Tracking Physics: A Virtual Platform for 3D Object Tracking in Tactile Internet Applications

1. Background

- Tactile Internet (TI) is a pioneering network paradigm that aims to communicate haptic feedback with ultra-low latency. It will enable new ways for us to interact with remote environments, such as transferring skills over the network and controlling remote objects [1].
- In this work, we propose a virtual platform for developing, evaluating, and comparing tracking solutions for TI applications.

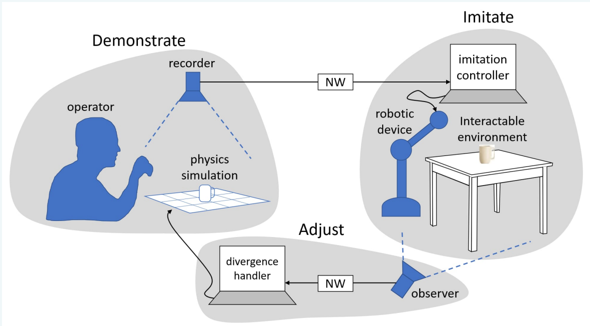

Figure 1: Using a physics engine to model the controlled domain, and providing real-time feedback to the master domain.

2. Methods

The virtual platform consists of the following components:

- A virtual depth camera based in Unity, which uses ray casting to generate point clouds from an arbitrary virtual scene.
- A tracking program which uses particle filters to track point clouds, using the PCL library.
- A communication interface that allows virtual and real devices to make use of the tracking program.

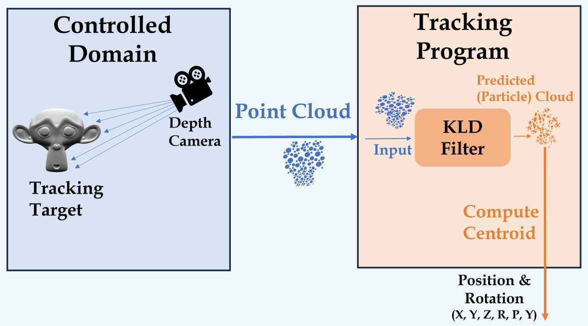

Figure 2: A schematic diagram of the communication framework which features two UDP communication channels. The first channel is used by Unity's virtual camera to transmit point cloud data. The PCL tracking program offers predicted positions (X, Y, Z, R, P, Y) used in the second communication channel.

3. Results

Tuning Hyperparameters of the KLD Filter

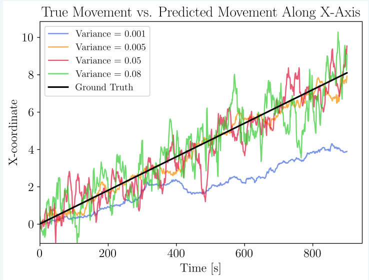

Figure 3: Tracking accuracy of translation when variance is changed.

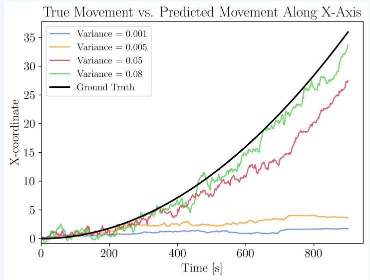

Figure 4: Tracking accuracy of acceleration when variance is changed.

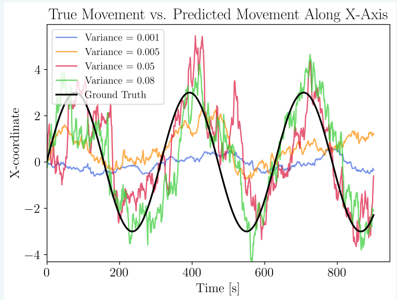

Figure 5: Tracking accuracy of periodic motion when variance is changed.

Execution Times and Trade-off Between Virtual Devices

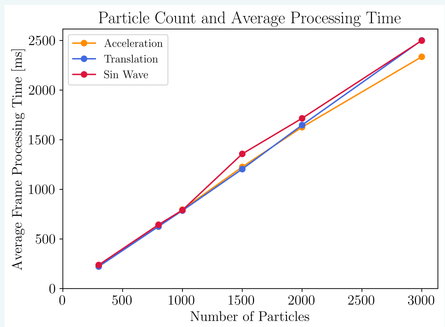

Figure 6: The execution time of tracking different types of motion, as the number of particle increases.

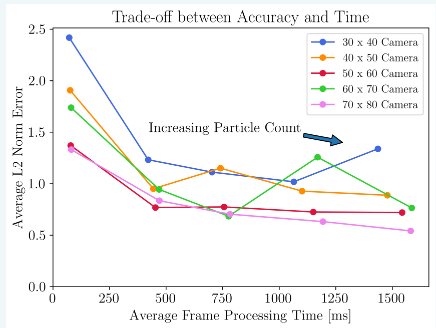

Figure 7: Trade-off between various resolutions of the virtual depth camera. The number of particles used (from left to right) is {100, 600, 1000, 1500, 2000}.

4. Discussion

- Variance in the Gaussian distribution needs to reflect the amount of movement per frame.
- There is a baseline for the number of particles that should be used, but after a certain level, the increase in tracking accuracy becomes negligible.
- Downsampling can reduce execution time at the cost of accuracy.
- Higher resolution point clouds can increase tracking accuracy without significantly increasing runtime.
- There is a large disparity between frame rate of virtual depth camera and processing rate of the tracking program as shown in Fig. 8, rendering it impractical to deploy the tracking program in real systems.

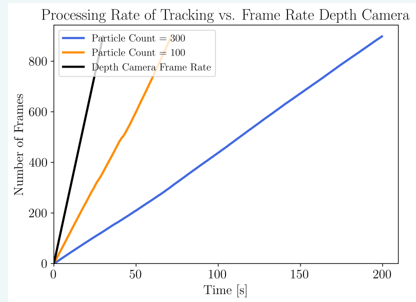

Figure 8: Comparison between the frame rate of the depth camera and the processing rate of the tracking program.

5. Conclusion and Future Work

Main Contributions:

- Highly configurable virtual depth camera that can produce synthetic point cloud data.
- Tracking program based on particle filters, which can interface with various devices.
- Analysis on how particle filters can be tuned for 3D object tracking.

Future Work:

- Further optimization of the PCL library, so that the particle filter is more time-efficient.
- Include additional sensors to guide the estimates of the particle filter algorithm.

References

1. Fettweis, G. P. (2014). The tactile internet: Applications and challenges. IEEE Vehicular Technology Magazine 9(1), 64–70. https://doi.org/10.1109/MVT.2013.2295069

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