MultiScale Sensing and Actuation Architecture and Performance

Diane Budzik, Amarjeet Singh, Per Henrik Borgstrom, Michael Stealey, Maxim Batalin, William Kaiser
Networked Infomechanical Systems (NIMS)

Introduction: Sampling high frequency spatiotemporal phenomena

• Many applications require distributed sensing capabilities because of the high frequency spatiotemporal distribution of the sensing phenomena
• Applications include
  – Environmental sampling
  – Public health environment monitoring
  – Precision agriculture
  – Security
  – Etc.

Motivation and Prior Art

• Static Network Sampling (SNS) requires an impractically large number of sensors
  Excessive cost in resources and potentially a source of disturbance to the environment under investigation
• Raster Scan Sampling (RSS)
  – Spatial sampling fidelity can be adjusted
  – Temporal latency increases with increasing spatial fidelity
• Adaptive Sampling (AS) techniques perform well when phenomenon is not changing significantly but are unsuited for dynamic phenomena

Proposed Solution: MultiScale Sensing

MultiScale Architecture

• Hierarchy of sensors according to sampling fidelity, spatial coverage, and mobility characteristics
• First tier, in this case an imager, is a static low fidelity, high spatial coverage sensor providing “global” information about the environment
  This information is used to extract regions of high phenomenon variability.
• Second tier is a mobile robot with high fidelity, low spatial coverage (spot measurement) sensor, in this case Photosynthetically Active Radiation (PAR) sensor

Methods and Experimental Results

MultiScale Performance Experiment

• Images captured every 15 sec from the real environment in the James Reserve
• Processed images to extract regions of interest (regions of high phenomenon variability)
• Use task allocation to assign mobile robot(s) to region of interest maximizing utility of the system
• Information captured by the robot (pixel values) provides feedback to guide the robot to the next region of interest in the next image
• Varied sampling density and speed of the robot to analyze the effect on information extracted and fidelity

Simulation results for Area and Time heuristics

– Graph on the left compares normalized sampled area for different densities and speeds
– Upper right graph compares normalized number of serviced tasks

MultiScale vs. Adaptive Sampling

• Used small, medium, and large sun fleck object sizes
• Images were either static or dynamic - object moved 12 pixels/min (12 cm/min) along horizontal and vertical axis
• Speed of mobile robot = 50 cm/s, Sampling time = 0.1 sec
• Size of the image: Length = 768 cm, Width = 480 cm

• Performance comparison of Adaptive Sampling and MultiScale Sampling for different object sizes
  – Upper graph examines static phenomena
  – Lower graph examines dynamic phenomena