Kalman Filter-Based Real-Time Detection and Localization of Objects on Conveyor Belt

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Introduction

- Real-time recognition and localization of dynamic objects is a significant prerequisite for conveyor belt manipulation.
- Random errors exist in localization part, affecting robot grabbing.
- Real-time Kalman filter is integrated in localization part to generate more accurate coordinates of the object.

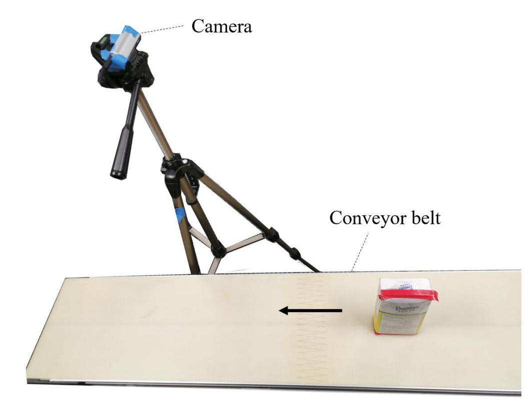

Fig. 1. we focus on the output coordinates of one object on a moving conveyor and assess the localization accuracy

Method

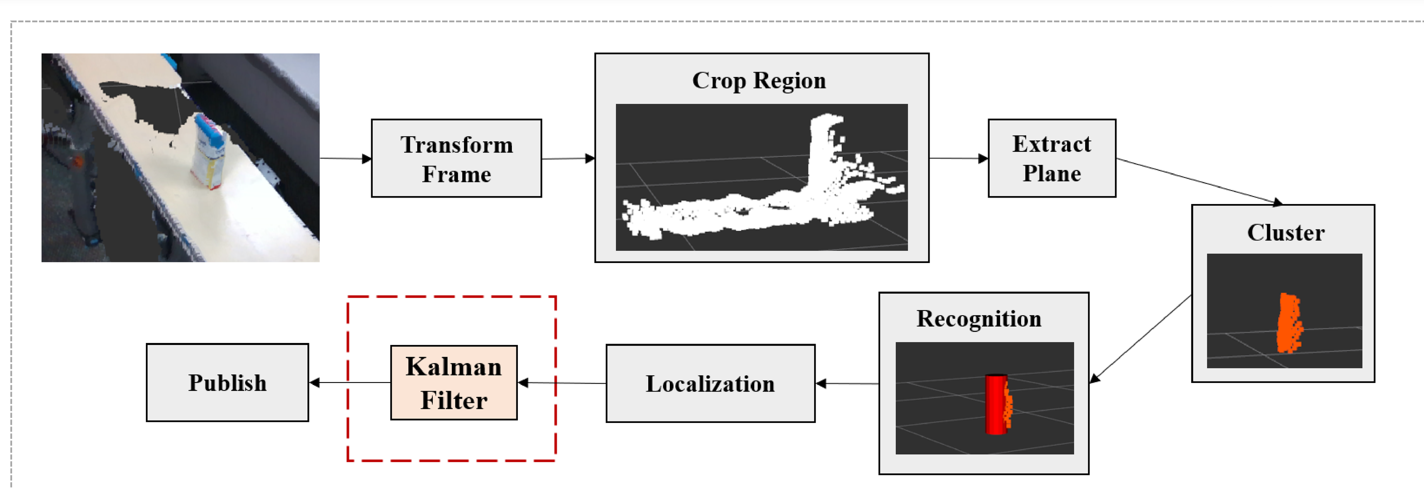

Fig. 2. The perception system is based on RGB-D sensor data and the base frame of UBTech's Walker robot, figure 2. The overall procedure is that input point cloud data is transformed from camera frame to base frame. The region without conveyor is cut out to avoid interference from other objects. Then conveyor geometry is extracted and remaining points are clustered. Those clusters are recognized and located to provide coordinates in base frame.

- A cuboid is placed at a start point on the conveyor where the detected x value is larger than 1.25m.
- Localization and filter will start working when conveyor moves at a speed of 3.2cm/s.
- Both the detected coordinates and filtered coordinates will be recorded when detected x value is smaller than 1.25m because the perception system has bad performance when the cuboid is too far away.
- Through doing linear curve fitting on detected data, we can get the speed of the cuboid in x-axis direction and y-axis direction.

Parameter	Definition	Value
A	State-transition model	1
H	Observation model	1
P	Predicted error covariance	2
Q_x	Covariance of process noise on x axis	0.005
Q_y	Covariance of process noise on y axis	9×10^{-6}
Q_z	Covariance of process noise on z axis	7.6×10^{-7}
R_x	Covariance of observation noise on x axis	0.0284
R_y	Covariance of observation noise on y axis	1.86×10^{-4}
R_z	Covariance of observation noise on z axis	3.61×10^{-5}
V_{0_x}	Value of x coordinate at time step 0	1.4 m
V_{0_y}	Value of y coordinate at time step 0	-0.15m
V_{0_z}	Value of z coordinate at time step 0	0.71m

Table. Ⅰ. The parameter settings of the Kalman filter. Since the values of x, y, and z are input to three filters respectively, they have different Q, R and initial values. The value of A, H, and P are set as the same because they are estimates that has little influence when the filter works.

