Title of Project： Hierarchical Bio-Navigation Integrating Cyber-Physical Space

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【Purpose of the Research Project】

Our world is filled with the activities of animals, including humans, and artificial objects. "Hierarchical navigation" is the primary mechanism supporting biological and human society. In this project, we define "navigation" (how to reach a destination) as individual-level activity, "interaction" as a mutual influence among individuals and with the environment, and "hierarchical navigation" as the behavior of groups reaching destinations in a hierarchical manner (Fig. 1).

We will develop measurement devices and analysis methods to determine the essential components of hierarchical navigation and the causal relationships among the components. By creating a new academic field named "Hierarchical Bio-navigation," we aim to transform the methodology and technology for the behavior of organisms, including humans.
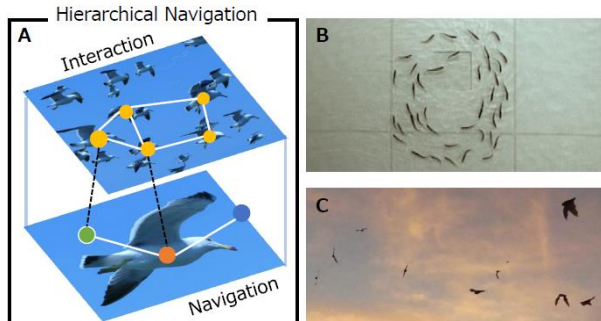

Fig. 1 Examples of various hierarchical navigation and a conceptual image of a behavioral diagram. Circles in A indicate various factors that affect navigation (e.g., food, destination, other individuals), B is a school of fish, and C is a group of bats flying in the sky. We also cover biological navigation of a wide variety of other species including nematodes and mice.

【Content of the Research Project】

The term "behavioral diagram" describes the causal relationship among the essential components of hierarchical navigation (Fig. 1A). For example, a bird searching for food may navigate by using cues such as the sun and smell, following its companion, and avoiding places where its natural enemies are waiting. However, it is not easy to answer which elements are essential and how each element interacts to influence behavior. Therefore, we will develop a research platform called "χ logbot" that seamlessly combines the latest measurement techniques and information science methods. The χ logbots are AI-driven logging robots that autonomously control behavioral measurements and interventions to understand hierarchical navigation. By attaching χ logbots to animals or installing them in the environment, we can automate the cycle of measurement of hierarchical navigation in physical space (real world), analysis of measured behaviors and selection of intervention strategies in cyberspace (on a computer), and actual intervention in physical space. Through this new experimental methodology, which we call "seamless CPS" (Cyber-Physical System), we realize a framework for refining behavioral diagrams by repeated construction and verification of mathematical and machine learning models.

【Expected Research Achievements and Scientific Significance】

The following main results are expected from this project. (1) Development of "χ logbots" will enable us to obtain information on hierarchical navigation of organisms with high accuracy. The development elucidates mysteries related to biological navigation, such as why migratory birds do not get lost and why fish can move in large groups. (2) The "seamless CPS" will enable us to validate various hierarchical navigation models and provide an informatics basis for analyzing information on the navigation of organisms, humans, and things. The method may lead to finding their unexpected commonalities and diversity. (3) By repeating the cycle of measurement, analysis, selection of intervention strategies, and actual intervention on the χ logbots, we will synergistically advance the respective fields of biology, engineering, and information science. In the future, the results obtained in this project can be applied to various social and engineering issues and also transform our "view of navigation."

【Key Words】

Hierarchical navigation: The behavior of interacting individuals and groups reaching a destination hierarchically.

χ logbots: Experimental robots that autonomously control measurements and interventions through functions such as "curious AI" and "causal reasoning." χ (Chi) stands for Curiosity/Causality-driven Highly Intelligent.

【Term of Project】FY2021-2025

【Budget Allocation】1,058,300 Thousand Yen

【Homepage Address and Other Contact Information】
https://bio-navigation.jp