Testing Autonomous CPS with BeamNG Simulations Softbody Environment

Group Fuego

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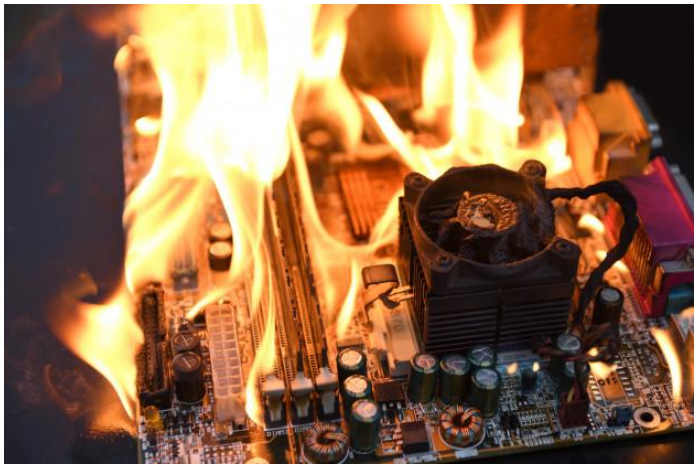
Project Context

Cyber-physical Systems (CPS)

Motivation - Relevance

CPS Problems:

- CPS are difficult and expensive to test
- Difficulty to repeat and test faulty scenarios



System Simulators Problems:

- Need a lot of computing power
- Are time consuming

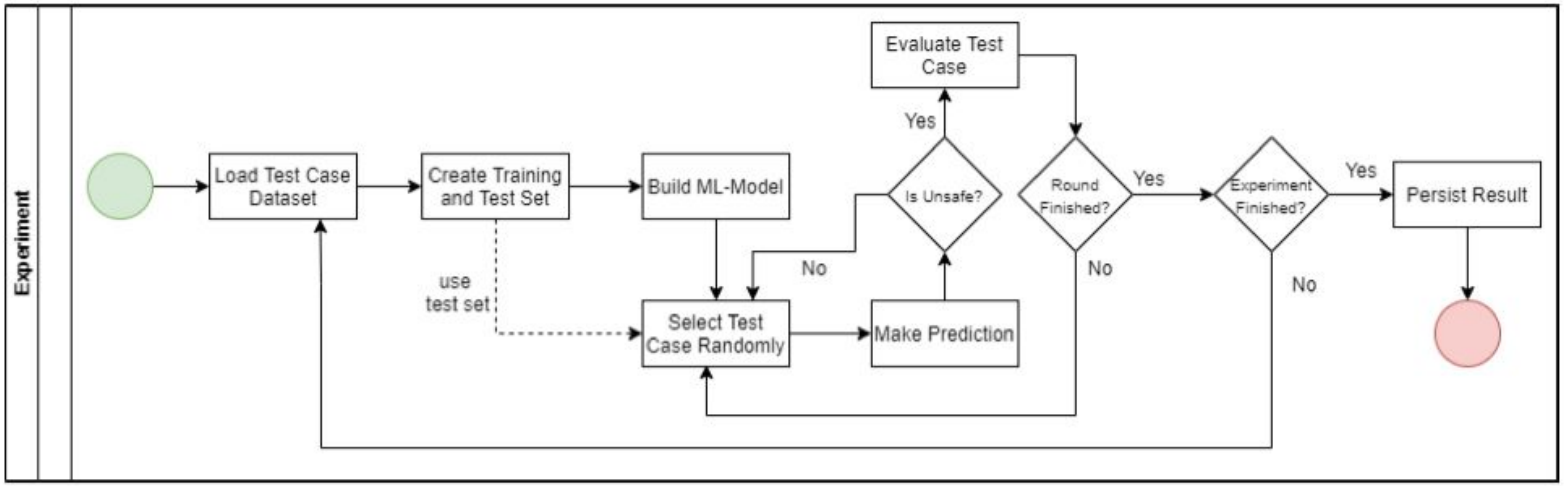
Related Work

Masterthesis:
“**Automatically Testing Cyber-physical Systems in Virtual Environments**”
by Bill Bosshard

His related Work:

- AsFault - A tool to generate test cases for self-driving cars
- Ac3R - Automatic Crash Constructor from Crash Report
- DeepJanus - Model-based Exploration of the Frontier of Behaviours for Deep Learning System Testing
- Simulators: BeamNG

What is the CPS Sorter?



