論文 / 著書情報
Article / Book Information

題目(和文)	
Title(English)	Quantitative Analysis of Biotic Olfaction and Multi-Perspective Solution based on Embodied Cognition
著者(和文)	ChewJouh Yeong
Author(English)	Jouh Yeong Chew
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9770号, 授与年月日:2015年3月26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,田中　正行
Citation(English)	Degree:, Conferring organization: Tokyo Institute of Technology, Report number:甲第9770号, Conferred date:2015/3/26, Degree Type:Course doctor, Examiner:,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

専攻： Department of	Mechanical & Control 専攻	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of (Engineering)
学生氏名： Student's Name	Jouh Yeong CHEW	指導教員（主）： Academic Advisor(main)	Daisuke KURABAYASHI
		指導教員（副）： Academic Advisor(sub)	－

要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

The objective of this study is (1) to decipher complex chemical plume tracing (CPT) behavior of biological systems, and (2) to propose a multi-perspective solution to improve CPT behavior of autonomous agents. This method is novel compared to previous studies that focus mainly on qualitative CPT attributes of biological systems. First, biological CPT behavior is analyzed from the quantitative perspective to understand its adaptive behavior. Then, resources of biological system to achieve efficient CPT are identified and a multi-perspective solution is proposed. The model is simulated using dynamic plume that is similar to actual environment to reduce difference between simulation and real application. The model is realized and optimized on autonomous agent and results are validated in uncontrolled environment.

Hazardous chemical plume is released into the environment through various activities, such as industrial accidents, terrorist attacks and natural disasters. This intentional and accidental release poses huge threats to lives and properties. Previous studies focused on finding efficient solutions to localize source of leaks using vision and acoustic. However, these method are limited to non-translucent chemicals and noisy leaks. Thus, solutions based on olfaction, i.e. CPT, is preferred because of its applicability to varying plume leaks. However, CPT is not a trivial task, especially for autonomous agents, because of complex plume diffusion entropy. Wind vector displaces chemical particles with vortical motion because of atmospheric turbulence. This produces plumes with high spatial temporal variability, non-continuous and intermittent. Thus, solutions have to be (1) applicable to different types of plume release, and (2) adaptive for handling instantaneous plume variation.

It is noteworthy biological systems exhibit adaptability to perform efficient CPT behavior as natural instincts, i.e. for homing, foraging, and mating. This efficiency is desirable and serves as the main motivation for this study. Previous studies have explored biological CPT behavior and proposed solutions based on qualitative behavior. However, localization results suggest success rate, time and distance to source have to be improved further. This is

reasonable because biological systems are nonlinear and qualitative algorithm is inadequate to decipher complex CPT behavior. Thus, quantitative solution is desired to (1) bridge the qualitative attributes with its quantitative behavior, (2) segment the CPT behavior to identify the prior, and (3) allow behavioral comparison under controlled condition to understand the adaptive behavior. First, the silk moth is identified as the research subject because (1) its qualitative behavior is widely studied, and (2) the relationship between stimulus input and behavioral output is clear. A hierarchical classifier is proposed for quantitative analysis by segmenting its CPT locomotion and building its inverse model for detecting stimulus input. The model detects stimulus input with good accuracy and indicates silk moths exhibit behavioral singularity and adaptive CPT locomotion.

Despite good estimation performance, the inverse model is inadequate as bio-inspired CPT solution primarily because physical features of autonomous agent is different from silk moth. A multi-perspective solution is desirable as an efficient solution. Thus, embodied cognition is proposed because the solution encompasses internal algorithm, embodied intelligence, and their interaction with environment to exhibit intelligent behavior. The adaptive behavior and long-lasting stimulus input are proposed as internal algorithm. Functionalities of flapping wings and bilateral sensing antennae are identified for embodied intelligence. Real-time interaction of these resources with the environment is expected to solve complex CPT task. The embodied cognition proposal is first simulated in vision-based plume diffusion model to decouple nonlinearity of biological systems and plume diffusion entropy. This allows simulations under controlled environment to identify the significance of resources. The model is realized and optimized on autonomous agent using the Taguchi method because it (1) reduces the number of experiments using orthogonal array, and (2) identifies the significant factors.

Simulation result for resource perturbation of embodied cognition is consistent with those from experimental verification. This suggests good performance for source localization and time to source compared to previous studies. Results also suggest introduction of adaptive behavior without embodied intelligence is able to improve CPT performance. However, the magnitude of improvement is smaller compared to using embodied intelligence without adaptive behavior. Most importantly, the system performance is relatively the best when using both embodied intelligence and adaptive behavior. This suggests (1) embodied intelligence and adaptive behavior improves CPT performance when independently introduced to autonomous agent, (2) good sensory system based on embodied intelligence for CPT outweighs the importance of internal algorithm, and (3) real-time interaction among internal algorithm, embodied intelligence, and environment yields intelligent behavior in contrast to

simple algorithm of the agent. Thus, it is possible to use embodied cognition to replace complex internal algorithm for solving CPT problem. The contributions are (1) an inverse model for quantitative analysis of biological CPT behavior, and (2) a novel bio-inspired CPT model based on embodied cognition that solves the problem from multiple perspectives.