6 Evaluation

6.1 Characterization of Localisation Accuracy

6.1.1 Experiments Inside the Energy Lab

To reliably evaluate the accuracy of the proposed indoor localisation algorithm, a walking model for the robot was designed, its measured track was collected through static UWB tag (frequency = 10 Hz) and corresponding X and Y coordinates are in 6.1:

Listing 6.1: Measured Ground Truth From UWB

```
1 xs: [5.799013605442178, 5.677136752136748, 5.70306106870229, 5.09885606060606,
    5.120082644628101, 4.572519379844961, 4.478495575221241, 2.03554054054054]
2 ys: [4.865020408163268, 4.234247863247866, 3.7864122137404563, 3.554515151515152,
    3.1047024793388442, 2.931767441860464, 2.4959646017699106,
    2.353558558558559]
```

It's a series of command of *move* and *rotate*:

Algorithm 1 Commands

```
1: procedure CONTROL
2:     move forward 0.7m
3:     rotate counter-clockwise 30°
4:     move forward 0.5m
5:     rotate counter-clockwise 30°
6:     move forward 0.5m
7:     rotate clockwise 150°
8:     move forward 0.5m
9:     rotate counter-clockwise 90°
10:    move forward 0.5m
11:    rotate clockwise 90°
12:    move forward 0.6m
13:    rotate counter-clockwise 90°
14:    move forward 2.5m
```

From the commands we can know, the robot has moved 5.8m in total in each single experiment. We sample 50 data in each experiment, which is about every 0.116m a point, and calculate the *mean error* and the *variance* based on the ten experiments and the result is:

```
mean = 0.24249670463171374 m, variance = 0.033868014433167205 m²
```

Assuming the initial pose [5.799013605442178, 4.865020408163268] is correct, based on the given commands we can also derive a theoretical track as bias correction, as shown in Figure 6.1.

