The Role of DevOps in Computer Vision and Robotics Simulations Optimization

Introduction:

Emerging Cyber-physical Systems (CPS)—from robotics, transportation, to medical devices—will play a crucial role in the quality of life of European citizens and the future of the European economy. One specific example is the public transport system, in which the percentage of fully-automated operation is expected to increase from today's 30% to 70% by 2030: CPS is a key enabler for this. In this context, autonomous systems development and adoption– e.g., Drones and Self-driving cars– is rising in recent years. For instance, it is expected that autonomous driving will have a profound impact on our society. More than 90% of accidents are caused by human errors (e.g, driving while being under the influence of alcohol, fatigue, and other distractions or simply driving too fast or misjudging situations). Autonomous driving has the potential to eliminate those errors, which would eliminate most accidents. In addition, the potential usage scenarios of drones are wide, including the fields of agriculture, aerial photography, delivery, or surveillance. Drones can directly reach places using specific routes, giving the possibility to improve many processes, or even enable new ones. Hence, both drones and autonomous driving systems represent emerging CPS, which can operate in dynamic environments, involving also interactions with humans. The reliability and safety of software systems are of high-relevance and it is of even more importance for CPS. One reason is that the environments and working scenario of CPS are often critical or unpredictable (e.g., the scene of a fire in case of drones). In general, the increasing automation fostered by CPS emerging systems, gives rise to many challenges, at the crux of which lies the hardware and software symbiosis. These new challenges arise from the increasing complexity of CPS software, seamless connectivity, abundant compute power and hardware heterogeneity.

Advisors:

- Dr. Panichella (ZHAW/UZH)
- Prof. Scaramuzza (UZH/ETH)

External supervision from

- Dr. Gambi (University of Passau, Germany)
- Prof. Stefano Mintchev (ETH)
- BeamNG research team (Bremen, Germany)

Goal of the Project:

Investigate the role of DevOps and advanced co-simulation strategies in the context of testing and quality assessment of Drones systems. The project Research and Development will be conducted with use of AirSim, Carla, and BeamNG simulators.
The involved students will have the concrete opportunity to perform an internship with the Research team of BeamNG (Bremen, Germany) proven they have the required skills.

Requirements from the students:

- Programming skills in Python (a bit of Java program Language)
- Knowledge of ROS is a plus

Tasks Description:

1. Conduct a survey on Limit and challenges of contemporary simulators:
    a. among them
        i. AirSim
        ii. Carla,
        iii. Gazebo and ROS - as the team of Prof. Mintchev are using them
            1. simulated the behavior of a ROVER
            2. simulate the Crazyflie with Gazebo
        iv. BeamNG
    b. We already identified relevant related work (see the following section "**Relevant references to start the Survey analysis**")
2. Set up a DevOps pipeline: ***goal*** is to make "Drone quality assessment in various simulated scenarios"
    a. concerning three simulators:
        i. AirSim,
        ii. Gazebo and ROS - as the team of Prof. Mintchev
            1. simulated the behavior of a ROVER
            2. simulate the Crazyflie with Gazeebo
        iii. and BeamNG
    b. Sub-task is to define a DSL supporting the
        i. **Co-simulation:** bindings on the various simulators, focusing on understanding how to integrate multiple simulators, as each of them has different capabilities
        ii. **Co-simulations optimization:** simulators are used in a self-adaptive mode to prioritize
            1. the aspect tested in the simulations
            2. to improve the costs-efficiency of testing
        iii. **Fault-based testing** by simulating mechanical problems:
            1. BeamNG is a soft-body simulator and might be used to simulate the effect of faulty and damaged components as well as other mechanical problems (e.g., friction between parts).
        iv. **Deployment:** to deploy and test the same drone or different drones behaviors automatically on all simulators
        v. **Multi-Deployment**: to deploy and test a set of communicating, cooperating or adversarial drones in the same simulation
3. **Internship:**
    a. During the course of the project, there would be an opportunity to do an internship with the BeamNG (Bremen, Germany) research team

Relevant references to start the Survey analysis:

Open source/Research
CARLA (- http://proceedings.mlr.press/v78/dosovitskiy17a/dosovitskiy17a.pdf)

Most used and known based on Unreal Engine
Self-driving car Challenge
? Is there anything about Drones?
? Multiplayer
? Physically accurate (inertia?)
- Not Faster-than-real time: According to “2019 International Conference on Robotics and Automation (ICRA), 2019, Generating Adversarial Driving Scenarios in High-Fidelity Simulators” by Yasasa Abeysirigoonawardena1, Florian Shkurti2, and Gregory Dudek1": P*hotorealistic driving simulators, such as CARLA [3], which are based on game engines like the Unreal Engine 4, are currently not able to render faster than real-time.*
? Supports importing maps generated with RoadRunner (OpenDrive)

BeamNG.research

- No paper describes it, so researchers cannot find it by their traditional means
+ Used in research
+ Faster than real time
+ Sync/async
+ Highly programmable/flexible (robust API)
+ Comes with many maps (CARLA has 2 or 3 small maps)
+ Possibility to (semi)-automatically generate “maps/levels”
+ Has its own map editor (not sure about CARLA)
+ Reports accurate crash/damage measurements
+ Many sensors (cameras, LIDAR, temperature, fuel usage, gforces, etc.)
+ Drone mods available

AirSim (https://arxiv.org/abs/1705.05065)
+ Focus on Drones (that’s original target of the simulator)
+ Based on Unreal Engine

DeepDriving.io
+ Based on Unreal Engine
- Recently bought by a company (not sure if open anymore)
- Not used in research (as far as I know)