The actual coordinates when cuboid moving are:

$$\begin{aligned} x &= -0.0319t + 1.245 \\ y &= -0.003t - 0.155 \\ z &= 0.71 \end{aligned} \tag{1}$$

where t(s) denotes the time when detected and filtered coordinates are generated and t is 0 when the cuboid is at start point.

Results

- Letting the cuboid move from start point to end point during experiment, we obtained **352** sets of coordinate values, **Fig.3**.
- After applying Kalman filter, the localization performance got significant improvement.
- The curves generated by filter have **less fluctuation and deviation** compared with detected ones.
- The filter effectively filtered lots of extreme values and made estimates which are closer to actual values.

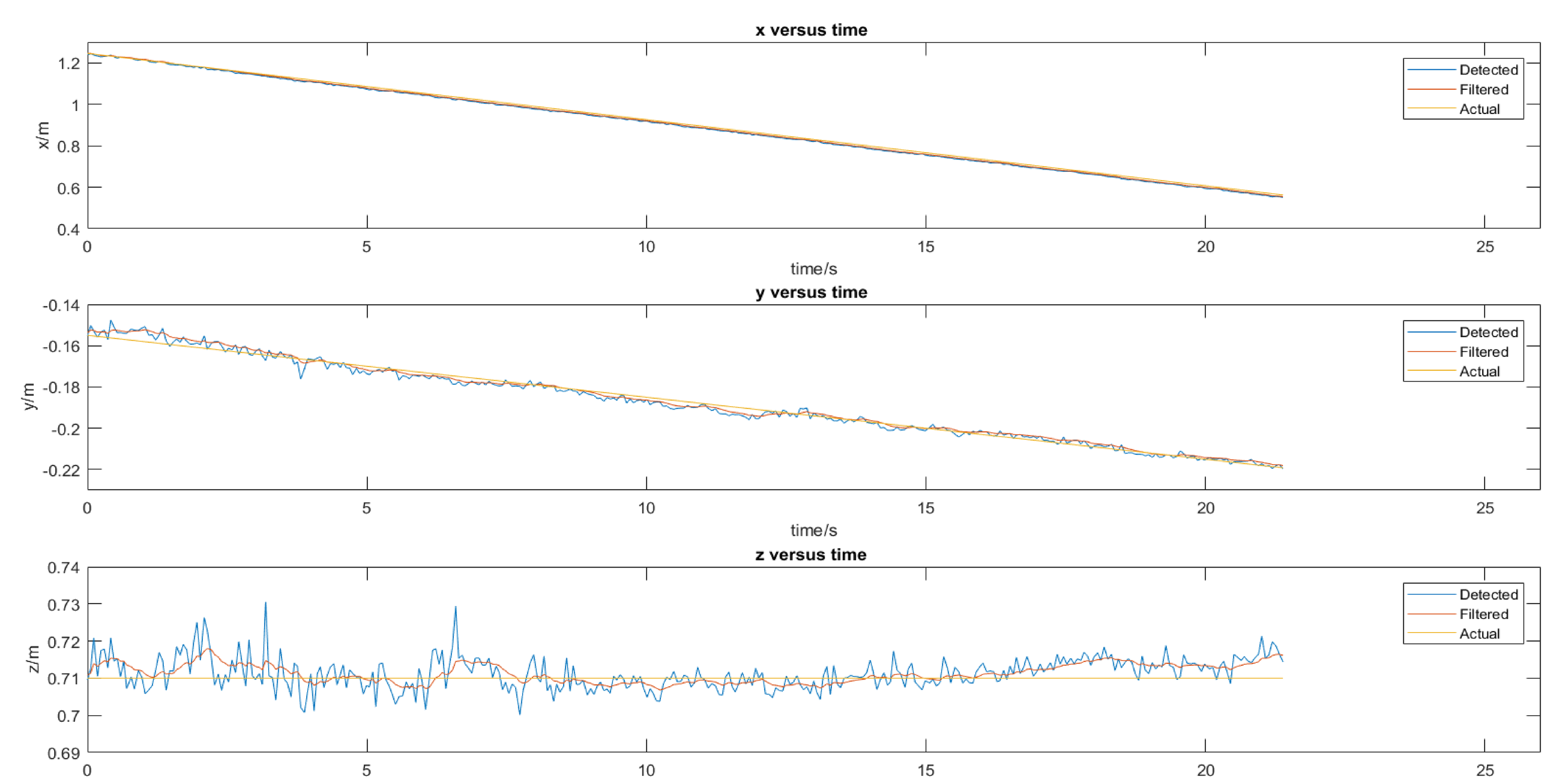

Fig. 3. From top to bottom, x,y, and z values of detected(blue), filtered(red), and actual(yellow) coordinates versus time are plotted

- In order to do a more rigorous analysis about the accuracy of the localization, we computed the errors of detected values and filtered values with regard to actual values, **Fig. 4**.
- Although the errors of filtered values are larger than errors of detected ones in some time periods, the filter does reduce the errors by looking at the general trend.
- The filter **obviously reduced the maximum error values** in whole process.

