How do you validate the Digital Twin in Digital Twin-based Reinforcement learning?

General concept

The general idea is to leverage simulation-based reinforcement learning (RL) for system optimization with the Digital Twin (DT) concept. Instead of training directly on or using data of a to-be-optimized system, a DT is created to serve as the training environment instead. More information on this idea can be found in the ASIMOV cookbook [1].

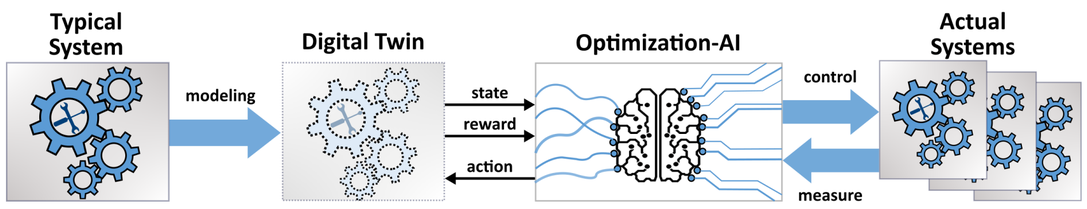

Figure 1: Overview of the development process of DT supported RL training

Validating the Digital Twin

High-level requirements can easily be defined for performance of the to-be-trained RL agent:

- Accuracy of result
- Reliability
- Time to result
- Explainability
- Footprint
- Maintainability
- Robustness
- Reproducibility
- Scalability
- Safety
- Integrability
- Development costs

Challenge: Requirements on the ASIMOV solution do not translate 1:1 to the DT as RL agents lack explainability.

"A model should be developed for a specific purpose (or application) and its validity determined with respect to that purpose." [2]

DT's purposes in DT-based RL training

1. RL training
2. Information from multiple CPS
3. Quick fine-tuning
4. DT as safety mechanism
5. Twinning
6. Status monitoring

One cannot directly infer the required accuracy of the DT from accuracy of results needed from the RL agent!

More information on DT validation as well as metrics an application can be found in Deliverable D2.5 [3].

[1] The ASIMOV Cookbook - https://www.asimov-project.eu/news-and-publications
[2] Sargent, Robert G. (2008): Verification and Validation of Simulation Models. In S. J. Mason, R. R. Hill, L. Mönch, O. Rose, T. Jefferson, J. W. Fowler (Eds.): Proceedings 2008 Winter Simulation Conference. Winter Simulation Conference, pp. 157–169.
[3] D2.5 - Digital Twin Validation - Methods and Techniques M32 - https://www.asimov-project.eu/news-and-publications
[4] https://carla.org/

The Devbed

For the goal of understanding what it takes to develop and validate a DT, a setup was created representing a miniature version of the Vehicle-in-the-loop testbed.

Figure 2: Picture of the setup as presented at the ESI Symposium

Both, the physical and the digital vehicle interact with an instance of the simulator CARLA [4] each. They run the same version of a custom-made lane-keep assistant (LKA).

We focused on modeling how the monitor and camera interact to affect the image that the LKA uses. We adjusted the image perspective, brightness, and blur to match real-world conditions.

The similarity metric selected for the validation is the distance in position at waypoints.

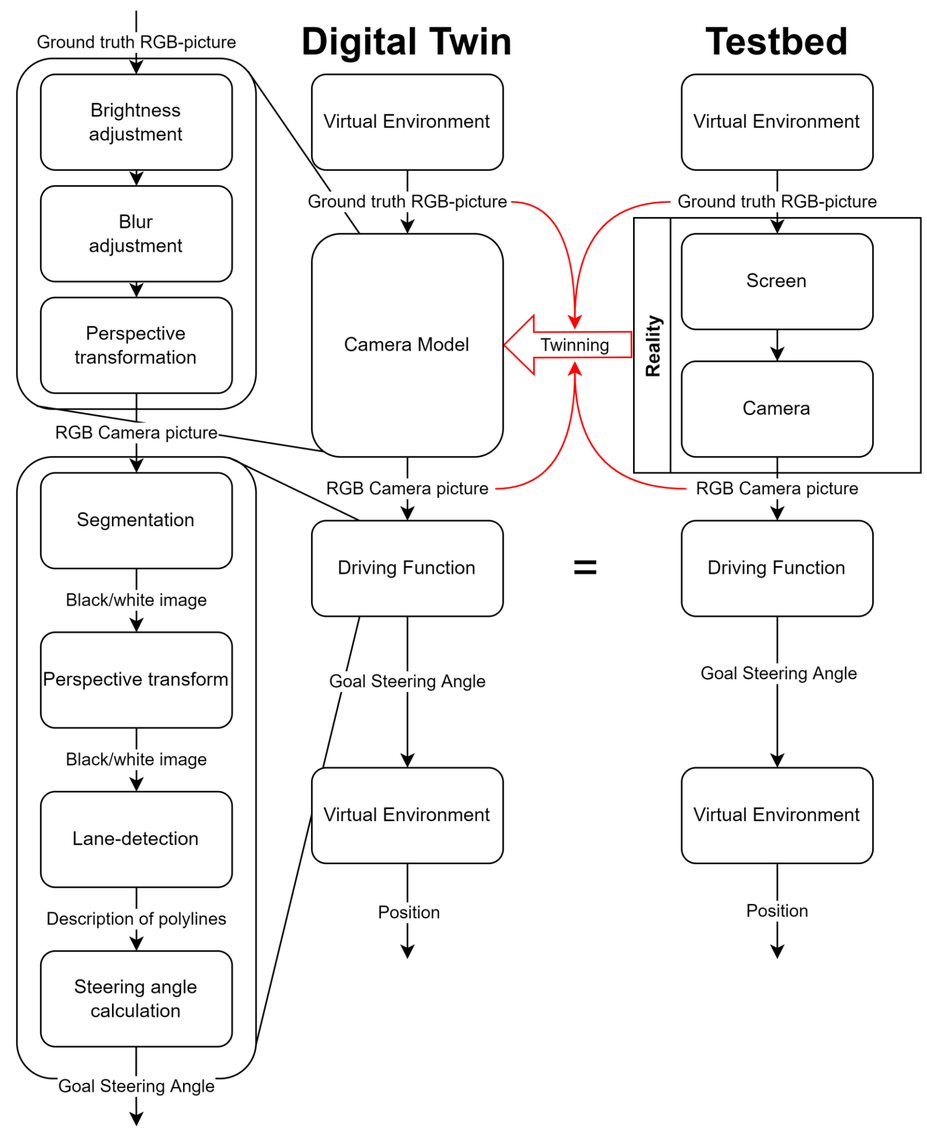

Figure 3: Block diagram comparing the DT's and Testbed's processing chain. The Twinning is highlighted as it parameterizes the camera model which represents the screen and camera.

Author: Elias Modrakowski (2024); elias.modrakowski@dlr.de

This research is also partially funded by the German Federal Ministry of Education and Research (BMBF) within the project ASIMOV-D under grant agreement 01IS21022G based on a decision of the German Bundestag.