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M2SIR: A Multi Modal Sequential Importance Resampling Algorithm for Particle Filters

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1. Introduction

Multi-sensor based state estimation is still challenging because sensors deliver correct measures only for nominal conditions (for example the observation of a camera can be identified for a bright and non smoggy day and illumination conditions may change during the tracking process). It results that the fusion process must handle with different probability density functions (pdf) provided by several sensors. This fusion step is a key operation into the estimation process and several operators (addition, multiplication, mean, median,...) can be used, which advantages and drawbacks.

In a general framework, the state is given by a hidden variable \mathbf{X} that define "what we are looking for" and that generates the observation, provided by several sensors. Figure 1 is an illustration of this general framework. Let \mathbf{Z} be a random vector that denotes the observations (provided by several sensors). State estimation methods can be divided in two main categories. The first family is based on optimisation theory and the state estimation problem is reformulated as the optimisation of an error criteria into the observation space. The second family proposes a probabilistic framework in which the distribution of the state given the observation has to be estimated ($p(\mathbf{X}|\mathbf{Z})$). Bayes rule is widely used to do that:

$$p(\mathbf{X}|\mathbf{Z}) = \frac{p(\mathbf{Z}|\mathbf{X})p(\mathbf{X})}{p(\mathbf{Z})} \quad (1)$$

When the state is composed by a random continuous variable, the associated distribution are represented by two principal methods: the first one, consists in the définition of an analytic representation of the distribution by a parametric function. A popular solution is given by Gaussian or mixture of Gaussian models. The main drawback of this approach is that it assumes that the general shape of the distribution is known (for example a Gaussian representing an unimodal shape). The second category of methods consists in approximate the distribution by samples, generated in a stochastic way from Monte-Carlo techniques. The resulting model is able to handle with non linear model and unknown distributions.

This chapter presents the probabilistic framework of state estimation from several sensors and more specifically, stochastic approaches that approximate the state distribution as a set of samples. Finally, several simple fusion operators are presented and compared with an original algorithm called *M2SIR*, on both synthetic and real data.

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