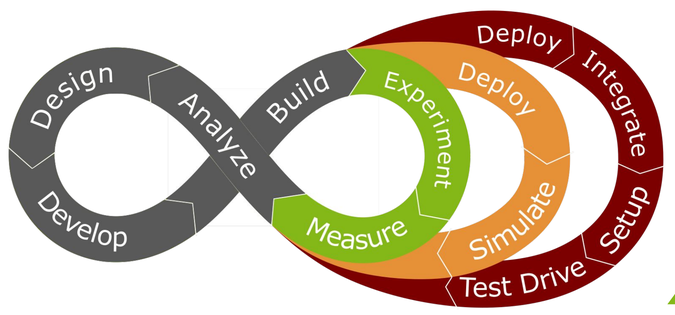
- Continuous Compositional Validation consisting of:
  - Closure of feedback cycles (Loop)
  - Testing on all stages of development (pyramid)

Validation Loop

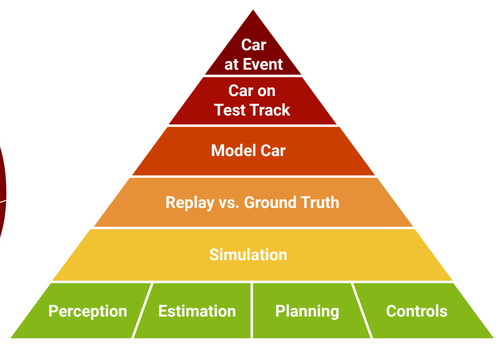
- Inner loop: Fast, componential level, **POC-phase**
- Middle loop: detailed quantifiable metrics, mostly automated, **Implementation-Phase**
- Outer loop: Slow, realistic, **Integration-Phase**



The **CoCoVa Workflow** Paradigm



Continuous Loop



Compositional Pyramid

Validation Pyramid

Lower levels:

- isolated Components
- fast & easy testing
- detailed metrics

Higher levels:

- System as a whole
- elaborate & realistic
- The ultimate metrics: **Performance at event**

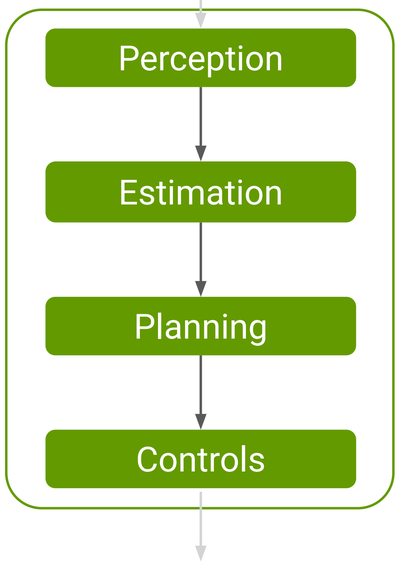
GET racing & JARVIC

GET racing

- Formula Student Team of TU Dortmund
- 65 students
- variety of expertieses
- Annually building a racecar
- Annually competing in Formula Student competitions

- race car for 2022/23 season: The **FS223**
- First **autonomous** concept car
- Track defined by cones
- Blue cone → left border
- Yellow cone → right border

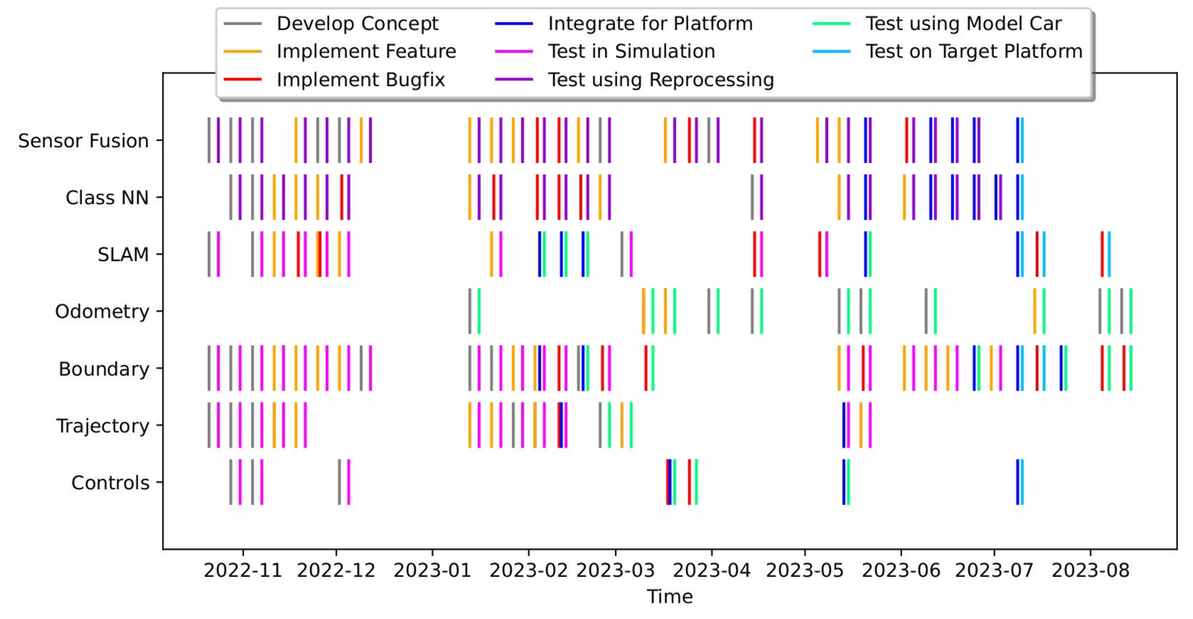
JARVIC



- Typical 4-step robotics pipeline
- **Perception** detects cones and their color
- **Estimation** creates a map and localizes the vehicle within
- **Planning** calculates a Trajectory to navigate
- **Controls** calculates the desired throttle and steering

Evaluation

- Three identifiable feature implementation stages:
  1. PoC (pink & gray)
  2. Implementation (orange & pink & purple)
  3. Integration (green & sky)
- All validation **accessible** through CI/CD
- **Cloud-based simulation** helps development
- Sensor **recordings** are evaluated through CI/CD
- A **wide variety** of validation was used.



GET racing

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