氏　　名	PINKAM, Nantawat			
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論文題目	Exploration of Mobile Robots for Multiple Radiation Source Estimation			
論文審査委員	主査	CHONG, Nak Young	JAIST	Professor
		NGUYEN, Minh Le	JAIST	Professor
		IKEDA, Kokolo	JAIST	Assoc. Professor
		CAPI, Genci	Hosei University	Professor
		LEE, Geunho	Univ. of Miyazaki	Assoc. Professor

論文の内容の要旨

In this work, we consider the localization problem of multiple unknown radiation sources with measurement uncertainty by using robotic systems in a geometric environment. The goal is to give an accurate map of radiation which contains a number of sources, locations, and intensities. Furthermore, the exploration cost must be minimized. We proposed the scheme for the localization of multiple radioactive sources using the particle filter. In a normal circumstance, a robot will estimate the source location by pursuing the intensive intensity site. However, a low radiation area has little information which makes an unpredictable estimation. Thus, an exploration algorithm must be utilized. In consequence, the exploration cost must be minimized because the exploration time might be restricted. We propose the exploration method using frontier-based exploration which involves the target point selection algorithm by considering the minimum distance from a robot to an unexplored region, and the increasing gradient direction. In addition, the area pruning algorithm is introduced to further decrease the exploration time by overlooking less important areas and applying Bayesian estimation to further eliminate the potentially no source area. After every source is discovered, we proposed the sources intensity separation algorithm to further raise the estimation accuracy. The proposed method has been verified by the simulations using MATLAB in both ideal environment and SLAM dataset of a real building. In addition, the uncertainty in the robot self-localization was introduced and experimented. The effect of environment attenuation that decreases the radiation measurement is also investigated and the robot is successfully localized the radiation source inside a single entrance room. The proposed strategy can incredibly decrease the exploration cost compared to the regular techniques and increment the accuracy of multiple sources localization.

Keywords: Bayes' theorem, source localization, information theory, exploration and path planning, mobile robot

論文審査の結果の要旨

This dissertation addresses the problem of localization and intensity estimation of multiple radiation sources using a team of autonomous mobile robots. The main technical challenge to this non-Gaussian, nonlinear estimation problem is that the radiation detectors used most frequently are myopic so that data can only be collected by on the spot robots. The author's main contribution is three-fold: First, the author proposed an online frontier-based collaborative exploration algorithm that enables collaborative robots to select the proper search direction based on the area pruning and utility function applying Bayesian estimation; secondly, he implemented the source intensity separation algorithm to enhance the intensity estimation accuracy in an offline manner; and thirdly, he extended the proposed idea to the non-line-of-sight source localization in an environment separately by multiple walls, incorporating the robot's self-localization uncertainty. The effectiveness of the proposed approach was verified through extensive computer simulations in the real world environment settings produced by the University of Freiburg, and compared to the benchmarking results.

Specifically, the author proposed a revamped particle filter approach to accommodate non-Gaussian distributions that can easily be implemented on commercial off-the-shelf mobile robot platforms. He thoroughly tested and compared a variety of exploration algorithms in a benchmarking environment testbed, in terms of exploration distance and time, and estimation accuracy. The proposed estimation model and its variants have been published in the Springer Intelligent Service Robotics and several IEEE conference proceedings. In contrast to most of existing source localization approaches that rely on sensors with an operating range, this work explores the benefits of a particle filter based on on-the-spot measurements, offering a good compromise between efficiency and ability for non-linearity and non-Gaussian belief. Overall, this research opens doors to impactful contributions to the mobile robots and multi-robot systems community. This is an excellent dissertation and we approve awarding a doctoral degree to PINKAM Nantawat.