Range sensor based Localization and control of mobile robots.

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Objectives

Our Aim is to make a group of Aerial Vehicles move in a GPS denied environment, with its own intelligence and communication system.âĂŃ

- We have experimented with a new proximity device to localize each UAVs in swarm
- We have tested different State Estimation techniques, for our model
- We have simulated some Navigation algorithm, which will make this vehicles to move freely without collision

Introduction

Swarm Robotics is a field which deals with collective robotics, inspired from the self-organized and social interactive behavior of robotsâĂŃ.

Unmanned Aerial Vehicle (UAV) are autonomous aircraft that are equipped with sophisticated sensors, for solving tasks such as exploration, mapping, inspection, search and rescue. Some of the other sensors which can give position feedback are limited to specific environment or needed huge computation.

Materials

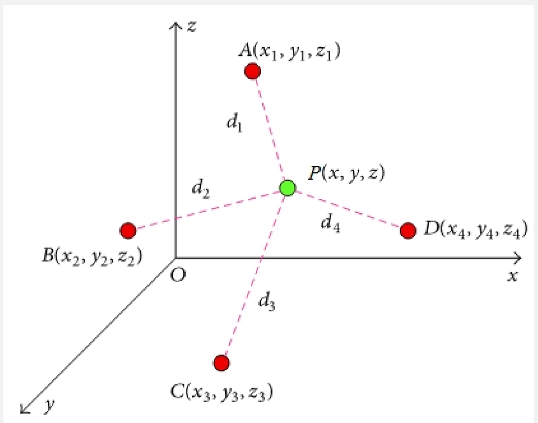
Ultra-Wide Band (UWB) sensor is a wireless sensor that transmits signal at $3-8$ (GHz) bandwidth, offers high accuracies of signal with low power. It can measure distance through Time of Flight (ToF) of the radio signal, providing measurement range upto 200m.

$r_{21} = c\,(t_2 - t_1)$ c-speed of light

We placed four Static UWB sensors (Anchors) on wall corners, tag UWB sensors is on Vechicle.

State Estimation Algorithms

The sensors give distances between each other. Our Algorithm will estimate the best position with algorithms due to sensor noise.



$$(P-A)^2 = d1^2 \quad (1)$$
$$(P-B)^2 = d2^2 \quad (2)$$
$$(P-C)^2 = d3^2 \quad (3)$$
$$(P-D)^2 = d4^2 \quad (4)$$
$$P = (x, y, z)$$
$$\text{Anchors} = (x_i, y_i, z_i)$$

Least Square: Estimating by minimizing the squared discrepancies between the data.

Subtracting (2), (3), and (4) from (1) we get:

$$2\begin{bmatrix} x_2-x_1 & y_2-y_1 & z_2-z_1 \\ x_3-x_1 & y_3-y_1 & z_3-z_1 \\ x_4-x_1 & y_4-y_1 & z_4-z_1 \end{bmatrix}\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} d_1^2-d_2^2-|B|^2-|A|^2 \\ d_1^2-d_3^2-|C|^2-|A|^2 \\ d_1^2-d_4^2-|D|^2-|A|^2 \end{bmatrix}$$

We obtain the $Y = AX$ form, can be solved by leastsq.

Kalman Filter: Recursive Gaussian Estimator, carry the previous state to reduce uncertainties in the new measurement, capable of fusing multiple sensors data. UWB and Accelerometer datas are fused.

Newton-dynamics, $x_k = x_{k-1} + v.T + a.\frac{T^2}{2} - a_b.\frac{T^2}{2}$

Extended Kalman Filter(EKF): measurement step is non-linear $r_k = \sqrt{(x-x_i)^2 + (y-y_i)^2 + (z-z_i)^2}$. Data is interpolated by Taylor series to make it work.

Information Filter: Gaussian represented by information vector and matrix, dual of Kalman Filter.

$\Omega_k^- = (A_k \Omega_{k-1}^{-1} A_k^T + Q_k)^{-1}$ Prediction Step

$\xi_k^- = \Omega_k\,(A_k \Omega_{k-1}^{-1} A_k^T + B_k u_k)$

$\Omega_k = \Omega_k^- + H_k^T Q_k^{-1} H_k$ Measurement Step

$\xi_k = \xi_k^- + H_k^T Q_k^{-1} y_k$

Canonical parameterization represent probability in a logarithmic form. In multi-robot problem integration of sensor data collected decentrally will be achieved by summing up through Bayes rule.

