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Implementation of Extended Kalman filter in tracking Maneuvering targets

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ABSTRACT

Millimeter wave radars are employed in a wide range of commercial, military and scientific applications for remote sensing, safety, and measurements. It can overcome the limit of cloud, fog, dust and observation at night and so on in addition it has many characteristics such as better resolving power and resolving precision. Millimeter wave sensors are superior to microwave and infrared based sensors in most applications. Millimeter wave radar offer better range resolution than lower frequency microwave radar and can be penetrate fog, smoke and other obscurants much better than infrared sensors. It is important to track the maneuvering targets correctly in time, to probe rightly, track; capture in air, on the sea or on the ground, EKF arithmetic is feasible in the application of target tracking in different dimension spaces. This paper discusses the design and implementation of some millimeter wave radar system for tracking and imaging applications. It shows the arithmetic has better robustness and precision, and tracking effect is better than other tracking methods.

Keywords: EKF, Millimeter Wave, Light Mess, Data Processing, Simulation , Robustness.

1. Introduction

Millimeter wave sensors are superior to microwave and infrared based sensors in multiple applications. In this project important to track the maneuvering targets correctly in time provide the different levels of radio frequency levels. MMW is mainly concentrate extended kalman filter is a signal processing techniques that estimates the state of a dynamic system from a series of different noise measurement. This one mainly concentrates on environmental like rain etc.

1.1 EKF application in radar data processing

Kalman filter is a signal processing technique that estimates the state of a dynamic system from a series of noisy measurements. It is used in a wide range of engineering applications from radar to computer vision. The application of a model identification procedure based on extended kalman filter (EKF) technique. The EKF technique is an important branch of the data fusion, and can probe, localize and track the maneuvering targets in the comparative accurateness, and the information, such as the position of the target speed and acceleration is given out in real time. An extended kalman filter framework is proposed in order to make use of constraints on individual radar observables that are introduced by these relations. Millimeter wave radar is an emerging desirable technique at present which is being developed to be applied to the

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precision teacking weapon. The kalman filter is essentially a set of mathematical equations that implement a predictor corrector type estimator that is optimal in the sense that it minimize the estimated error covariance. Millimeter wave generally is referred to as the electromagnetic wave of 1-10mm which corresponding frequency is 30-300GHZ both wave length and frequency of millimeter wave lie in between microwave and infrared respectively. One of the early applications of kalman filter was the trajectory estimation and control problem for Apollo project. The radar sensor detects a static target or maneuvering target in the air, on the sea, or on the land, the track data is obtained from the position information of the target. Which is preprocessed the new point track data is correlated with the existed track data, the correlated point track data is used to update the flight path information and the gate is formed to predict next position of the target if the uncorrelated point track is applied to process the initial state of new flight path. The purpose of the state estimation is primarily to smooth past running state of the target to filter current running state of the target and to predict the future running state of the target, these running states include the target position, speed and acceleration. The effectiveness of the tracking system depends directly on the consistency of EKF estimations. The EKF output estimations are frequently biased. The bias in EKF estimation can be seriously degrades the tracking performance.

2. Related Work

In microwave systems transmission loss is accounted for principally by the free space loss. However in the millimeter wave bands additional loss factors come into play such as gaseous losses and rain in the transmission medium. The infrared laser and visible light go through atmosphere their attenuation losses are much higher.

2.1 Characteristics of millimeter-wave tracking system:

2.1.1. Less loss in penetrating through atmosphere

In some part of the light and electronic wave band the attenuation number through atmosphere can attain 40 to 100dB per kilometer, the signal intensity travelling through one kilometer decreases to 0.01-0.1. Transmission losses occur when millimeter waves travelling through the atmosphere are observed by molecules of oxygen, water vapor and other gaseous atmosphere constituents. These losses are greater at certain frequencies coinciding with the mechanical resonant frequencies of the gas molecules. If the visibility is less than 2 KM the radar performance of the electro optical weapons do not work well under the climate conditions such as rain, fog, and the usual performance of the weapons is much hard to take effect. It shows several peaks that occur due to absorption of the radio signal by water vapor (H_2O) and oxygen (O_2). At these frequencies absorption results in high attenuation of the radio signal and therefore short propagation distance. For current technology the important absorption peaks occur at 24 and 60 GHz. But the millimeter wave band has the four window band through which the attenuation number travelling through atmosphere is less which center frequency are 35,94,140 and 220GHz respectively. The H_2O and O_2 resonance have been studied extensively for purposes of predicting millimeter propagation characteristics. But the attenuation number with the millimeter wave travelling through the atmosphere is bigger than that of the microwave in all weather fight capability but it holds the finite all weather battle capability.

