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Interacting Multiple Model-Based Extended Kalman Filter for Wireless Capsule Endoscope Tracking

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Abstract— **This paper develops an extended Kalman filter (EKF)-based location tracking method for a wireless capsule endoscope (WCE) in order to achieve precise localization accuracy and computation cost acceptable for real-time tracking. This study compares two kinds of EKF based on constant velocity(CV) and interactive multiple models (IMM) transition functions and evaluates the performances based on computer simulations. Our evaluation results demonstrate that the proposed EKF-based tracking achieves the estimation accuracy of around 8 mm with both models, which means that the proposed method is applicable to WCE movement tracking.**

I. Introduction

Wireless capsule endoscope (WCE) is an in-body medical device, that provides the video data from inside the gastrointestinal (GI) tract of a human, so WCE's location is influential. To realize precise location tracking, it is important to properly consider a nonlinear transition model to represent the WCE movement inside a small intestine. The study is dedicated to the evaluation of the extended Kalman filter (EKF) with different transition models for the previously derived movement of the WCE. Several transition models of WCE localization have been described so far. In particular, interacting multiple models (IMM) for WCE as a combination of movement and immobility was suggested [1], whereas EKF based on constant velocity (CV) model is quite a common method for tracking applications. In this paper, we apply the EKF-based location tracking to the WCE movement with the CV and IMM-based EKF to discuss the performance variation for different kinds of transition models. The simulations are created with Matlab Sensor Fusion and Tracking and Optimization toolboxes.

II. Proposed Methods

CV and IMM-based EKFs are compared based on the data provided by the propagation model [2]. IMM is represented by constant velocity (CV) and constant turn (CT) models, since they are supposed to describe the movement of a capsule more precisely than a constant acceleration (CA) model used in [3] due to the crooked nature of the small intestine. These models can be applied by using a Markov chain with transition probabilities $\binom{0.9\ 0.1}{0.1\ 0.9}$. Eight receivers are supposed to be placed on a body surface forming a cube with a size of 40 cm $\times$20 cm $\times$40 cm getting received signal strength indicator (RSSI) data generated by the propagation model derived by [2]. Then the previously simulated RSSI data is recalculated to position through least squares method. This helps to reduce the sizes of matrices in EKF calculations.

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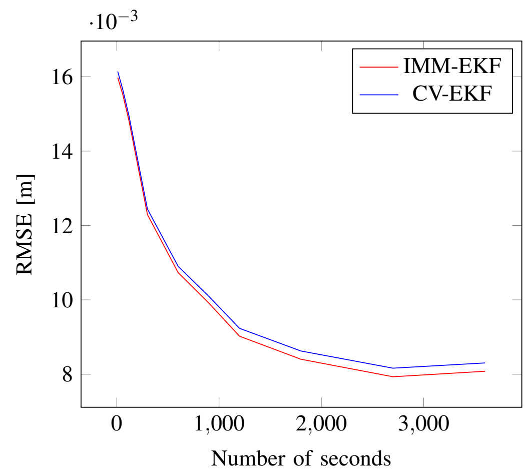

Fig. 1. RMSE of CV and IMM-based EKFs

III. Performance Evaluation and Discussions

Fig.1 shows the root mean square error (RMSE) of the proposed EKF location tracking based on the CV and IMM models. Performance of the IMM-based tracking has slightly been improving compared with a CV-EKF after about 8.5 minutes of the simulated. The filters converge to 8 mm, which is about a third of the WCE's length, so the achieved accuracy is adequate. Nevertheless, further research with other kinds of Kalman filters is planned. Both methods fulfill the requirements for the real-time applications, because the computational time is less than 1 ms for one filter loop. Hence, our proposed tracking accomplishes acceptable computation complexity without any sacrifice of localization accuracy for real-time WCE tracking.

References

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