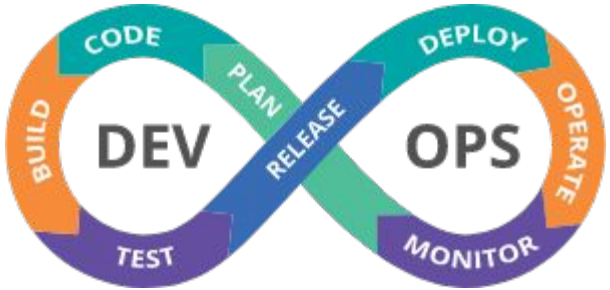
Safety Definition

Based on context of Bill Bosshard's thesis:

- Safe vs. Unsafe
- **Lane-keeping** is fundamental ➜ going out of bounds is dangerous
- **Out of bounds** incident: more than two meters from the lane center
- **Unsafe** ➜ if out of bounds.

Goal of the Project

- Extension of the original study by Bill Bosshard
- “Self-Driving Quality Assessment” of safe and unsafe scenarios through DevOps integration
- Optimize the pipeline by using selection with determined safety critical criterias

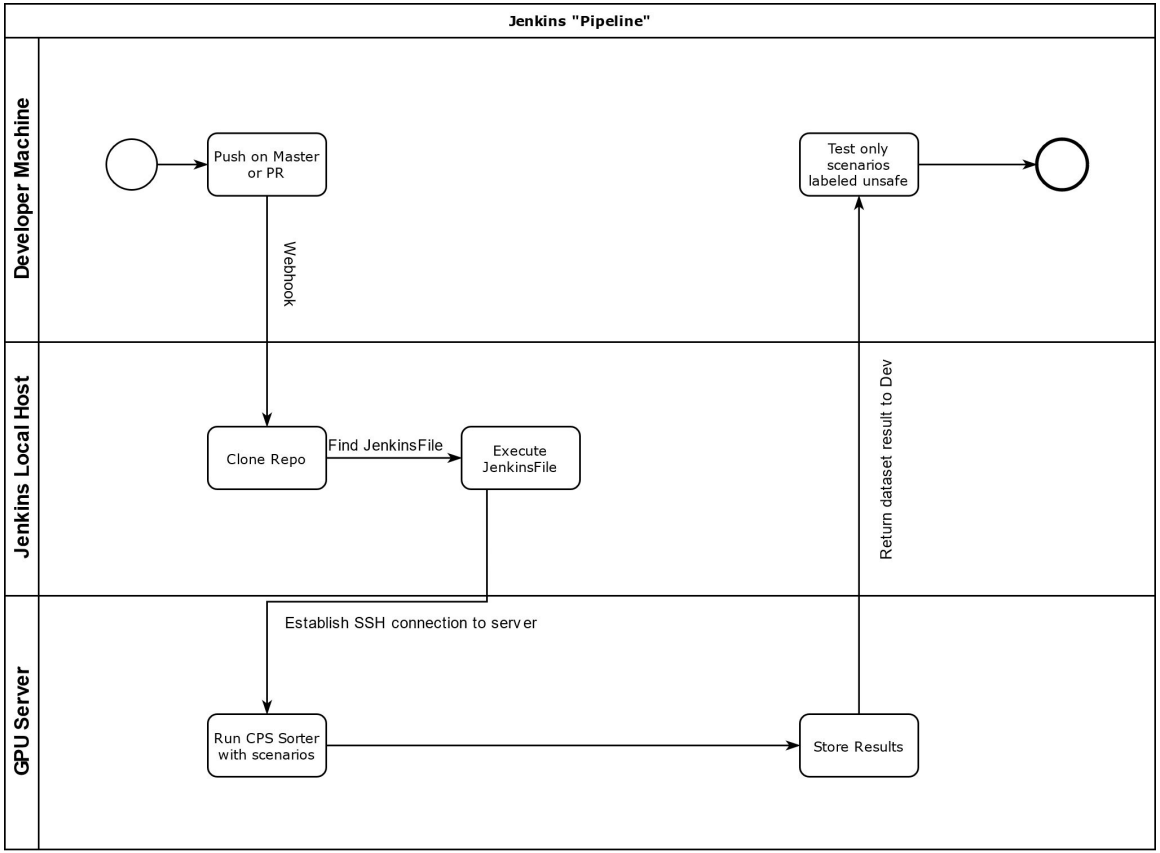


Project Outline

- DevOps Pipeline based on Jenkins
  - Automatic remote “self-driving quality” assessment

- Determine other safety criteria
  - future integration into the pipeline
  - assess other simulators than BeamNG

Pipeline: Methodology 1



Pipeline: Methodology 2

- Set up DevOps pipeline on Jenkins
- Triggered by Github repo
- Label scenarios “safe” or “unsafe”

```
node {
    def remote = [:]
    remote.name = "ubuntu"
    remote.host = "160.85.252.170"
    remote.allowAnyHosts = true
    withCredentials([sshUserPrivateKey(credentialsId: 'jenkins', keyFileVariable: 'identity', passphraseVariable: 'pa
        remote.user = user
        remote.identityFile = identity
        remote.passphrase = pass
        stage("Copy Files Over"){