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RAIN LOSSES:

Millimeter wave propagation is also effected by rain. Rain drops are roughly the same size as the radio wavelengths and therefore cause scattering of the radio signal.

A. SMALL VOLUME AND LIGHT MASS:

Size of the MMW apparatus is basically proportional to its wavelength which holds water of the microwave, so the measurement of the millimeter wave is very less than that of the microwave. It is right the reason that the millimeter wave is welcome in the precision tracking. The MMW apparatus are easily installed assembled and it is convenient to maintain and exchange.

Precision measurement and better resolving power

A system output power levels is frequently the critical factor in the design, and ultimately the purchase and performance of almost all radio frequency and microwave equipment. The identifying of power goal lies on the beam width of the antenna, narrower the beam is higher resolving power. The beam width of the antenna is as follows

$$\theta=K\lambda/D \qquad (1)$$

Here K is constant, and is concerned with the irradiation function of the antenna, in general we assume 0.8 to 1.3, λ is the wavelength, and D is the antenna diameter.

Instance when the diameter of the antenna is 12cm, the beam width of the microwave with 10GHz is about 18º moreover the beam width of the millimeter wave with 94 GHz is about 1.8º. so when the size of antenna is fixed, the beam width of millimeter wave is much narrower than that of microwave. The MMW radar system can provide with high measurement precision and resolving power of angle, the resolving power of MMW radar is inferior to that of electro optical radar. In practice it is sufficient for identification the goals such as tank and armored car.

C. Identifying high power of metal goal:

The passive MMW radar identifies the goals with the difference of millimeter wave energy emitted by between the goal and its background. Required capability with which objects eradiated millimeter wave energy lies on its own temperature and the radiance object use in millimeter wave band, it can be denoted with the brightness temperature T_B.

$$T_B = xT \qquad (2)$$

Where T is the thermodynamic temperature of object itself, and x is the object radiance. From expression one although the different objects lie in the equal temperature and their eradiated energy is difference due to the different radiance. For suppose the own temperature of object influence directly the eradiated energy is

$$X = \alpha = 1 - P \qquad (3)$$

Herein α represents the absorptive of object and P represents the reflectivity of object.

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3. Methodlogy

The objects which have high conductivity such as metal water and body etc. the big reflectivity against the MMW, so the radiance is small and the object with low conductivity such as soil, pitch and rubber etc, has very less reflectivity against the MMW, so the radiance is high. The object is identified by with different radiance of different objects. The radiance of steel and other object make no variation in the 4 to 10 µm infrared wave bands. If it is the metal object the brightness temperature is much lower than that of nonmetal object. Even object lies in the same absolute temperature. The radiometer can be distinguishing metal goal from non-metal goal.

Arithmetic of EKF

In this extended kalman filter mainly consists of mean and covariance values is simple feasible arithmetic by which state is estimated and filtered, the common use method is extended kalman filter estimate. It is obtained by expanding equation of nonlinear state equation and measurement. The discrete state equation of the nonlinear system is as follows.

$$G(k + 1) = f [k, x(k)] + G(k)V(k) \qquad (4)$$

In this there is no control input, the process noise is additive white noise with zero mean value, and the noise distribution matrix G(k) is known then

$$E[V(k)]=0, E[V(k)V^{'}(j)]=Q(k)\delta_{kj} \qquad (5)$$

The measure equation is expressed as follows:

$$Z(k)=h[k,X(k)]+W(k) \qquad (6)$$

The measure noise is also the additive white noise with zero mean value

$$E[W(k)]=0, E[W(k)W^{'}(j)]=R(k)\delta_{kj} \qquad (7)$$

We assume process noise series is independent of the measure noise series each other and estimate matrix $X\hat{}$ (0|0) and covariance matrix of the initial state p(0|0) is known.

Suppose that the estimation at time k is as follows

$$X\hat{}(k|k) \sim E[X(k)|Z^{k}] \qquad (8)$$

Herein P(k|k) is approximate mean square error and not covariance.

We have obtain the prediction state $X\hat{}(k+1 \mid k)$ is the nonlinear function is expanded in the Taylor progression around $X\hat{}(k \mid k)$ in the equation (1), the extended kalman filter of one order or two orders come to being correspondingly. The expanded of two order is as follows:

$$X(k+1) = f [k, X\hat{}(k)] + f_x(k)[X(k) - X\hat{}(k \mid k)] + ½ \sum_{i=j}^{n} e^{[X(k)-X\hat{}(k|k)]'} fxx(k)[X(k) - X\hat{}(k \mid k)] + G(k)V(k)$$

