Hydrid method

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1 Introduction

This document is for hydird method simulation platform. The core idea of hydrid method is to combine the accurate and expensive detection algorithm (ED), cheap and poor detection algorithm (CD) and cheap tracking algorithm together to optimize the computation resources. Adding more cheap algorihtms to maintain the same detection or tracking quality without redundant computations. In our simulation platform, ED is represented by observations with less uncertainty and more information, while CD is denoted by observation with more noises and limited information, which makes sense in reality.

2 Notation

Moving object continuous state: $X_{mot} = \begin{bmatrix} x_{mot} \\ y_{mot} \\ \alpha_{mot} \\ v_{mot} \end{bmatrix}$ (Random variables follow gaussian distribution)

Moving object other: $O_{mot} = \begin{bmatrix} P^{c_1}_{mot} \\ L_{mot} \\ W_{mot} \\ H_{mot} \end{bmatrix}$

Filter measurments from ED: $Z_{ED} = \begin{bmatrix} x^z_{ED} \\ y^z_{ED} \\ \alpha^z_{ED} \end{bmatrix}$ for filter updating

Other measurments from ED: $O_{ED} = \begin{bmatrix} P^{c_1}_{ED} \\ L_{ED} \\ W_{ED} \\ H_{ED} \end{bmatrix}$

Filter measurments from CD: $Z_{CD} = \begin{bmatrix} x^z_{ED} \\ y^z_{ED} \end{bmatrix}$ for filter updating

3 Processing model

Motion model is $X_{mot}(k+1) = F(X_{mot}(k)) + Q_{mot}$, where Q_{mot} is process model noise

$$\begin{bmatrix} x_{mot} \\ y_{mot} \\ \alpha_{mot} \\ v_{mot} \end{bmatrix}(k+1) = \begin{bmatrix} x_{mot} \\ y_{mot} \\ \alpha_{mot} \\ v_{mot} \end{bmatrix}(k) + dt * \begin{bmatrix} v_{mot}(k) * cos(\alpha_{mot}(k)) \\ v_{mot}(k) * sin(\alpha_{mot}(k)) \\ 0 \\ 0 \end{bmatrix}(k) + Q_{mot}$$

dt is discreate time in Euler approximation.

Jacobian of states in process model is as following.

$$J = \begin{bmatrix} 1 & 0 & -v_{mot}(k) * dt * sin(\alpha_{mot}(k)) & dt * cos(\alpha_{mot}(k)) \\ 0 & 1 & v_{mot}(k) * dt * cos(\alpha_{mot}(k)) & dt * sin(\alpha_{mot}(k)) \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Prediction step:

$\hat{X}_{mot}$(k+1) = F($\hat{X}_{mot}$(k))

$P_{mot}(k+1|k) = J * P_{mot}(K|K) * J^T + Q_{mot}$

4 Observation Model

Two observation models: ED and CD, the observation noise R_{ED} is much smaller than R_{CD}, to represent ED methods are better and expensive than cheap methods.

4.1 ED

$Z_{ED}(k) = h(X_{mot}(k)) + R_{ED}$

$$Z_{ED}(k) = \begin{bmatrix} x^z_{ED} \\ y^z_{ED} \\ \alpha^z_{ED} \end{bmatrix}(k) = \begin{bmatrix} x_{ED} \\ y_{ED} \\ \alpha_{ED} \end{bmatrix}(k) + R_{ED}$$

Observation model is linear system. $Z_{ED}(k) = H * X_{mot}(k) + R_{ED}$

$$H == \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

4.2 CD

$Z_{CD}(k) = H(X_{mot}(k)) + R_{CD}$

$$Z_{CD}(k) = \begin{bmatrix} x_{CD} \\ y_{CD} \end{bmatrix}(k) = \begin{bmatrix} x_{CD} \\ y_{CD} \end{bmatrix}(k|k-1) + R_{CD}$$

Observation model is linear system. $Z_{CD}(k) = H * X_{mot}(k) + R_{CD}$

$H == \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$

Updating step:

$S = H * P(k+1|k) * H^T + R$

$K = P(k+1|k) * H^T * S^{-1}$

$X(k+1|k+1) = X(k+1|k) + K * v$

$P(k+1|k+1) = P(k+1|k) - K * S * K^T$

4.3 Inializaiton

It is assumed that robot location is perfectly known, so the inialization of moving object is just based on uncertainty of sensor noise.

4.4 ED

Filter measurments from ED: $Z_{ED} = \begin{bmatrix} x^z_{ED} \\ y^z_{ED} \\ \alpha^z_{ED} \end{bmatrix}$

$$X_{mot}(0) = \begin{bmatrix} x_{mot} \\ y_{mot} \\ \alpha_{mot} \\ v_{mot} \end{bmatrix}(0) = \begin{bmatrix} x^z_{mot} \\ y^z_{mot} \\ \alpha^z_{mot} \\ rand - velocity \end{bmatrix} + \begin{bmatrix} x_r \\ y_r \\ 0 \\ 0 \end{bmatrix} + R_{ED}$$

where $\begin{bmatrix} x_r \\ y_r \end{bmatrix} = \begin{bmatrix} 0 \\ -Hmap \end{bmatrix}$

$$\begin{bmatrix} \hat{x}_{mot} \\ \hat{y}_{mot} \\ \hat{\alpha}_{mot} \\ \hat{v}_{mot} \end{bmatrix}(0) = \begin{bmatrix} x^z_{mot} \\ y^z_{mot} \\ \alpha^z_{mot} \\ rand - velocity \end{bmatrix} + \begin{bmatrix} x_r \\ y_r \\ 0 \\ 0 \end{bmatrix} + noisevalue$$

$$P(0) = \begin{bmatrix} R_{ED} & 0 \\ 0 & R_{velocity} \end{bmatrix} (4 \times 4matrix)$$

4.5 CD

Filter measurments from CD: $Z_{CD} = \begin{bmatrix} x^z_{ED} \\ y^z_{ED} \end{bmatrix}$

$$X_{mot}(0) = \begin{bmatrix} x_{mot} \\ y_{mot} \\ \alpha_{mot} \\ v_{mot} \end{bmatrix}(0) = \begin{bmatrix} x^z_{mot} \\ y^z_{mot} \\ rand - angle \\ rand - velocity \end{bmatrix} + \begin{bmatrix} x_r \\ y_r \\ 0 \\ 0 \end{bmatrix} + R_{CD}$$

where $\begin{bmatrix} x_r \\ y_r \end{bmatrix} = \begin{bmatrix} 0 \\ -Hmap \end{bmatrix}$

$$\begin{bmatrix} \hat{x}_{mot} \\ \hat{y}_{mot} \\ \hat{\alpha}_{mot} \\ \hat{v}_{mot} \end{bmatrix}(0) = \begin{bmatrix} x^z_{mot} \\ y^z_{mot} \\ rand - angle \\ rand - velocity \end{bmatrix} + \begin{bmatrix} x_r \\ y_r \\ 0 \\ 0 \end{bmatrix} + noisevalue$$

$$P(0) = \begin{bmatrix} R_{CD} & 0 & 0 \\ 0 & R_{angle} & 0 \\ 0 & 0 & R_{velocity} \end{bmatrix} (4 \times 4 matrix)$$