

Title: Interacting Multiple Model-Based Human Motion Prediction For Motion Planning Of Companion Robots

Abstract:

Motion planning of human-companion robots is a challenging problem and its solution has numerous applications, such as for accompanying elderlies at home and guiding visitors in museums. A desirable robot motion behavior needs to satisfy certain requirements, such as safety, comfortableness and naturalness. Safety serves as the fundamental requirement for companion robots that collision with humans should be avoided. Comfortableness and naturalness compose constraints on the social aspects of robots; the former requires robots to maintain appropriate distance from humans and the latter emphasizes on the similarity in motion speeds between robots and humans.

To design a socially desirable robot motion planner, two issues need investigation. First, human motion usually involves different motion models, such as straight-line movement, making turns and change of speed, which makes it difficult for accurate human motion estimation and prediction. Second, a time-efficient motion planner that can generate robot motion behavior in accordance with the aforementioned requirements is necessary. In this work, a model predictive control (MPC)-based motion planner incorporating human motion prediction capability is developed for an autonomous robot to accompany a target person in a socially desirable manner, which takes into consideration the safety, comfortableness and naturalness requirements. To estimate and predict human motion states, the Interacting Multiple Model (IMM) framework is utilized, which can incorporate different dynamic models and computes mode probabilities of each model. To deal with the nonlinear dynamics of the human motion, Unscented Kalman filter (UKF) is applied to each model in the IMM framework, resulting in the so-called IMM-UKF approach. Such approach has benefits compared to traditional estimation and prediction methods that utilize a single motion model, such as Kalman filter (KF) and UKF; these single motion model-based methods cannot consider various human motion patterns and thus results in less accurate estimation and prediction. By using the predicted human positions in the prediction horizon, the robot motion planning is formulated as an MPC problem that explicitly considers safety, comfortableness and naturalness requirements on the robot's motion.

The proposed motion planner is evaluated in a simulated scenario that the robot accompanies a target person moving in an environment containing obstacles. Several estimation and prediction methods, including KF, UKF and IMM-KF, were compared with the IMM-UKF approach to evaluate its performance. In addition, a reactive motion planner was compared with the MPC-based planning method on generating socially desirable motion behaviors. Results have shown higher accuracy and faster response time using IMM-UKF for human motion estimation and prediction than other three methods. MPC-based motion planner has shown to

generate desirable robot motion behaviors while the reactive planner results in large oscillation of robot velocity.