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Parasitic Robot System for Waypoint Navigation of Turtle

Dae-Gun Kim[1], Serin Lee[2], Cheol-Hu Kim[1], Sungho Jo[3], Phill-Seung Lee[1]

1. *Department of Mechanical Engineering*, *Korea Advanced Institute of Science and Technology* (*KAIST*), 373-1 *Guseong-dong*, *Yuseong-gu*, *Daejeon* 34141, *Republic of Korea*
2. *Institute for Infocomm Research*, 1 *Fusionopolis Way*, #21-01 *Connexis*, *Singapore*
3. *Department of Computer Science*, *Korea Advanced Institute of Science and Technology*, (*KAIST*) 373-1 *Guseong-dong*, *Yuseong-gu*, *Daejeon* 34141, *Republic of Korea*

Abstract

In research on small mobile robots and biomimetic robots, locomotion ability remains a major issue despite many advances in technology. However, evolution has led to there being many real animals capable of excellent locomotion. This paper presents a "parasitic robot system" whereby locomotion abilities of an animal are applied to a robot task. We chose a turtle as our first host animal and designed a parasitic robot that can perform "operant conditioning". The parasitic robot, which is attached to the turtle, can induce object-tracking behavior of the turtle toward a Light Emitting Diode (LED) and positively reinforce the behavior through repeated stimulus-response interaction. After training sessions over five weeks, the robot could successfully control the direction of movement of the trained turtles in the waypoint navigation task. This hybrid animal-robot interaction system could provide an alternative solution to some of the limitations of conventional mobile robot systems in various fields, and could also act as a useful interaction system for the behavioral sciences.

Keywords: parasitic robot, operant conditioning, waypoint navigation, red-eared slider, trachemys scripta elegans
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1 Introduction

Remarkable progress has been made in the development of robot technology. Many variations of robot products and machine systems are now used in numerous industries. Moreover, the need for robots has extended to almost every segment of society. Notably, in the defense sector and certain industries, demands exist for small mobile robots that can explore hazardous areas and dangerous environments, such as the scenes of accidents or disasters. However, small robots that can operate in inhospitable environments can only do so for a limited time and within a given range owing to battery limitations. The actuators and sensors of the robot can also be easily damaged or destroyed in harsh and humid conditions.

Therefore, researchers have strived to develop a means of controlling animals to make use of their locomotive abilities to perform particular tasks. Many animals have extraordinary means of locomotion that have evolved through natural selection over millions of years. Thus, their bodies are ideal for designing small mobile locomotion platforms. In this study, we examined the prospect of a hybrid animal-robot system.

Meanwhile, in recent years, there has been considerable interest in virtual reality and augmented reality through wearable computing. The commercialization of products from several companies has become imminent because of rapid technological advancements in the fields of sensors, displays, and computing. Nevertheless, with the technology available to date, it is difficult to completely deceive human senses. Humans are very intelligent and have highly attuned sense organs, making it nearly impossible to deceive all human senses with existing technology. On the other hand, lower-level animals are more dependent on virtual stimuli than humans. These lower-level animals react to virtual reality and assume it to be their reality, despite the existence of limited stimuli.

Several studies have shown that certain animals can effectively interact with virtual stimuli; accordingly, the application of an animal control system has been pro-

Corresponding author: Phill-Seung Lee
E-mail: phillseung@kaist.edu

posed. In some of these studies, the feasibility of a biorobot was demonstrated. In 1997, Holzer and Shimoyama connected the antennae of a roach, which are used to detect adjacent obstacles, to the output pin of an 8-bit μ-controller board. Thus, the roach movement was induced[1]. In addition, rats have been guided through the application of electric stimuli to the brain as cues and rewards[2–5]. For agricultural applications, a virtual fence system of sound stimuli used for restricting cattle movement was proposed[6]. Moreover, Harvey *et al*. recorded the behavior of mice on a virtual linear track. They showed that the mice could interact with a virtual reality device[7–9]. Furthermore, it was demonstrated that trained dogs could be guided by remote audio commands through wearable GPS unit control[10]. Lee *et al*. controlled the movement of a turtle by leveraging the characteristic obstacle avoidance capability of creature[11,12]. Meanwhile, Cai *et al*. modulated motor behaviors of pigeons by electric stimulation of specific neurons[13].

Studies have also been conducted for controlling rat movement through automation control. Zhang *et al*. developed an automatic control system for "rat-bot" navigation[14]. Gao *et al*. developed a rat-bot automatic navigation system based on a distance measurement in unknown environments[15]. Furthermore, Sun *et al*. applied the General Regression Neural Network (GRNN) algorithm for automated navigation of rat-bots by enabling automatic decision control[16].

As mentioned above, a training system can be developed to automatically control animal behavior using a particular virtual reality system. In this paper, we propose a "parasitic robot system" that mimics the behaviors of natural parasites. It is known that some parasites that live in the bodies of host animals can influence the host behavior to fulfill the specific objectives of parasite. Similarly, the proposed parasitic robot is attached to a target animal and invokes specific behavior through virtual stimulation.

We selected the turtle as the host animal because it can effectively sense visible light[17]. In addition, it is relatively intelligent and has long-term memory, which enables it to be trained to develop certain behaviors[18]. Furthermore, the turtle moves sufficiently slow to be easily controlled and observed. Moreover, its hard shell is an ideal surface for attaching the robot device.

We developed a parasitic robot for the turtle to achieve a waypoint navigation task in a water tank. We observed the parasitic robot and turtle interaction and recorded the extent to which the waypoint navigation performance of the parasitic robot is improved.

To this end, a heads-up display for the turtle was adopted as the virtual stimulator for navigation. The parasitic robot used a heads-up display (cue) and feeder (reward) to train the turtles to move in a certain direction of the heads-up display. The robot obtained the turtle pose information and waypoint position from an indoor monitoring system using wireless communication. All of the experimental tests were conducted in a water tank. The results validated the usefulness of the proposed concept system.

The remainder of this paper is organized as follows. Section **2** describes the concept of the parasitic robot and the experimental setup. In addition, details of the parasitic robot and turtle are presented. In section **3**, the experimental results are provided. In section **4**, we discuss the results and future work is described. In section **5**, conclusions of the study are presented and the contributions of this research are summarized.

2 Material and methods

We tested an example of the parasitic robot concept. In this study, the turtle was selected as the host animal and a parasitic robot was designed to induce the turtle to navigate between waypoints.

2.1 Parasitic robot system concept

Parasitism is a life form relationship between two organisms: one is a parasite, and the other is the host. A parasite lives inside or on the body of a host, either temporarily or permanently. It benefits from the host, such as by removing nutrients from the host to sustain itself and reproduce. Certain kinds of parasites can manipulate the behavior of the host to increase the probability of its own reproduction. For example, a three-spined stickleback (*Gasterosteus aculeatus*) infected with a bird tapeworm (*Schistocephalus solidus*) behaves in a way that increases its exposure to piscivorous (carnivorous) birds. This behavior enables the tapeworm to lay its eggs in the stomach of bird. The eggs are then widely spread through the feces of the bird[19]. Likewise, some parasites can change the behaviors of their hosts through special interactions.

Similarly, in the proposed concept of a "parasitic

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