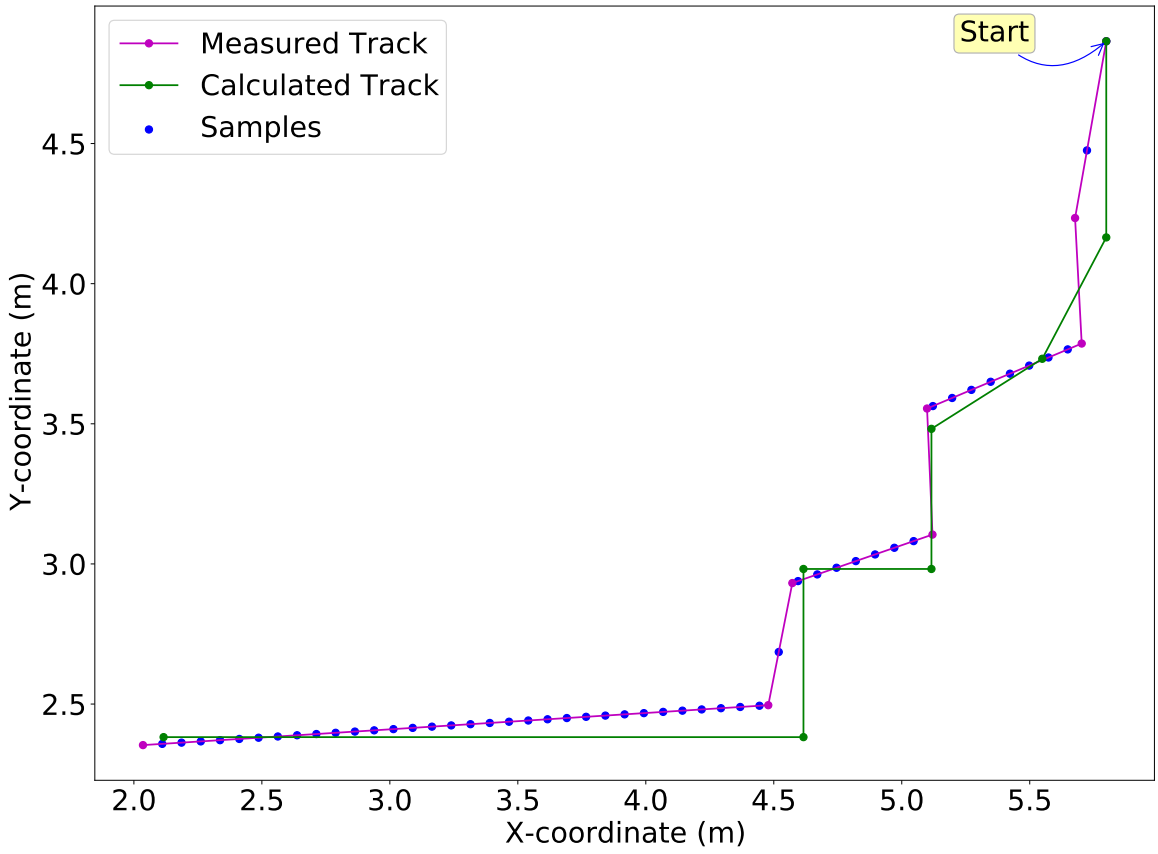

Figure 6.1: Measured vs. Calculated Ground Truth and sample points for measured track

By remote control, the filter result is shown in Figure 6.2.

