DYNAMIC ADAPTIVE SAMPLING FOR ENVIRONMENTAL AND SMART LIGHTING DISTRIBUTED SENSOR APPLICATIONS

By

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ABSTRACT

In recent years, real-time observation and monitoring have been facilitated by emerging sensor technologies. A spatially distributed network of compact and low cost sensor nodes can estimate important features of the underlying phenomena from a set of point measurements in time and space. A principal challenge posed by these networks is the selection of sampling locations and times in order to most effectively describe features and detect events of interest in the distributed observation field. Furthermore, after an initial sensor deployment, long term monitoring of a time-varying process requires dynamic redeployment and selection of sensors in response to the process changes. In addition, the incorporation of robotic technologies adds mobility to the sensor network, enabling more adaptive observation of the underlying phenomena in a spatial and temporal manner. Distributed monitoring technologies also result in new resource constraints such as a limited number of sensor nodes and energy.

This research focuses on adaptive dynamic feature sampling of phenomena which occur as temporal and spatial distributions of variables using distributed sensor networks. In previous work, a Multi-scale Adaptive Sampling (MSAS) has described a method to generate a variation sensitive sample distribution based on multi-scale variation sensitive modeling. However, MSAS is designed for sampling static fields. In this thesis, MSAS is extended to dynamic process sampling. A Kalman filter is employed in cooperation with MSAS to achieve model-based state estimation of the underlying dynamic process, which is then utilized to guide the local adaptive selection and redeployment of sensors. The resulting Dynamic MSAS (DMSAS) algorithm can achieve time-efficient redeployment of monitoring resources in response to dynamic changes of the underlying phenomena. A series of simulations have been implemented to evaluate the DMSAS algorithm, and the simulation results demonstrate the validity of DMSAS to achieve high quality estimation and fast sampling time. The application and evaluation of the DMSAS algorithm to environmental monitoring has been studied through simulation of 3D motion of

autonomous undersea vehicles (AUV) for the observation of ocean plankton distributions.

This thesis also considers application of MSAS and DMSAS to light field monitoring in smart lighting system design. For the development of adaptive control in smart lighting, it is important to have a systematic methodologies for monitoring the generated light field. Based on MSAS, a systematic approach to light field sampling using a distributed sensor network is introduced. This approach is based on the multiscale representation of the light field and adaptive selection of sample locations to maximize the information obtained from the field. Furthermore, for monitoring dynamic light field disturbances, this adaptive light field sampling approach is extended to dynamic light field sampling with adoption of the DMSAS principles. The resulting dynamic adaptive sampling approach can guide the adaptive selection and real-time reallocation of sample locations to track and estimate the generated light field and daylight disturbances. This approach generates a multi-scale functional representation of the light field, which can be an effective basis for lighting control. Experimental results have shown that a systematic dynamic selection of sensor locations can significantly reduce the error in representation of the light field with corresponding improvement in the lighting control.