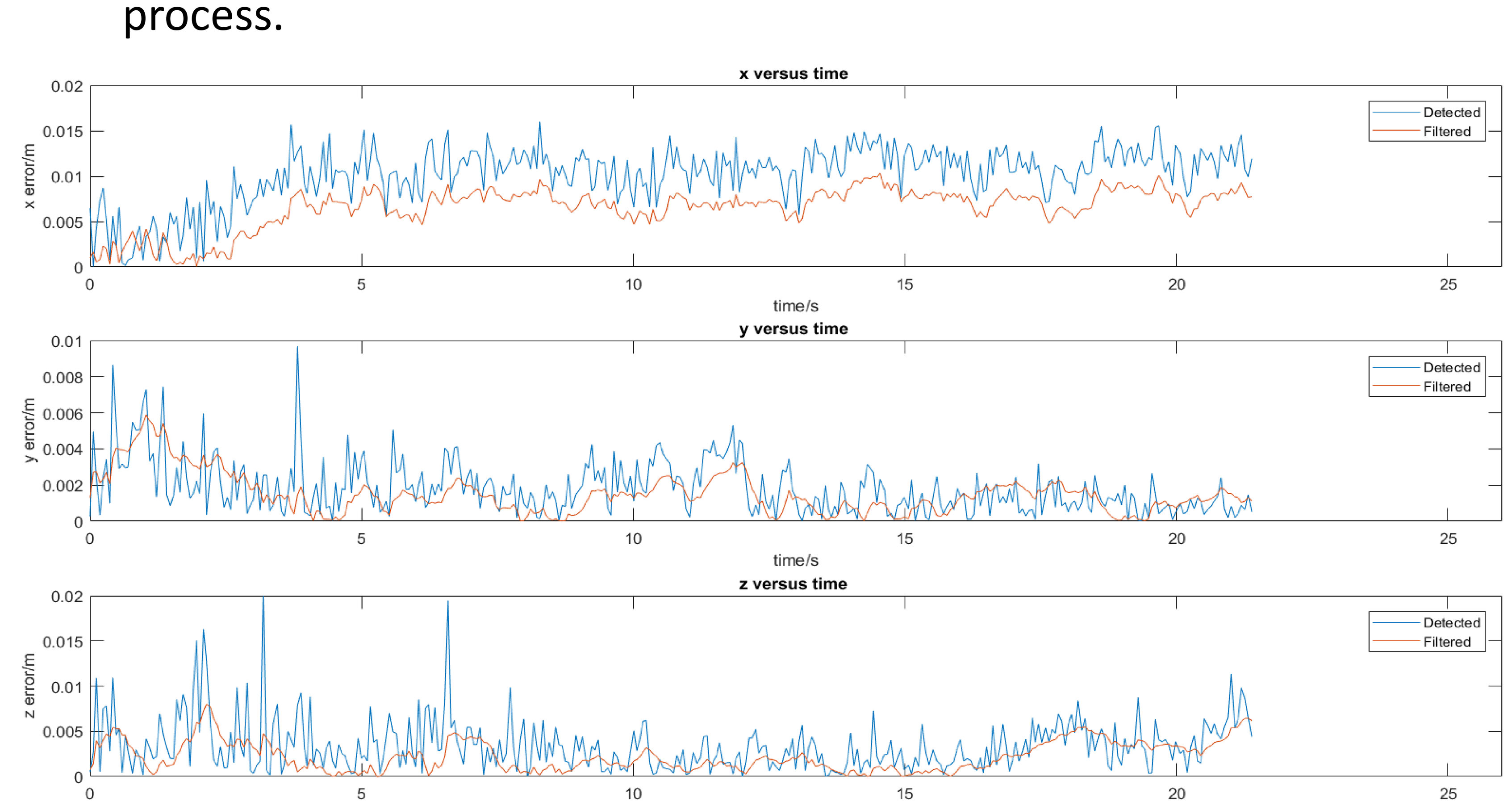

Fig. 4. From top to bottom, errors of x,y, and z values of detected(blue), and filtered(red) coordinates with regard to actual ones versus time are plotted

- We also compute the average absolute errors under these two condition, **Table II**.
- The Kalman filter reduce the average errors by **36.27%** on x axis, **16.67%** on y axis, and **35.29%** on z axis.

Condition	Error Value (m)
Detected x axis	0.0102
Filtered x axis	0.0065
Detected y axis	0.0018
Filtered y axis	0.0015
Detected z axis	0.0034
Filtered z axis	0.0022

Table. Ⅱ .Average absolute errors of detected values and filtered value are computed.

Conclusion

We have made improvement on an existing perception system by applying Kalman filter to the localization part. The experimental results show that the modified system is able to locate the object much more accurately. The curves of the object position varying with time fluctuates less and deviates less. Besides, most of the extreme values are filtered out and the error between published coordinates and actual ones was reduced by 16.67~36.27%.

In the future, we will verify the system performance when conveyor moves faster. In addition, the detection of object orientation will be integrated to this system for output more information of the object.

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