            sshPut remote: remote, from: 'C:/Users/Solo de Zaldivar/Documents/HS20/cps/test_scenarios/Master-Thesis-C
        }
        stage("Run cps_sorter on files"){
            sshCommand remote: remote, command: 'source Documents/FuegoGroup/cps/CPS-SORTER/venv/bin/activate
            \ncps_sorter run-model-eval -i ~/Documents/FuegoGroup/cps/test_scenarios/remoteTests/beamng_risk_1.5 -o ~
        }
        stage("Copy results from remote to local"){
            sshGet remote: remote, from: 'Documents/FuegoGroup/cps/test_scenarios/remoteTests/solodezaldivar/output',
        }
    }
```

Pipeline: Results

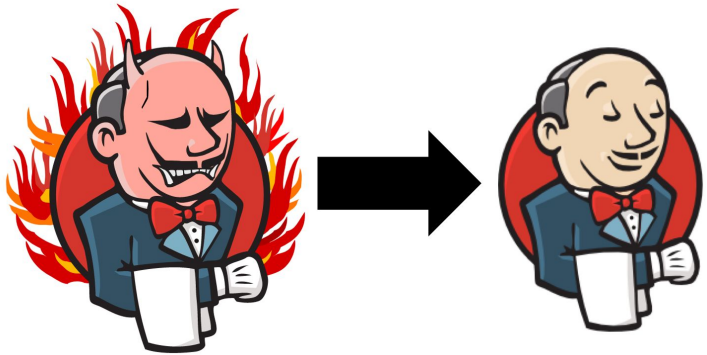
direct_distance	road_distance	num_l_turns	num_r_turns	num_straights	median_angle	total_angle	mean_angle	std_angle	max_angle	min_angle	median_pivot_off	mean_pivot_off	std_pivot_off	max_pivot_off	min_pivot_off	safety
239.4373897	2041.302731	10	7	4	255	3495	205.5882353	130.2360115	345	15	27	28.17647059	13.66935299	47	2	safe
116.1741886	2517.616059	11	8	4	255	3900	205.2631579	105.0623084	345	45	17	17.78947368	12.59314328	47	2	unsafe
235.3610504	2261.60108	8	7	3	255	2970	198	111.067547	345	30	22	23	14.39907404	47	2	unsafe
26.78348258	1628.239187	3	5	3	97.5	1125	140.625	101.7176699	300	15	32	30.125	14.56397525	47	2	safe
177.5049295	1159.771118	10	10	5	202.5	3675	183.75	143.9433482	345	15	17	24	13.26649916	47	7	safe
225.2710563	2034.56002	8	7	3	270	2940	196	124.3543325	345	15	27	29	14	47	7	safe

