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Fusion of infrared vision and radar for estimating the lateral dynamics of obstacles

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Abstract

Automotive forward collision warning systems are based on range finders to detect the obstacles ahead and warn or intervene when a dangerous situation occur. However, the radar information by itself is not adequate to predict the future path of vehicles in collision avoidance systems due to the poor estimation of their lateral attribute. In order to face this problem, this paper proposes the utilization of a new Kalman based filter, whose measurement space includes data from a radar and a vision system. Given the superiority of vision systems in estimating azimuth and lateral velocity, the filter proves to be robust in vehicle maneuvers and curves. Results from simulated and real data are presented, providing comparative results with stand alone tracking systems and the cross-covariance technique in multisensor architectures.

Keywords: Fusion; Infrared; Radar; Kalman filter; Path prediction; Collision avoidance

1. Introduction

The ultimate scope of an automotive preventive safety system is the reduction of road accidents, especially those caused by human errors, which represent the 90% of fatal road accidents [1]. Adaptive Cruise Control (ACC) system is a radar based system, which maintains the distance from the preceding vehicle and prevents rear-end collisions with the obstacles in front. The limitations of such systems have been identified (e.g. in [2,3]) and the development of next generation ACC and forward collision warning (FCW) systems is in progress, while research has shown that systems using only one sensor often lack reliability and robustness in specific situations [4]. However, although promising results have been achieved in sensor technologies, not much research effort has been spent to the design and implementation of multisensor multiobject tracking algorithms in automotive applications.

The problem addressed in this paper is the inaccurate estimation of the lateral motion of obstacles in front by range finders. Although radars are robust against bad weather (e.g. rain and fog), they do not have enough angular resolution. This fact is a source of false alarms and misses in automotive real-time applications. In contrast, vision sensors carry out efficient lateral estimation, but fall short in estimating longitudinal parameters, which are perfectly evaluated by mmw radars [5,6]. Stereo vision allows reliable depth measurements up to a disparity of 5 pixels, which corresponds only to a maximum operative distance of 50–60 m [4], while the radar range reaches 150–200 m of range.

In Figs. 1 and 2, the position measurement errors of the two sensors utilized in the paper are shown. In Fig. 1, the resolution of the radar is depicted and corresponds to radial and angular accuracy of $\sigma_R = 1$ m and $\sigma_\theta = 0.01$ rad respectively. The field of view of the radar is about ±11°. The resolution of the vision sensor, which has a field of view of about ±10°, is depicted in Fig. 2. The vision sensor, using image processing techniques,

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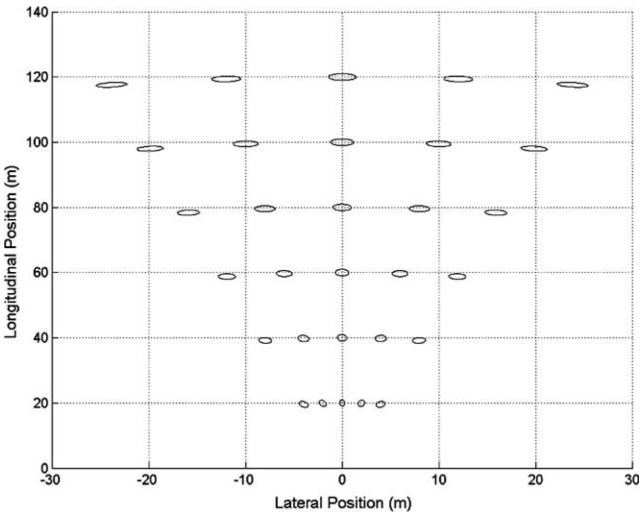

Fig. 1. Radar accuracy on ground plane (field of view about ±11°).

