Robotic Autonomous Experimental Design

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Currently available robotic systems lack the ability to act and react without human intervention. As we expand to more diverse fields, we will require increasingly autonomous instruments that are able to conduct remote science operations independently. This paper presents an intelligent system that can autonomously collect and interpret data in order to determine what data should be collected next. The three fundamental steps of the scientific method are hypothesis generation, experimental design, and data interpretation. A successful intelligent instrument must be capable of performing this cycle independent of human assistance. Our system is able to generate an initial hypothesis by using the supplied constraints of the environment in question. The inquiry engine relies on Bayesian adaptive exploration techniques to choose experimental measurements that are expected to provide maximal information gain. The inference engine then uses a nested sampling algorithm to generate a set of data from which the inquiry engine can calculate information gain probabilities. The instrument we have designed is able to characterize a white circle arbitrarily placed within a black field in as little as twelve point measurements. The system is able to complete the cycle of learning autonomously during each experiment, resulting in an actual smart robot. We have successfully developed an intelligent system that is able to infer circle parameters based on the data it has and design experiments by asking binary questions based on the information it needs. In future experiments, we will hope to improve the quality of inferences made from the data produced by the light sensor.