Console Output

```
Started by user Ramon Solo de Zaldivar
Checking out git https://github.com/solodezaldivar/SME/ into C:\Users\Solo de Zaldivar\AppData\Local\Jenkins\.jenkins\workspace\CPS Pipe@script to read Jenkinsfile
The recommended git tool is: NONE
using credential f4fd1a50-108b-47ee-9b7e-b3c200c6c24f
 > git.exe rev-parse --is-inside-work-tree # timeout=10
Fetching changes from the remote Git repository
 > git.exe config remote.origin.url https://github.com/solodezaldivar/SME/ # timeout=10
Fetching upstream changes from https://github.com/solodezaldivar/SME/
 > git.exe --version # timeout=10
 > git --version # 'git version 2.23.0.windows.1'
using GIT_ASKPASS to set credentials GitHub Pass
 > git.exe fetch --tags --force --progress -- https://github.com/solodezaldivar/SME/ +refs/heads/*:refs/remotes/origin/* # timeout=10
Seen branch in repository origin/master
Seen 1 remote branch
 > git.exe show-ref --tags -d # timeout=10
Checking out Revision e2884d0bb6649e604313d95460dabe3675355706 (origin/master)
 > git.exe config core.sparsecheckout # timeout=10
 > git.exe checkout -f e2884d0bb6649e604313d95460dabe3675355706 # timeout=10
Commit message: "test with jenkinsfile"
 > git.exe rev-list --no-walk 369c86960905301e32438ba460acf49dc58eb5c3 # timeout=10
Running in Durability level: MAX_SURVIVABILITY
[Pipeline] Start of Pipeline
[Pipeline] node
Running on Jenkins in C:\Users\Solo de Zaldivar\AppData\Local\Jenkins\.jenkins\workspace\CPS Pipe
[Pipeline] {
[Pipeline] withCredentials
Masking supported pattern matches of %identity% or %pass% or %user%
[Pipeline] {
[Pipeline] stage
[Pipeline] { (Run cps_sorter on files)
[Pipeline] sshCommand
Executing command on ****[160.85.252.170]: source Documents/FuegoGroup/cps/CPS-SORTER/venv/bin/activate
cps_sorter run-model-eval -i ~/Documents/FuegoGroup/cps/test_scenarios/remoteTests/beamng_risk_1.5 -o ~/Documents/FuegoGroup/cps/test_scenarios/remoteTests/solodezaldivar/output sudo: false
```

Pipeline: Challenges & Evaluation

- setup (requirements)
- fully understanding CPS Sorter
- Server and SSH connection
- Jenkins on Server vs Ngrok



Pipeline Demo

Video Pipeline

Safety: Methodology

1. Evaluation of **other simulators**
    - which one to choose?
2. Extend **safety classification** of scenarios
    - what makes a scenario unsafe?

