

Autonomous Sensor Placement

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Abstract

With an increasing reliance on robotic platforms to perform scientific exploration in remote or hostile environments, it is becoming crucial that robotic system be able to perform autonomous intelligent sensor placement as well as autonomous experimental design. Such a system requires encoding of scientific knowledge, the ability to make inferences from data, and the ability to identify the most relevant question to ask given both the instruments prior knowledge and the issue it is designed to address. This requires implementation of two computational engines: the inference engine and the inquiry engine.

Here we demonstrate our first efforts to develop intelligent instruments that rely on autonomous sensor placement. The prototype is a robotic arm equipped with a light sensor. The robot is placed in a black field and is programmed to find a white circle in the field, and to correctly categorize it according to its center coordinates and radius. The inference engine relies on Skilling's nested sampling algorithm, which not only estimates the model parameters, but also computes the evidence of the model. The inquiry engine relies on computing the entropy of a sampled set of probable measurements for each considered sensor placement position to decide which measurement or experiment is expected to provide the greatest amount of information. This is in accordance with both Loredó's Bayesian Adaptive Exploration and the present authors Inquiry Calculus. The inference-inquiry loop is then closed resulting in an instrument that takes measurements, makes inferences, and decides which measurements to take next. The system will stop when a pre-programmed level of tolerance is reached.

Kevin Knuth was born in Fond du Lac, Wisconsin, USA in 1965. He received his B.S. from the University of Wisconsin-Oshkosh (1988), his M.S. in physics from Montana State University (1990), and his Ph.D. in physics with a minor in mathematics at the University of Minnesota (1995). He held postdoctoral positions studying neuroscience at Louisiana State University Medical Center (1996), the City University of New York and the Albert Einstein College of Medicine (1997-1998), where he was later an instructor. He was also an instructor at the Weill Medical College of Cornell University (1999) where he worked on neurodatabases, and was a research scientist at the Center for Advanced Brain Imaging at the Nathan Kline Institute (1999-2001). From 2001-2005 he worked as a Research Scientist developing machine learning techniques and their applications in the Intelligent Systems Division at NASA Ames Research Center. He joined the University of Albany faculty in October 2005 with a dual appointment in the Departments of Physics and Informatics. His scientific interests include: probability theory, astrophysics, complex systems, and brain dynamics. For recreation, he enjoys hiking, birdwatching and poking around tidal pools.