Building a Digital Twin of a LiDAR-Based 3D-Point-Cloud for AI-Perception Training Purposes

Master‘s Thesis of Jingyao YU

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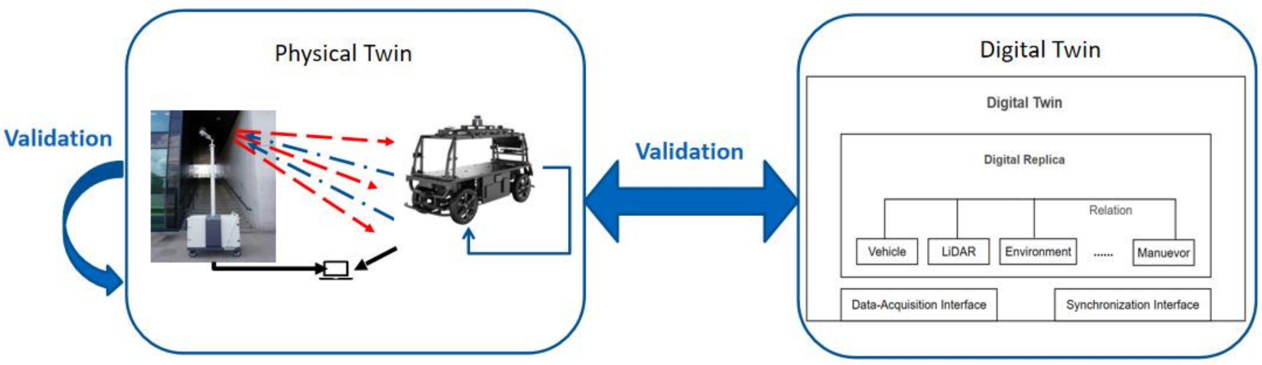
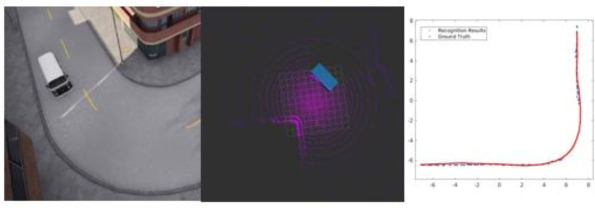




In this thesis, a Cyber Physical System (CPS) consists of a digital twin, including the vehicle, lidar sensor model, surrounding environment and manuver and its physical twin is developed.

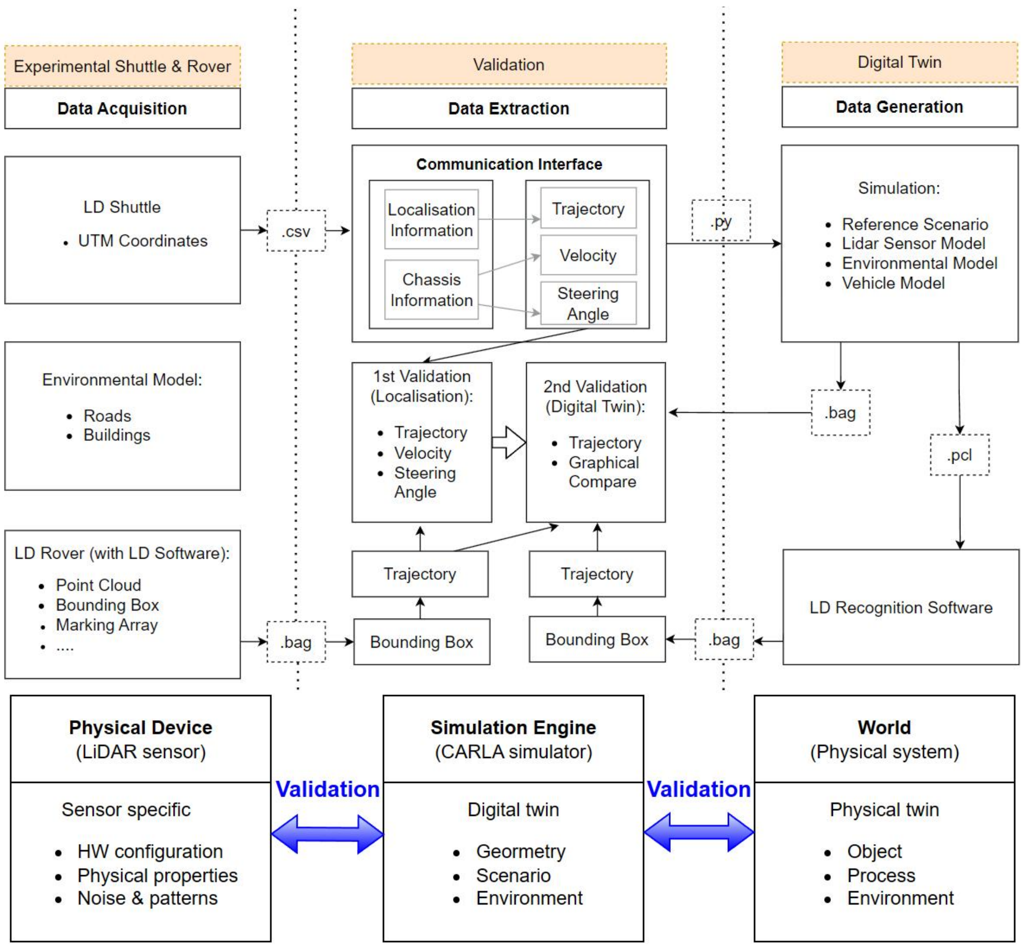
The physical twin is an experimental scene on a campus corner that includes a self-driving shuttle and the Liangdao Rover, a mobile station integrated LiDAR sensors and recognition algorithms. The Rover will perceive and recognize the moving shuttle.