Flightmare: A Flexible Quadrotor Simulator

Yunlong Song, Selim Naji, Elia Kaufmann, Antonio Loquercio, Davide Scaramuzza

Robotics and Perception Group
Depts. Informatics and Neuroinformatics
University of Zurich and ETH Zurich

Simulator Assessment

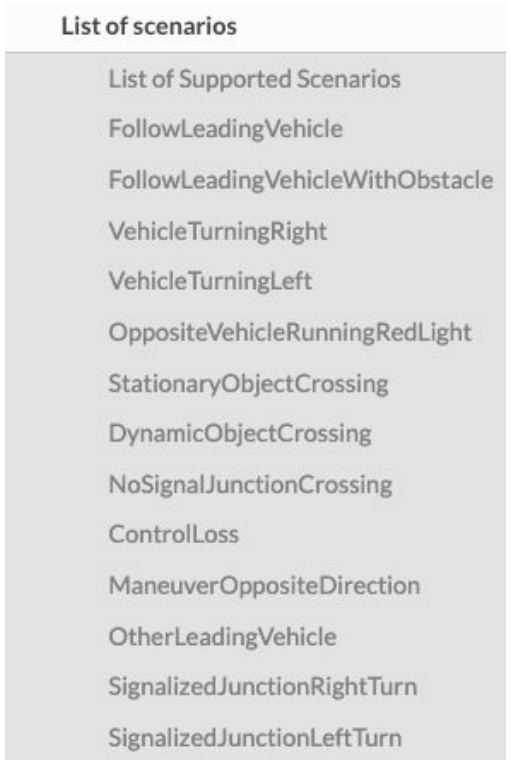
- Requirements given by our environment
- Documentation
- Active community
- Autonomous agent
- Custom scenario support

Autonomous Agent

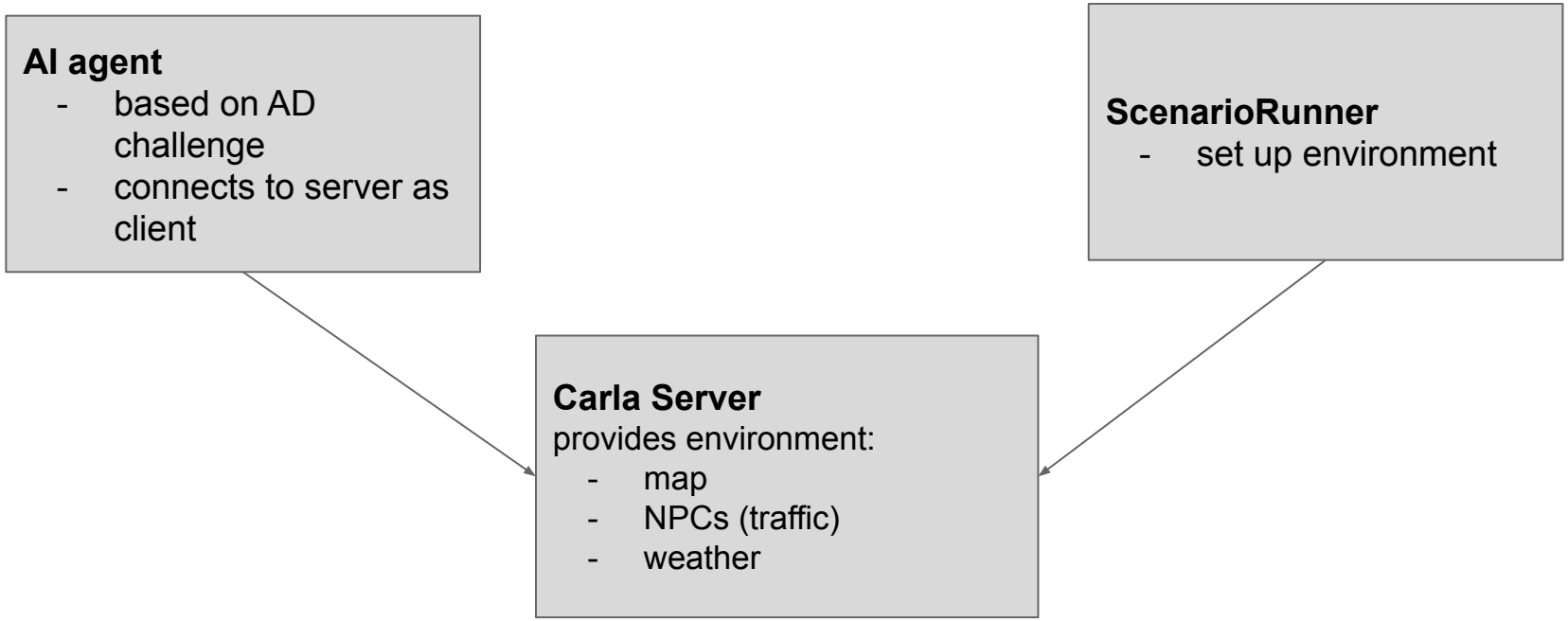
- AI agent required to evaluate scenarios
- Baseline provide through the “Carla Challenge”

