論文 / 著書情報
Article / Book Information

題目(和文)	生物規範と情報理論規範の混成による適応的匂い源探索行動のモデル化
Title(English)	Modeling adaptive olfactory searches by a hybrid framework based on bio-mimetic and information-theoretic methods
著者(和文)	HernandezReyes Cesar Augusto
Author(English)	Cesar Hernandez Reyes
出典(和文)	学位:博士(工学), 学位授与機関:東京工業大学, 報告番号:甲第12079号, 授与年月日:2021年9月24日, 学位の種別:課程博士, 審査員:倉林 大輔,蜂屋 弘之,中島 求,塚越 秀行,中尾 裕也
Citation(English)	Degree:Doctor (Engineering), Conferring organization: Tokyo Institute of Technology, Report number:甲第12079号, Conferred date:2021/9/24, Degree Type:Course doctor, Examiner:,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	要約
Type(English)	Outline

論文要約

Thesis outline

Cesar Hernandez-Reyes

Recent years have seen important advancements in various areas of robotics and artificial intelligence (AI) research. In this era, it is not rare to find robots serving not only as tools in factories but also in various other applications that directly impact the lives of humans. The past decade alone has seen a significant increase in the number of robots serving as personal assistants, delivering packages, working as clerks in various businesses, among many other applications. For a robot to undertake complex tasks along with humans, it is fundamental that they can accurately sense the environment.

Perhaps motivated by a tendency to emulate our own physiology, humans have dedicated large efforts to researching ways to give visual, auditory, or tactile sensory capabilities to robots. While these sensory capabilities have proven to be valuable in many applications, research on robotic olfaction is comparatively less common. Nonetheless, robotic olfaction has a wide range of applications.

One such application is in disaster-struck areas. After a large earthquake, collapsed infrastructure would result in broken gas pipes that might release hazardous chemicals or result in an explosion. Typically, the most viable solution to find these leaks is to deploy search dogs and human personnel. Other applications of olfactory searches occur in similarly dangerous environments. For example, in decommissioning of power plants, or in security operations where harmful chemicals, drugs or explosives need to be found quickly. In those situations, the appearance of the object being searched is typically unknown. In other words, the only signal emitted by the object are chemical particles. To conduct the tasks mentioned before, safely and efficiently, a robot capable of searching and finding the source of chemical particles is necessary.

However, developing artificial olfactory search behaviors is a difficult task. This is because of the spatio-temporal complexity of odor plumes. In most cases, odor particles are distributed via turbulent wind flows. Hence, fast and adaptive decision-making is required to conduct olfactory searches.

Despite the complexity of odor source localization (OSL), various animals conduct these searches instinctively. Insects are particularly interesting from the point of view of computational efficiency. When compared to mammals, insects have several orders of magnitude less neurons (approximately 10^{11} for mammals; 10^5 to 10^6 for insects). Despite this, male specimens of several species of moths are capable of tracking the trail of pheromones emitted by the female, even when such trail is turbulently diffused across scales of kilometers.

Given how insects can efficiently conduct olfactory searches with limited computational resources, understanding their behavior has motivated several previous studies. In addition, accurately modeling their decision-making processes contributes to the improvement of the field of AI, and other related fields such as neuroscience and neuroethology.

While bio-mimetic models of olfactory behavior deepen the understanding of their decision-making processes; thus contributing to the fields of neuroscience and ethology, their implementation in robots presents multiple challenges. First, the behavior learned from insects is optimized for the habitat of said insects. For example, an OSL model learned from a silk moth would be effective on an open space, where the odor plume is symmetrical (not meandering) and periodic, and where there are no disturbances such as obstacles. In addition, the sensors and actuators of insects are significantly different to those of robots.

To develop OSL algorithms that are more suitable for robots, previous work has adopted the paradigm of probabilistic robotics. This paradigm considers that a robot can only partially observe its environment via noisy sensors. Therefore, the environment is modeled as a stochastic process by the concept of the Markov property. As such, the environment is represented as a *state variable*, where the present state contains all the necessary information about the past states.

For this reason, probabilistic robotics methods typically encode the environment as a probability map, or *belief*, which is updated by Bayesian inference throughout a search, by the sequence of sensory stimuli experienced by the agent. One of such probabilistic OSL methods is known as infotaxis. Infotaxis models an odor plume as a belief which is updated based on the likelihood of experiencing a sequence of odor detections. Such likelihood is a probability density function that depends on estimated values of physical properties of the odorant particles.

While both bio-mimetic and probabilistic frameworks have contributed to understanding what makes an agent effective at searching and finding an odor source, their potential applications often diverge. Bio-mimetic algorithms tend to be effective in environments that are similar to the habitat of the animal that inspired the model. On the other hand, probabilistic algorithms provide more generality and adaptivity. However, they are often constrained by the technological capabilities of the robot where they are implemented. Namely, they often require spatial awareness and high computational resources.

This thesis is motivated by the necessity for a hybrid framework to model, implement, and evaluate olfactory behaviors of either natural or artificial agents.