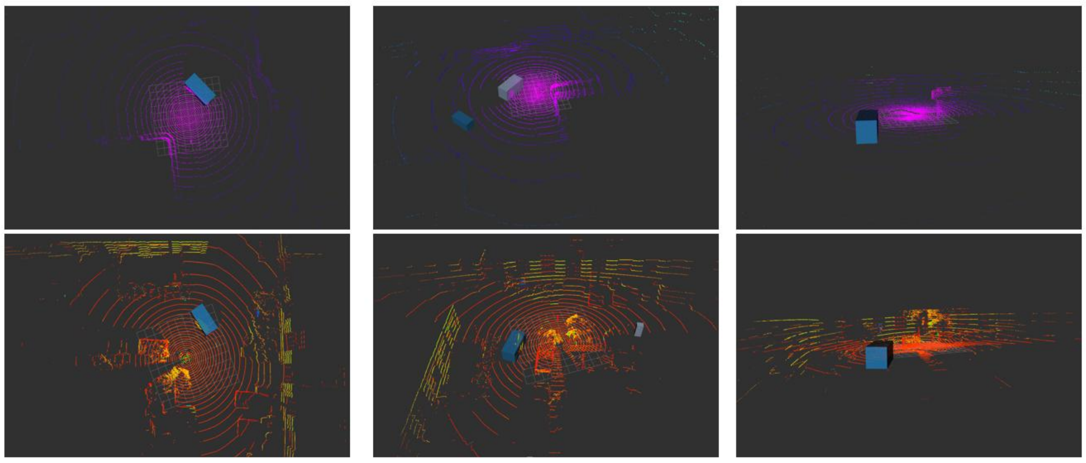
Meanwhile, a digital twin that mirrors the physical world is generated. Virtual LiDAR will generated synthetic point cloud data. The synthetic point cloud data is then fed into the recognition algorithm to obtain detection results from virtual vehicle.

And multiple validation methods are presented for the CPS. The physical twin model is validated by comparing its detected trajectory with the true trajectory, which is a validation of the Rover detection and recognition function. The accuracy of the digital twin model is assessed by comparing the synthesized data with the real data at 2 levels, namely the point cloud in raw data level and the object recognition in application level. In this way, we can validate the functionality of the physical twin and the reliability of the digital twin.

The figures below provide a comprehensive graphical comparison showing the point cloud and recognition results of the digital twin and the corresponding results in the physical twin from different view. And by analysing the similarity of trajectories, we use Hausdorff distance to evaluate the validation result. The Hausdorff distance for physical twin and digital twin is respectively 0.8824m and 0.3248m.

In physical twins, potential problems with the High Hausdorff distance may be environmental obstacles (trees and buildings) and/or special viewpoints that make recognition difficult. In digital twin, the potential problem could be that the trajectory tracking controller is non-optimal and/or the software has difficulty identifying vehicle's pose.

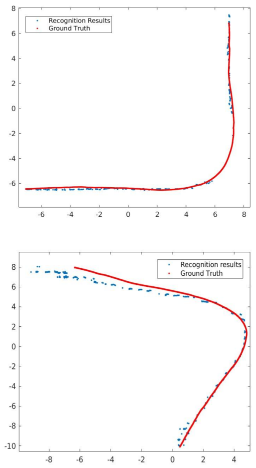




Top View

Side Top View

Front View



The differences in trajectories and inaccuracies in pose we just observed illustrate that continuous improvement is necessary. To address existing challenges and improve the reliability and applicability of digital twin models, we should explore alternative experimental configurations, algorithm enhancements, controller optimization, and the research of different scenarios as well as the time synchronization test.