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Hereinto t_1 is of the high orders e_i is the i-th radical vector in the rectangular coordinates and n is the dimension number of the state vector X(k) there is:

$$f_x(k)=[\nabla_x f^{'}(k,X)]^{'}_{x=X\hat{}(k)} \qquad (10)$$

$f_x(k)$ is a Jacobian matrix of vector f, which is obtained from the most approximate estimate value if the state. Similarly,

$$f^{i}_{xx}(k) =[\nabla_x \nabla^{'}_x f^{i}(k,X)]^{'}_{x=\hat{x}(k)} \qquad (11)$$

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herein $f^{i}_{xx}(k)$ is Heaviside matrix of the i-th vector of matrix f.

the state prediction from time k to time k+1 is predicted value on the condition that in the equation (6) in Z^k is taken as condition to the higher order term is omitted.

$$X\hat{}(k+1 \mid k) = f(k, X\hat{}(k \mid k)) + 1/2 \sum_{i=1}^{n} e_i^{tr} [f^{i}_{xx}(k), P(k \mid k)] \quad (12)$$

The corresponding covariance is

$$P(k+1 \mid k) = f_x(k)\, P(k \mid k)\, f'_x(k) + ½ \sum_{i=1}^{n} \sum_{j=1}^{n} e_i e_j^{tr} [f'_{xx}(k) P(k \mid k). \quad (13)$$

The state prediction equation(12) includes modified term of two orders, and then omitted in the extended kalman filter of one order, so only one order term is kept in the expanded procession equation(9).

Where up on the state update equation of the extended kalman filter arithmetic is as follows:

$$X\hat{}(k+1|k+1)=X\hat{}(k+1|k)+K(k+1)v(k+1) \quad (14)$$

Herein

$$V(k+1) = Z\tilde{}(k+1 \mid k) = Z(k+1) - Z^{\wedge}(k+1|k) = Z(k+1) - h_x(k+1)Y(k+1|k) \quad (15)$$

The above formula is called as new information or the measure residual error.

The error covariance update equation of the extended kalman filter arithmetic is as follows:

$$P(k+1|\, k+1) = P(k+1 \mid k) - p(k+1|\, k)h_x{}'(k+1)^{S-1}(k+1) \quad h_x(k+1)p(k+1|k)= p(k+1|k) - K(k+1)S(k+1) K'(k+1) = [I - K(k+1)h_x(k+1)]P(k+1|k)=[I-K(k+1)h_x(k+1)]P(k+1|k)[I-(k+1)h_x(k+1)]' + K(k+1)R(k+1)K'(k+1) \quad (17)$$

Computer simulation:

Some millimeter radar is selected to do experiment, it works at the 35.4Hz frequency, such as when it tracks the maneuvering target, tracking precision is much higher, and correspondingly tracking error is much less. We assume that a maneuvering target in the sky is probed and tracked by 3-dimensional coordinate's radar and the initial point coordinates of maneuvering target is 1000m and maneuvering target move linearly with constant speed along y axes in the duration of t0~350 it's moving velocity is -15 meter per second in the duration of t=350~550 seconds it turns X axis directions slowly with 90º angle, the acceleration are $U_X=U_Y=U_Z=0.075$ meter per square second, after slow turning ends its acceleration decreases to 0. The turning is conducted with 90º angle from t=560 seconds at the same time its acceleration is 0.3 meter per square second, at 660 seconds the turning the turning ends and its acceleration decreases to 0. The scan period of radar is T=2 seconds, the values are observed along x,y and z-axis independently, all the standard error of the observation noise is 50 meters.

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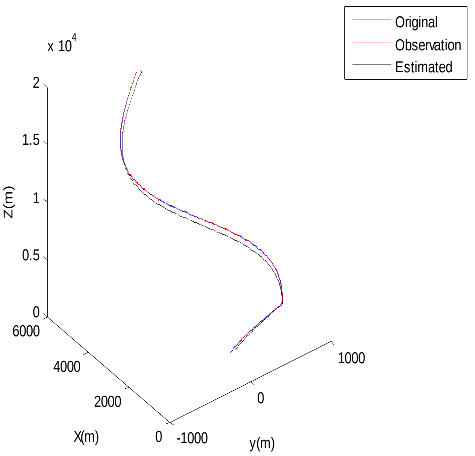

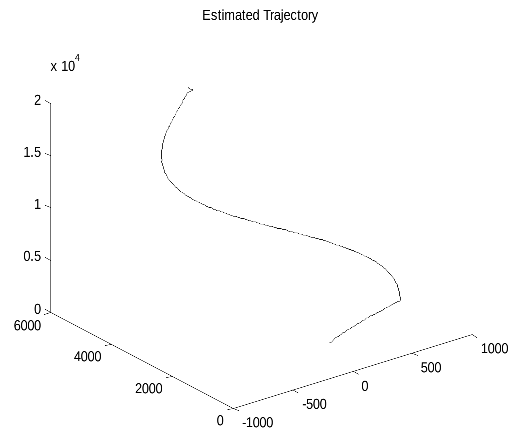

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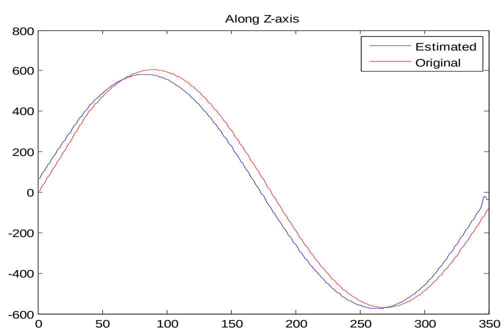

