A LINEAR KALMAN FILTER APPROACH FOR ESTIMATION OF A VEHICLE'S MOTION PARAMETERS USING RANGE-DOPPLER TRACKING AND ROAD INFORMATION

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1. INTRODUCTION

The algorithm described in this paper is part of a processing chain [1] for the ISAR imaging of curving vehicles. After range compression and motion compensation related to the scene center, moving targets with a significant velocity in line of sight can be detected and tracked in the exoclutter area of the range-Doppler domain. Thus information about the distance between the target and the SAR platform as well as the target velocity in line of sight is obtained. For the final ISAR processing, some more vehicle parameters are needed, especially the angular velocity of the curving vehicle's rotation. But also the trajectory of the target is of interest to compensate the translational motion and thus to obtain the pure rotational component.

When there are cooperative targets, these parameters can be measured e.g. by GPS and / or INS (Inertial Navigation System). In most cases (uncooperative targets) there are no such measurements available. Under the assumption that the vehicle is moving on a road, the additional parameters can be estimated by fusing the range-Doppler measurements and the road information with a model which is based on the equation of motion.

2. POSITION AND VELOCITY MEASUREMENTS

The first step is to calculate position and velocity measurements in Cartesian coordinates. For this purpose, the road is described by a set of equidistant positions. The difference vectors between the adjacent positions are normalized to the length of one and thus represent unit vectors of the direction of the vehicle's velocity. For each time instant in azimuth, the range from the particular platform position to each road position is calculated. The road position, for which the range is closest to the range of the target, represents a target position measurement. To obtain a velocity measurement in Cartesian coordinates, the measured velocity in line of sight is projected on the road.

In the case that the road is mostly parallel to the trajectory of the SAR platform, the probability of ambiguous measurements is very high. But on the other hand, vehicles moving parallel to the platform trajectory do not have a significant velocity component in line of sight and thus are not expected to appear outside the clutter region.

The obtained measurements of the vehicle's position and velocity are influenced by several error sources. For example, the accuracy of the road positions depends on the map data from which they are obtained. Another source of errors is the

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ranging accuracy of the radar system or the quality of the tracking in the range-Doppler domain. For this reason, the measurements are further processed using a Kalman filter which contains a motion model.

3. THE KALMAN FILTER [2], [3]

A nine element state vector describes the vehicle's position, velocity and acceleration, each in Cartesian coordinates. Assigned to this state vector is a covariance matrix. The elements on the main diagonal correspond to the variances of each element in the state vector. In the first filter step, this state vector and its covariance matrix are propagated by multiplication with a time dependent state transition matrix. Here, the matrix elements correspond to the coefficients of a Taylor series of the equation of motion. Then a residual is calculated by building the difference between the measurements at the particular time instant and the corresponding observation of the predicted state vector.

A Kalman gain, which contains the predicted covariance and the variance of the measurement noise is used for the weighting of the residual. Thus, a correction term is calculated which is added to the predicted state vector to obtain the filter estimate. After this update, the estimated state vector is again propagated. The covariance of the filter estimate is also calculated via the Kalman gain.

3. FIRST RESULTS

During the first tests, the algorithm showed a satisfying performance. The covariance of the estimated values is decreasing as well as the residual. The vehicle positions are situated on the road and a realistic velocity in Cartesian coordinates was obtained. The next step will be to use these measurements to calculate the angular velocity of the rotation relative to the SAR platform. Further results and an outlook will be presented in the final paper.

4. REFERENCES

[1] P. Berens, U. Gebhardt, J. Holzner, “ISAR imaging of ground moving vehicles using PAMIR data”, Forschungsgesellschaft für Angewandte Naturwissenschaften e.V. (FGAN), submitted to International Radar Conference 2009 (RADAR 09), Bordeaux, France

[2] Loffeld, O, *Estimationstheorie I + II*: Oldenbourg-Verlag, 1990.

[3] Kalman, R. E., “A New Approach to Linear Filtering and Prediction Problems”, Research Institute for Advanced Study, Baltimore, Md., 1960