Results

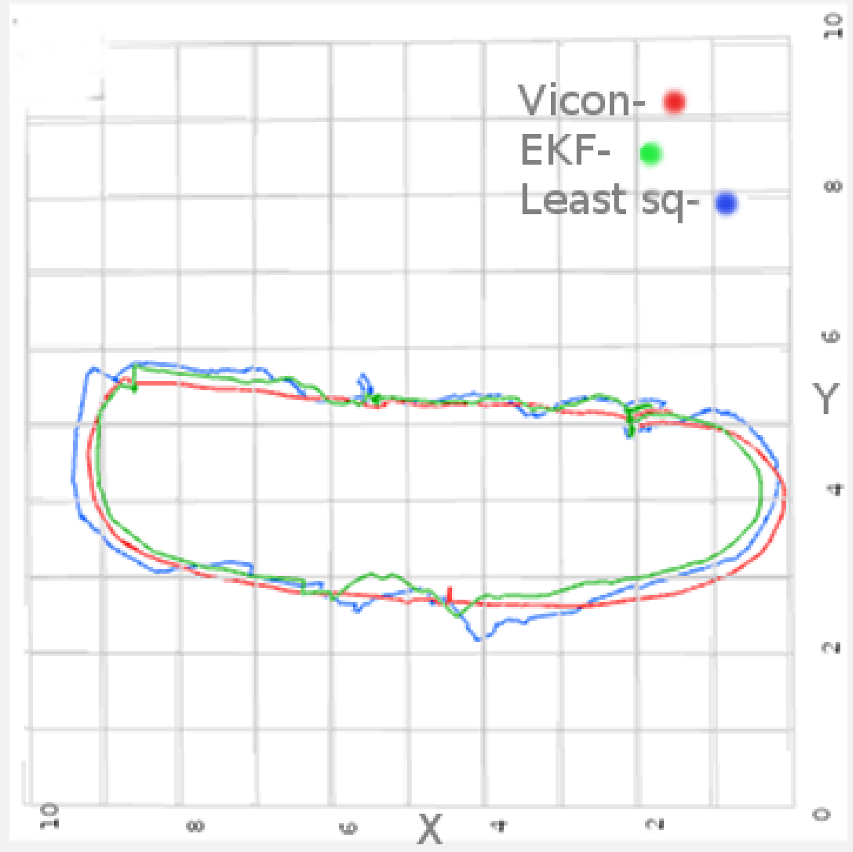


Figure: Trajectories

In our experiment we tested algorithms with Vicon system as ground truth. All the experiments were done on ROS (Robot Operating System).

Position Error	X axis	Y axis	Z axis
Least sq	0.103m	0.117m	0.653
EKF	0.096m	0.109m	0.097

Table: Mean Error of UWB

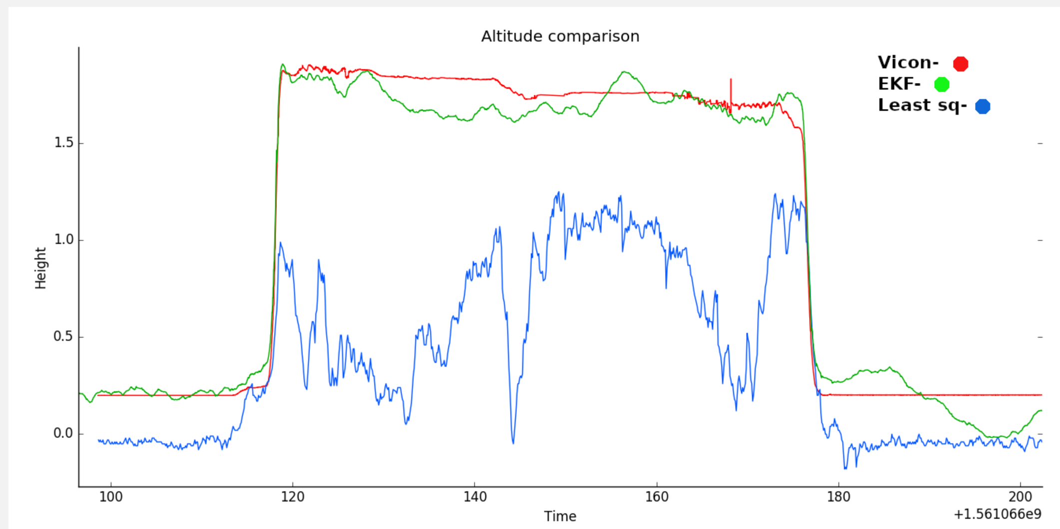


Figure: Height variation

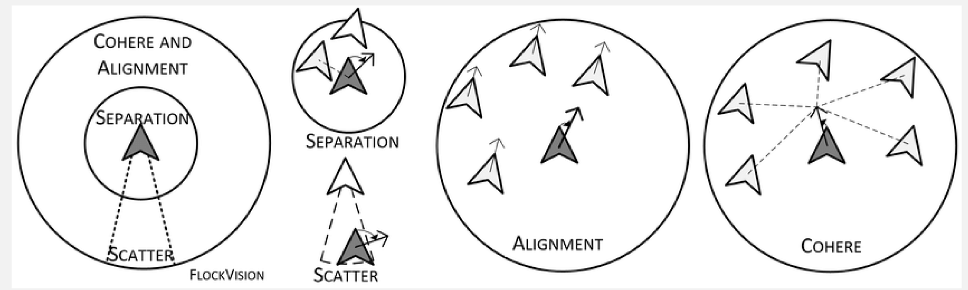
Fusion is biggest advanatage in EKF.

Least square output frequency max is 10Hz. while EKF loop frequency is 50Hz.   Arena-(10x10m)

Path Planning

Based on environment and robot dynamics, we want to provide continuous sequence of collision free configurations to our goal.

Boids Model: Inspired by the bird's flock. The basic aggregation algorithm which can be applied to robots decentrally. Follow three simple rules in group Approach , Align, Avoid.



Conflict Based Search: Multi-Agent Path Finding (MAPF) provides the solution for hundreds of agents in previously known constrained environment. It uses MAPF solver that plans for individual bots by Astar algorithm; then recursively checks its collision chance, provides the path with minimum cost.

Conclusion

- UWB solution is affordable, portable,with low computation provides best position estimate.
- Information Filter is the stablest Gaussian filter doesnot divereges easily.
- There should be atleast four Anchors fixed to produce a good location estimate.
- Moving Anchors provides good relative localization rather exact. We can control swarm in this case by planning efficient navigation algorithm.

References

1. Sebastian Thrun, Wolfram Burgard, Dieter Fox "Probabilistic Robotics" MIT Press 2006.
2. Dan Simon "Optimal state estimation Kalman and nonlinear approaches" Wiley-Interscience 2006.