Title	リソースに制限のあるマルチロボットによる環境モニタリングのための分散アクティブセンシング
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Abstract

This thesis addresses the problem of trajectory planning over discrete domains for monitoring an environmental phenomenon that is varying spatially. The most relevant application corresponds to environmental monitoring using an autonomous mobile robot for air, water or land pollution monitoring. Since the dynamics of the phenomenon are not known *a priori*, the planning algorithm needs to satisfy two objectives simultaneously: 1) Learn and predict spatial patterns and, 2) adhere to resource constraints while gathering observations. Subsequently, the thesis brings the following contributions:

Firstly, it formulates a resource constrained information-theoretic path planning scheme called *Resource Constrained Decentralized Active Sensing (RC-DAS)* that can effectively trade-off model performance to resource utilization. Since, these objectives are inherently conflicting, optimizing over both these objectives is rather challenging. However, weighted combination of these objectives into a single objective function is proposed such that the total path length is bounded by the maximum operational range. This path planner is then coupled with a distributed Gaussian Process (DGP) framework to allow the robots to simultaneously infer and predict the dynamics of the environment of interest.

Secondly, optimal weight selection method is proposed wherein the weights of the *RC-DAS* cost function are dynamically updated as a function of residual resources. This extended scheme is referred to as *RC-DAS*† which additionally ensures that the robots return to base station at the end of their respective mission times. This prevents the robots from getting stranded amidst the field and is a first step towards making the architecture fail-proof.

Thirdly, an operational range estimation framework is proposed to interpret the bounds on maximum path length attainable by the robots. This should be used as the limiting condition for terminating the exploration to ensure a safe path to the base station. This framework is then generalized to encompass various classes of robots and is made robust to operate with high accuracy even when subject to natural environmental disturbances like strong wind gusts or uneven terrains.

Fourthly, the *RC-DAS* framework is scaled to multiple robots operating in a fully decentralized fashion in communication devoid environments. Owing to such a setting, multiple inferred models of the environment can be obtained. However, neither all models can be fully trusted nor forthrightly rejected. To solve this dilemma and to obtain one globally consistent model, a pointwise fusion of distributed GP models is introduced and referred to as *FuDGE.*

Keywords: *Active Sensing, Decentralized Multi-robot Teams, Resource Constraints, Map Fusion, Range Estimation.*