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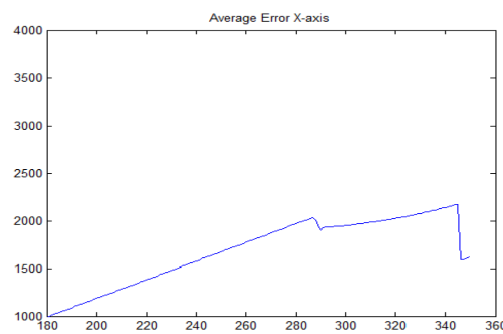

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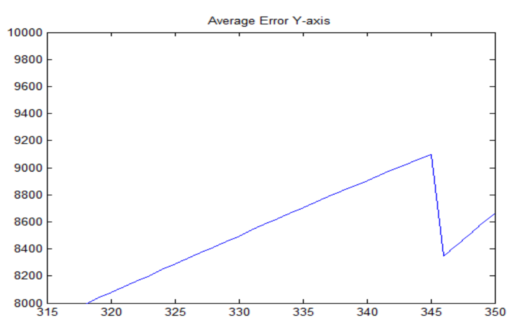

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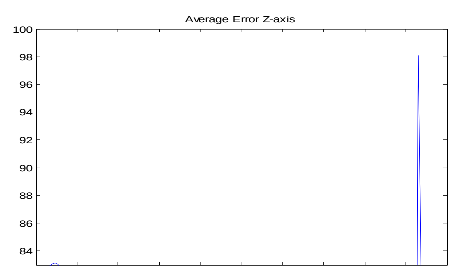

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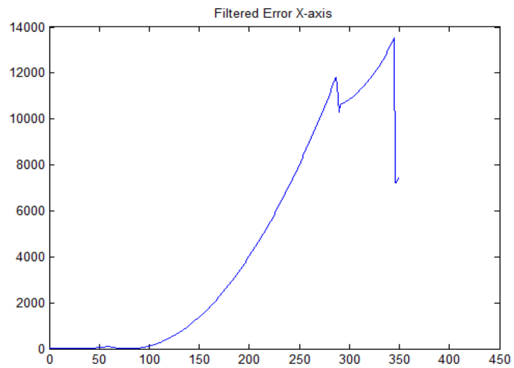

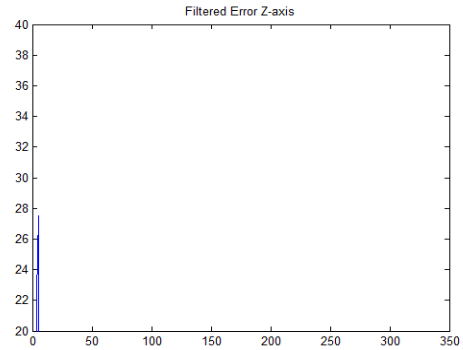

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Fig. 1. Trajectory of maneuvering target, observation trajectory and estimation trajectory.

Fig.2. Processed estimation trajectory by extended Kalman filter.

Fig.3 observation trajectory

Fig.4 Average error along x-axis,

Fig.5 Average error along y-axis,

Fig.6 Average error Z-axis,

Fig.7 Filtered error along X-axis.

Fig.8 Filtered error Z-axis.

4. Conclusion

The above simulation results, the noise variance by system fluctuations is supposed as 0 in the general non-maneuvering model. The main contribution of this work is the application of formal methods to maneuvering target estimation algorithms under a realistic air to air planner scenario. The noise variance by system fluctuation is supposed to 5% of acceleration estimation values in the general maneuvering model, the weighted attenuation factor is α =0.75 and the maneuvering detection threshold is 25, the detection threshold of exit maneuvering state is 10. The above simulation results we give out observation data trajectory, the filtered data trajectory and estimation error curve, the standard error curve. The

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filtered data error is bigger at the beginning with the time passed by the filter error decreases promptly the estimation trajectory is approximated to the true trajectory.

This project introduces the radar data processing techniques and extended kalman filter arithmetic, of the maneuvering target in 3-dimension sky is simulated in computer. All these validates that the arithmetic has better robustness and tracking precision.

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