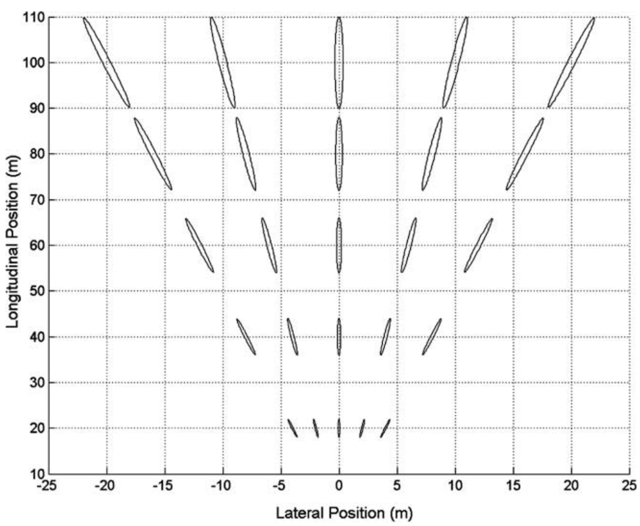

Fig. 2. Camera accuracy after transition to ground plane (field of view about ±10°).

delivers the position of the obstacles in the image plane. The transition from image to ground plane, which is needed for the spatial alignment of the sensors, and the pitch angle of the vehicle insert uncertainty in longitudinal axis. The lateral position is unaffected from pitch and, thus, the error is less and the measurements are more credible. On the other hand, the lateral estimation of the radar is affected from the poor quality of angle measurements. As shown in Fig. 1, in large distances, the efficiency is falling, while the camera's estimation can be valuable.

Thus, a fusion system consisted of a mmw radar and a vision system can improve the motion parameters' estimation of objects tracked by an automotive system. Data fusion is naturally recognized as the only promising technique to generate a new "artificial" sensor, which, while combines to the maximum possible extent the individual sensor capabilities, strives simultaneously to eliminate their drawbacks. In literature, this combination is often met [5,7–9] using the information of the radar sensor for segmentation or the definition of search areas in the image to realize video-based (stereo or mono) obstacle detection and lane tracking systems. In [4], the fusion algorithm consists of two steps, namely, obstacle detection and lane tracking. The longitudinal and lateral estimation are separated; the former is radar based with a constant velocity model, while the latter is based on the assumption that the derivative of the lane position is zero.

Research on sensor fusion is focusing on improving vision systems' performance. In [10], an innovative multihypothesis tracking scheme is proposed for radar tracking and it seems promising for its detection rate, but it does not take care of the properties of the lateral motion. In contrast, this paper proposes a new tracking filter in ground plane that estimates accurately the lateral velocity of automobiles using a mmw radar and a far infrared camera (FIR). The target application is the support of next generation collision warning and avoidance systems in night and adverse weather conditions.

In the proposed algorithm, as in [4], the longitudinal and lateral motion of the vehicle is separated. The method introduced in the paper has a hybrid tracking architecture which deploys both measurements and tracks in an Uncoupled Double Filter (UDF) that compensates the dynamics of moving obstacles tracked by an automotive fusion platform, integrated on a test vehicle. The Uncoupled Double Filter consists of a mixture of range and angle filters in polar coordinates, where radar tracks are considered as range filter measurements and camera tracks as angle filter measurements respectively. The coexistence of the above mentioned sensors is a prerequisite for the proper functionality of the method.

The structure of the paper is as follows. It starts giving the structure of the radar and image tracking system that allows the implementation of the proposed method. In the tracking architecture of the radar, all individual parts (data association, filters, track management etc.) are designed given the limitations of real-time automotive systems; in the image tracking, image processing and correlation data association are described given a real-time frame grabbing process. In turn, the fusion methods for the overall system are described. Initially, the cross-covariance method for the two sensors is presented and then the UDF algorithm is introduced. The results are tested by means of simulated data sets and real data, as well. For the tests, a collision warning and night vision system is the use case incorporating data from a mmw radar and images from a far infrared camera. The paper ends with a brief remark on