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Defense 2019-06-04

Title: On Informative Path Planning for Tracking and Surveillance

Abstract

This thesis studies a class of sensor management problems called informative path planning (IPP). Sensor management refers to the problem of optimizing control inputs for sensor systems in dynamic environments in order to achieve operational objectives. The problems are commonly formulated as stochastic optimal control problems, where to objective is to maximize the information gained from future measurements. In IPP, the control inputs affect the movement of the sensor platforms, and the goal is to compute trajectories from where the sensors can obtain measurements that maximize the estimation performance. The core challenge lies in making decisions based on the predicted utility of future measurements.

In linear Gaussian settings, the estimation performance is independent of the actual measurements. This means that IPP becomes a deterministic optimal control problem, for which standard numerical optimization techniques can be applied. This is exploited in the first part of this thesis. A surveillance application is considered, where a mobile sensor is gathering information about features of interest while avoiding being tracked by an adversarial observer. The problem is formulated as an optimization problem that allows for a trade-off between informativeness and stealth. We formulate a theorem that makes it possible to reformulate a class of nonconvex optimization problems with matrix-valued variables as convex optimization problems. This theorem is then used to prove that the seemingly intractable IPP problem can be solved to global optimality using off-the-shelf optimization tools.

The second part of this thesis considers tracking of a maneuvering target using a mobile sensor with limited field of view. The problem is formulated as an IPP problem, where the goal is to generate a sensor trajectory that maximizes the expected tracking performance, captured by a measure of the covariance matrix of the target state estimate. When the measurements are nonlinear functions of the target state, the tracking performance depends on the actual measurements, which depend on the target’s trajectory. Since these are unavailable in the planning stage, the problem becomes a stochastic optimal control problem. An approximation of the problem based on deterministic sampling of the distribution of the predicted target trajectory is proposed. It is demonstrated in a simulation study that the proposed method significantly increases the tracking performance compared to a conventional approach that neglects the uncertainty in the future target trajectory.