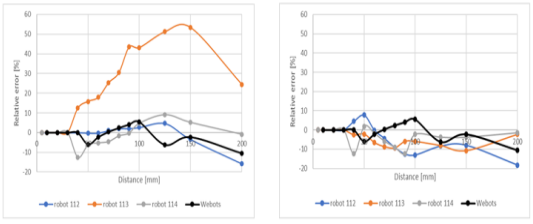
Calibration of High-Fidelity simulator Leveraging Machine-Learning Techniques

Raphael Uebersax

Professor : Alcherio Martinoli
Assistant(s) : Cyrill Baumann

Despite the actual potential of high-fidelity representation of the physical reality using simulation software, the behavior of real robots is still noticeably different from their simulation. This project aimed at decreasing the reality gap between the real Khepera IV robots and their simulation in Webots using calibration techniques. To do so, infrared and ultrasound sensors as well as actuators of the real robot were compared to their simulation using multiple different small experiments. Although the ultrasound sensors showed major issues in the simulator and were thus not calibrated, good results were obtained for the infrared sensors and actuators.

First, the infrared sensors of the simulator were badly calibrated beforehand which had to be fixed by implementing a lookup table in Webots' Proto node to simulate average behavior of the real IR sensors. Experiments also showed that measurements of the IR sensors located on the ring depend on the ground color due to unexpected light reflections. Another major issue came from the difference in behavior between individual IR sensors of the real robot. The idea was thus to homogenize all sensors such that the lookup table matches them all. Since the usual manual calibration process is rather long and painful, an automatic experiment to acquire data was designed using a Braitenberg behavior for the real robot navigating in a small arena. Using the tracking system Swistrack, it was then possible to extract distance to an obstacle for each sensor and sensor measurement. The homogenizing step is then done by implementing support vector regression on this data to extract each individual sensor behavior.

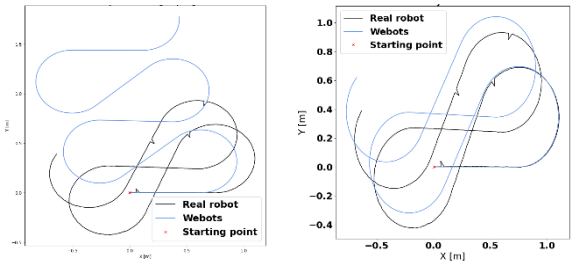


Relative error of the estimated distance for the front sensor before (left) and after (right) "homogenization"

In addition to that, a good Webots texture simulating both type of obstacles used at DISAL (white walls and carton boxes) has been found for experiments using infrared sensor.

Ultrasound sensors showed major problems which need to be fixed first in the simulator as well as on the real robot. The simulator is not able to detect any obstacle when the sensor is not facing it directly (no inclination) whereas the ultrasound sensors on the real robot have an interference problem for certain distances and orientations. This interference results in not detecting the obstacle or estimating the distance to it very badly.

The reality gap of the actuators has been reduced by correcting a bug in the programming interface and by mapping the speed input of the real robot to its simulation. Results were then very accurate for straight motions but the simulation is constantly underestimating rotational movements. The calibration of the axle length has been investigated as potential reasons for it but results showed that the error is coming elsewhere. It seems to be coming from error in the motion integration of Webots. However, this error can be limited by rotating the robot using low speeds only.



Trajectory matching of an "complicated" motion before (left) and after (right) calibration

During this project, the overall reality gap between the Khepera IV robot and the Webots simulator has been considerably reduced. The simulation accuracy of the IR sensors and actuators was improved whereas major issues related to the US sensors have been found.