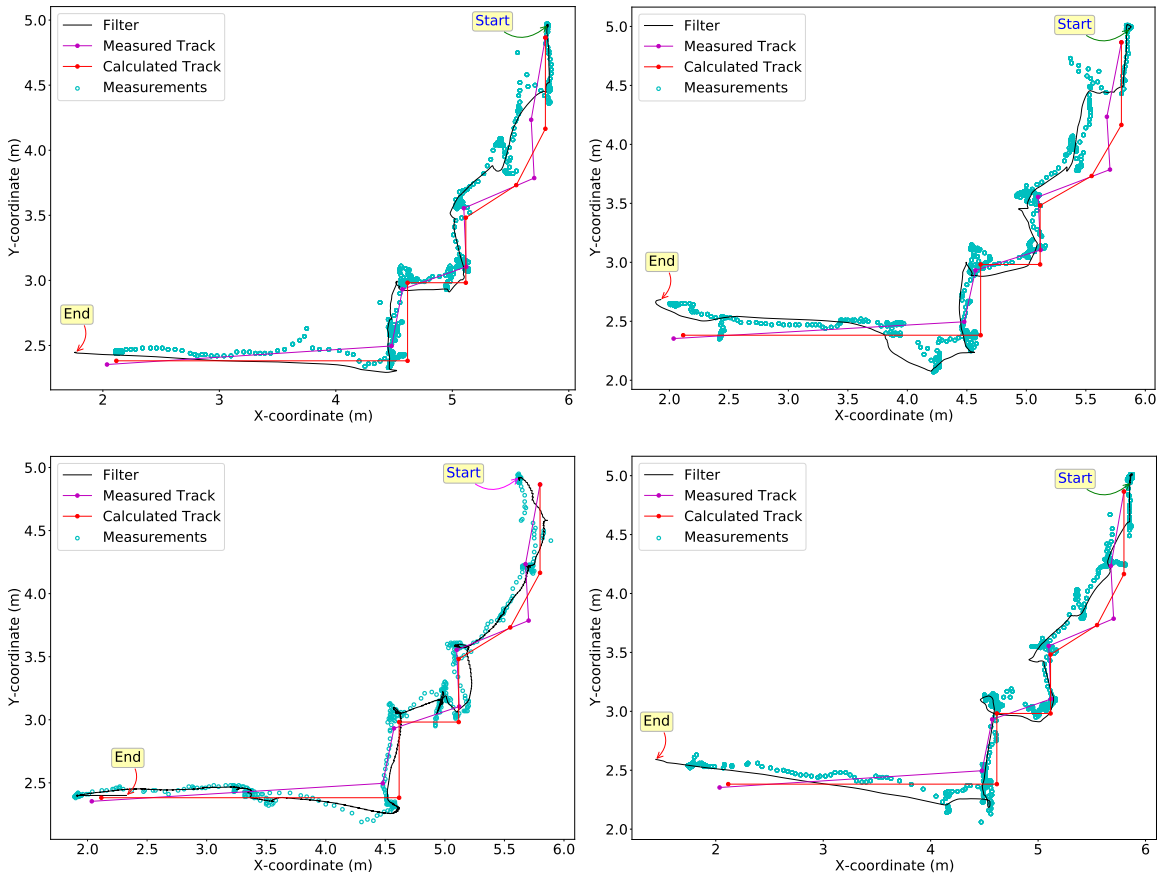

Figure 6.2: Plots of four repetitive experiments inside the energy lab

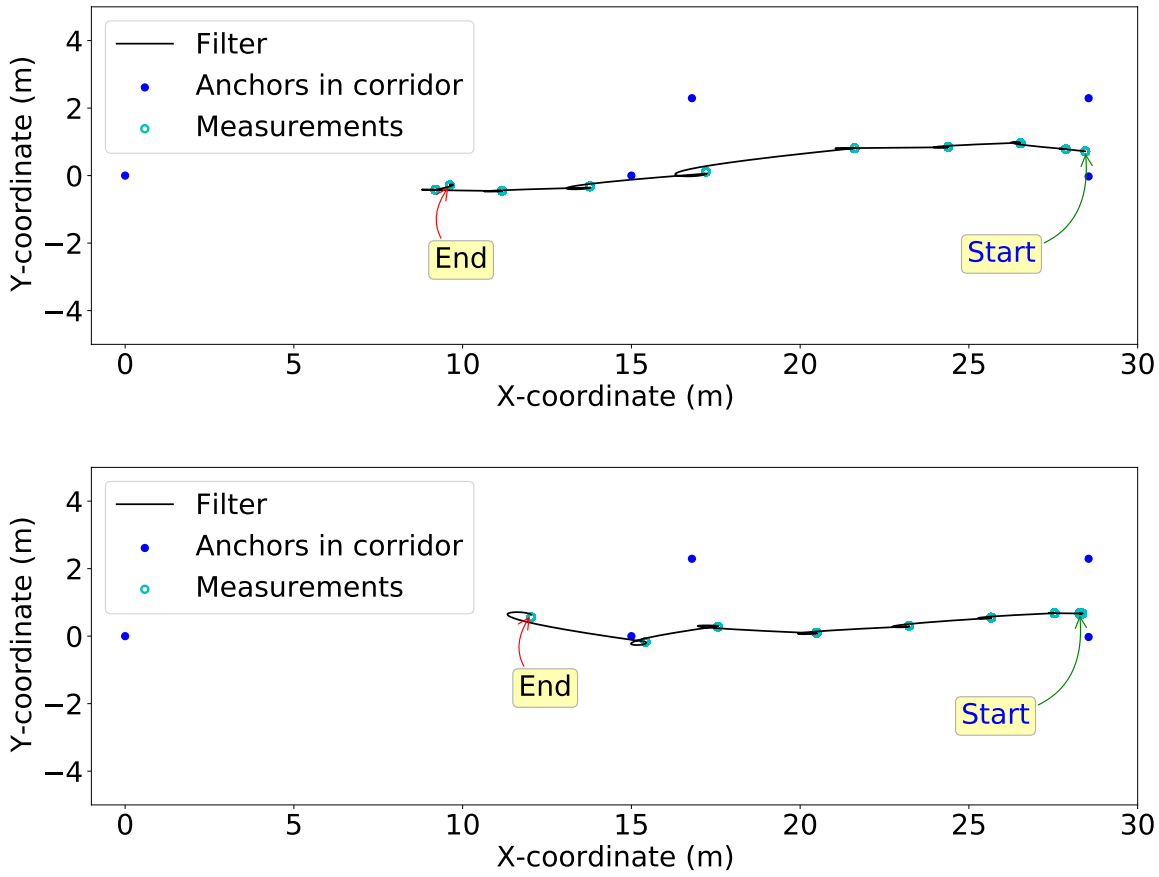

Figure 6.3: Plots of Kalman Filter In Corridor

6.1.2 Experiments In the Corridor

In order to further evaluate the effect of kalman filter, experiments were also conducted in the around $30m \times 2.293m$ corridor. Considering that the maximum working distance of UWB is approximately 30m, five UWB units were configured as anchors and the fusion result is in Figure 6.3.