Apollo/Baidu
? This is mostly an entire infrastructure rather than a simulator

VISTA (MIT) - Virtual Image Synthesis and Transformation for Autonomy
https://pypi.org/project/vista/

https://celebhood.online/mit-csails-vista-autonomous-vehicles-simulator-transfers-skills-learned-to-the-real-world/
http://www.mit.edu/~amini/vista/

Webot/Sim-ATAC

- The simulator Webots does not handle **non-zero starting velocities** well, time and distance is stepped back while simulating acceleration.
+ Robotics

Paper: Cumhur Erkan Tuncali et al. “Sim-ATAV: Simulation-Based Adversarial Testing Frame- work for Autonomous Vehicles”. In: Proceedings of the 21st International Conference on Hybrid Systems: Computation and Control (Part of CPS Week). HSCC ’18. Porto, Portugal: Association for Computing Machinery, 2018, 283–284. isbn: 9781450356428. doi: 10.1145/3178126.3187004. url: https://doi.org/10.1145/3178126.3187004

+ In the paper, “DEEPCRASHTEST: Turning Dashcam Videos into Virtual Crash Tests for Automated Driving Systems. Sai Krishna Bashetty1, Heni Ben Amor1, Georgios Fainekos1” they use: *Webots simulation environment [6] using the Sim-ATAV framework [7].*

+ *6.* O. Michel, “Webotstm: Professional mobile robot simulation,” 03 2004.
+
+ 7. C. E. Tuncali, G. Fainekos, H. Ito, and J. Kapinski, “Simulation-based adversarial test generation for autonomous vehicles with machine learning components,” *2018 IEEE Intelligent Vehicles Symposium (IV)*, pp. 1555–1562, 2018, to appear in Transacion of Intelligent Transportation Systems. Available: https://cpslab.assembla.com/spaces/sim-atav/ (edited)

Olivier Michel. “Cyberbotics Ltd. WebotsTM: Professional Mobile Robot Simulation”. In: International Journal of Advanced Robotic Systems 1.1 (2004), p. 5. doi: 10.5772/5618. eprint: https://doi.org/10.5772/5618. url: https://doi.org/10.5772/5618

Gazebo and ROS

+ Robotics

Udacity Simulator

+ Based on Unity
+ Well known (maybe most known?)
- Not really accurate

TORCS/SpeedDreams

-Old fashioned racing games;
+ mostly used in robotics research

Commercial Solutions

RFPro (http://www.rfpro.com/)
? Are they involved in research

- They offer a super accurate simulations, but need to “manually” map roads with their truck.
- Is this a service or a software to download? It seems like a cloud/web based service
- According to this rFPro might collaborate with Mcity (Michigan university, which is a leader in this type of research) https://www.autofutures.tv/2020/03/09/rfpro-mcity/

Matlab Autonomous Vehicle package
PreScan (Siemens)
LGSVL
https://www.lgsvlsimulator.com/
-Platform support (Unix/Win/etc)

VTD (Virtual Test Drive - VIRES https://vires.com/)
This one is tightly bounded to OpenDrive, OpenScenario, and the like
NVIDIA Drive Sim (NVIDIA Drive Constellation)
? Not sure this is really something people can use
https://www.youtube.com/watch?v=DXsLDyiONV4

Curated Lists

https://github.com/manfreddiaz/awesome-autonomous-vehicles

Additional References

- Those might be worth to keep around https://www.dmv.ca.gov/portal/dmv/detail/vr/autonomous/disengagement_report_2019

- **A STUDY OF DRIVING SIMULATION PLATFORMS FOR AUTOMATED VEHICLES**

- **Nice comparison of simulators in CCAD:** https://www.researchgate.net/publication/340271665_Integrated_simulation_platform_for_conventional_connected_and_automated_driving_A_design_from_cyber-physical_systems_perspective

Table 1: Summary of simulators in CCAD

Simulator	Vehicle model		V2X	Traffic model		Visualization		User	License
	Physics	Sensor	COM.	3D map	Dynamics	Graphics	Context	interface	
SUMO	-	-	-	-	X	-	-	-	GPL
Vissim/ Aimsum	-	-	-	X	X	-	-	-	commercial
Prescan/ Carmaker	X	X	-	X	X	X	X	HIL	commercial
Omnet++/ NS3	-	-	X	-	-	-	-	-	GPL
Webots/ Gazebo/ USARSim	ODE/ ODE/ Unreal	X	-	X	-	OpenGL/ Ogre3D/ Unreal	X	Driving	GPL
CARLA/ AirSim	Unreal	X	-	X	-	Unreal	X	Driving/ HIL	GPL
Veins	-	-	X	-	X	-	-	-	GPL
DYNA4	X	X	-	X	X	Unity	X	HIL	commercial
CAT	ODE	X	-	X	-	Ogre3D	X	Driving	GPL
Deepdrive	Unreal	X	-	-	-	X	X	HIL	GPL
rFpro	X	X	-	X	-	rFpro	X	HIL	commercial

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Prescan/ Carmaker	X	X	-	X	X	X	X	HIL	commercial
Omnet++/ NS3	-	-	X	-	-	-	-	-	GPL
Webots/ Gazebo/ USARSim	ODE/ ODE/ Unreal	X	-	X	-	OpenGL/ Ogre3D/ Unreal	X	Driving	GPL
CARLA/ AirSim	Unreal	X	-	X	-	Unreal	X	Driving/ HIL	GPL
Veins	-	-	X	-	X	-	-	-	GPL
DYNA4	X	X	-	X	X	Unity	X	HIL	commercial
CAT	ODE	X	-	X	-	Ogre3D	X	Driving	GPL
Deepdrive	Unreal	X	-	-	-	X	X	HIL	GPL
rFpro	X	X	-	X	-	rFpro	X	HIL	commercial