Carla ScenarioRunner

- extension module for Carla simulator
- developed in the context of the Carla AD Challenge
- provides traffic scenario integration
  - through Python Interface
  - or OpenSCENARIO standard
- initial set of pre-built scenarios



Experiment Setup



Scenario Classification

validity:

- 0: unable to run scenario
- 1: able to run scenario

city:

- 0: not in city environment
- 1: city environment

lane change:

- 0: lane change not required
- 1: lane change required

turn:

- 0: no turn
- 1: curve (< 90 degrees)
- 2: hard turn (e.g. at intersection)

safety level:

- 0: no objects
- 1: static object(s)
- 2: dynamic objects
- 3: multiply dynamic (and static) objects

success:

- 0: no success (e.g. collision)
- 1: success with minor difficulties (e.g. accidental lane crossing)
- 2: complete success

Safety: Results

- custom AI agent integrated into ScenarioRunner
- evaluation of 124 pre-built scenarios
  - based on our 6 safety criterias

ControlLoss_11	x="-40.4" y="-229.5" z="3" yaw="131"	1	0	0	0	1	no inference
ControlLoss_12	x="-45" y="37.2" z="11" yaw="0"	1	0	0	0	1	no inference
ControlLoss_13	x="90.9" y="-66" z="3" yaw="67"	1	1	0	2	1	stayed at STOP forever
ControlLoss_14	x="-54.7" y="110.9" z="0.1" yaw="90"	1	1	0	1	1	proper drive despite turn
ControlLoss_15	x="119.1" y="-142.7" z="0.1" yaw="-170"	1	1	0	1	1	crossed lane at turn
CutInFrom_left_Lane	x="284.4" y="16.4" z="2.5" yaw="180"	1	0	0	0	2	proper break
CutInFrom_right_Lane	x="284.4" y="16.4" z="2.5" yaw="180"	1	0	0	0	2	proper break
FollowLeadingVehicle_1	x="107" y="133" z="0.5" yaw="0"	1	1	0	0	2	proper break does not actually follow veh
FollowLeadingVehicleWithObstacle_1	x="107" y="133.5" z="0.5" yaw="0"	1	1	0	0	3	proper break with interfering cyclist
FollowLeadingVehicleWithObstacle_2	x="105" y="199.1" z="3" yaw="0"	1	1	0	0	3	proper break and following
FollowLeadingVehicle_3	x="105" y="199.1" z="0.5" yaw="0"	1	1	0	1	2	multiple lane crossings and proper follow
FollowLeadingVehicleWithObstacle_3	x="28.7" y="302.5" z="0.4" yaw="180"	1	1	0	1	3	crosses lane and collides with leading vel

Safety: Challenges & Evaluation

- setup (requirements)
- spawning the agent into a scenario
- AI agent modification
- processing power (GPU)

- more **sophisticated AI** agent required

Safety Demo

Video Scenario

Future Work

Pipeline

- Host Jenkins Pipeline on a Server
- Extend CPS-Sorter to automatically test the unsafe scenarios with Carla simulator

Safety Criteria

- Build a more sophisticated AI agent
- Build custom, simplified scenarios
- Examine compatibility of scenarios with other simulators

THANK YOU