6.1.3 Experiments In the Foyer of APB

In order to further evaluate the performance of the implemented kalman filter, experiments were also conducted in the around $18.573m \times 13.657m$ foyer of APB. Four UWB units were configured as anchors and corresponding coordinate systems and experimental route are illustrated in Figure 6.4. The explanation is as below:

- Blue lines with arrow: Global coordinate system
- Green lines with arrow: Initial local coordinate system of the robot
- Black lines with arrow: Experimental route of the robot

We can see the initial angle between the global and local coordinate systems is 180°, which means they don't correspond to each other since the very beginning of the experiment and we can't apply collected data directly into the state transition function as we discussed in chapter 5. So in order to fuse the collected data, following operation was conducted to the UWB data:

1. UWB tag Y-coordinates stay the same
2. new UWB tag X-coordinates = Length of the experimental environment along X-axis(18.57, the same precision as configured for UWB anchors) - original collected UWB tag X-coordinates

Afterwards the fusion result with sample points for evaluation is in Figure 6.5. From the experiments we can know, the robot has moved 20.22m in total in each single experiment. We sample 50 data in each experiment, which is about every 0.404m a point, and calculate the *mean error* and the *variance* based on the nine experiments and the result is:

`mean = 3.2215134321303758 m, variance = 7.926237762905229 m²`

A random walk in the foyer was also conducted, in which the robot stopped at where it started, as shown in Figure 6.6.

6.2 Observation

Compare different experiment results we can know, smoothing filter result heavily depends on the fluent remote control process, which is not always the case. It would always be harder to control the robot to follow a straight line rather to move randomly and smoothly.

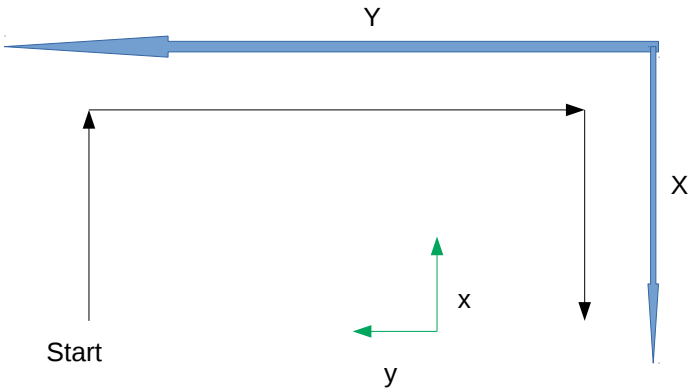

Figure 6.4: Illustration of the experiment in the foyer of APB

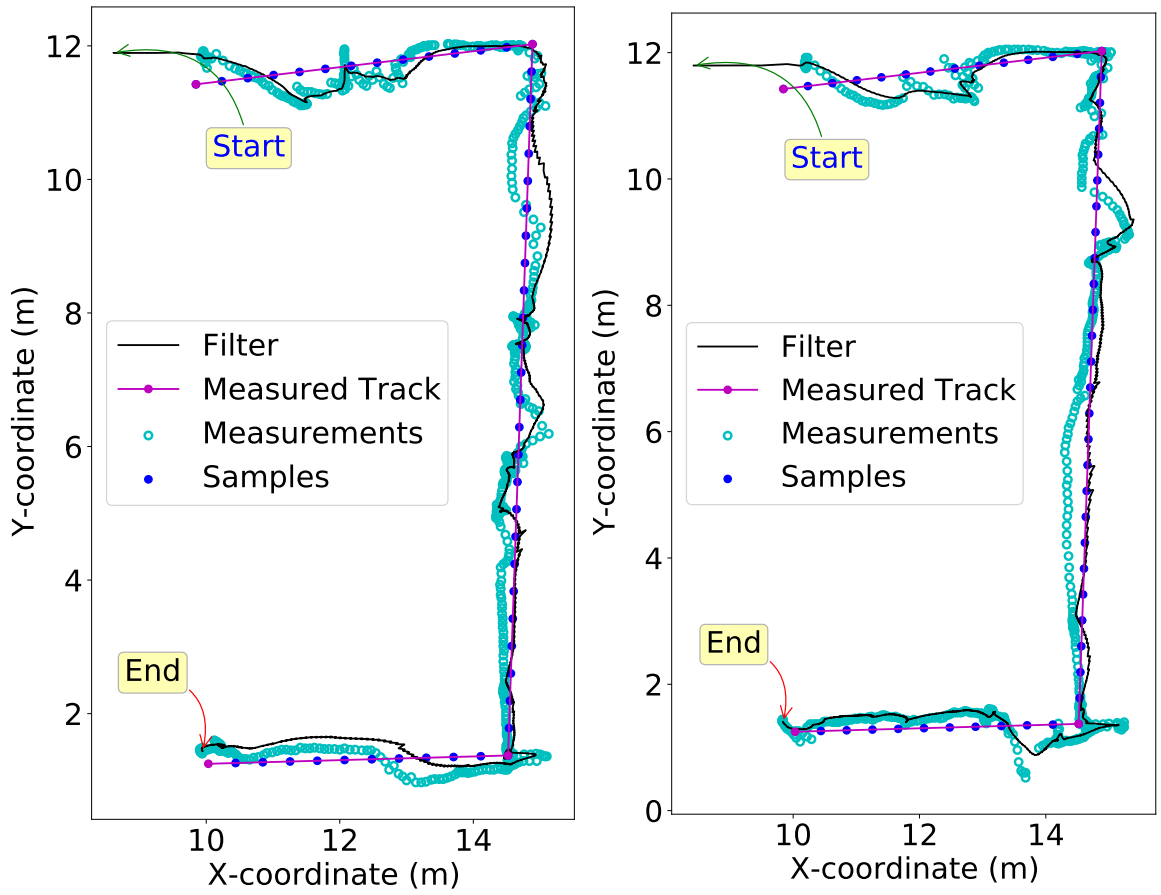

Figure 6.5: Running process inside the foyer of APB

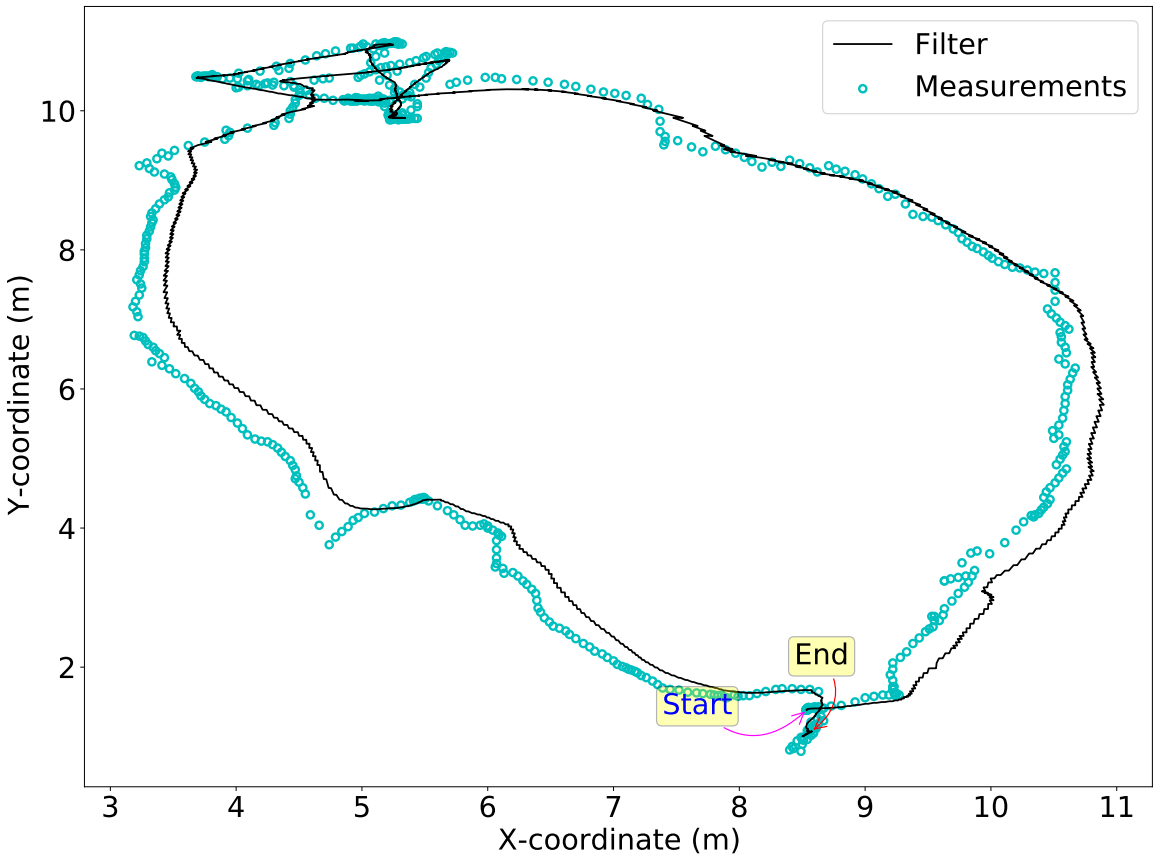

Figure 6.6: Random control inside the foyer of APB