【Grant-in-Aid for Transformative Research Areas（B）】

Chimeric Reconfiguration of Morphology, Motor Control, and Sensory Processing Reveals Latent Ultimate Intelligence in Insects

Principal Investigator	Tohoku University, Graduate School of Engineering, Associate Professor OWAKI Dai　Researcher Number : 40551908
Project Information	Project Number : 26B401　Project Period (FY) : 2026-2028 Keywords : Ultimate Embodied Intelligence, Chimerization, Design Biology, Arthropods, Standardization

Purpose and Background of the Research

●Outline of the Research

Animals adapt using limited resources such as morphology, motor, and sensory systems, yet this observable adaptability is only the “tip of the iceberg.” They also possess **Ultimate Embodied Intelligence (Fig.1 Left)**, a latent capacity that emerges under extreme conditions and exceeds normal limits. For example, a cricket missing three legs can still walk by exploiting its remaining limbs, revealing hidden adaptive abilities.

This project establishes **Design Biology for Ultimate Embodied Intelligence**, integrating biology, robotics, mathematics, and information science. We define this intelligence as self-organized, emergent behavior under novel body configurations or extreme environments. Through **Chimeric Reconfiguration (Chimerization)**—creating hybrid biological–artificial bodies—we aim to uncover new principles of ultimate intelligence. Using arthropods such as insects and centipedes, we replace or augment body, locomotor, and sensory components with artificial elements, enabling analysis of adaptive processes beyond natural evolution.

While such extreme adaptations have been viewed as anomalies, this research treats them as designable phenomena. “**Design**” refers to a framework in which chimeric interventions reproducibly reveal latent intelligence and its causal structure. We aim to establish **Design Biology** as a new discipline, advancing understanding of life and linking it to engineering applications.

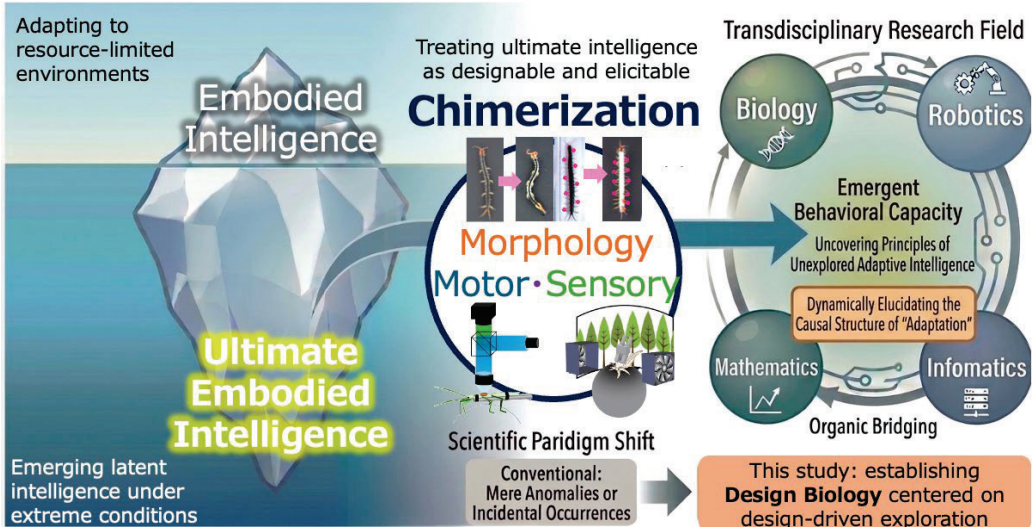

Figure 1. Concept of This Research Area

●Motivation for Our Research

This research field arises from a conceptual shift in using intervention and measurement technologies for biological behavior. Methods such as Motion Hacking, insect virtual reality (VR), ablation, neural blockade, optogenetics, and transplantation have been developed separately. By integrating them, we propose **Chimeric Reconfiguration (Chimerization)**, a unified framework to build hybrid biological–artificial systems in insects and centipedes.

This approach makes Ultimate Embodied Intelligence experimentally accessible and reproducible. We aim to establish a standardized, cross-disciplinary framework to study this extreme adaptive intelligence. Rather than relying on evolution, our vision is that such intelligence can be created through **Design**.

Expected Research Achievements

●Research Objectives and Methodology

Research Steps 1 & 2: Development

In **A01**, we study centipedes to develop body chimerization that alters morphology and degrees of freedom using prosthetics, revealing latent adaptability through behavior and a chimeric simulator to extract locomotion principles under extreme conditions. In **A02**, we combine Motion Hacking and muscle imaging to create motor chimerization by embedding artificial reflexes, enabling analysis of sensorimotor dynamics from muscles to inter-limb coordination. In **A03**, we use insect VR for sensory chimerization, integrating behavioral and electrophysiological data across species to identify shared and distinct principles of sensory integration, including effects of sensory deficits.

Research Step 3: Integration

Step 3 integrates body, motor, and sensory chimerization into a unified chimera arthropod platform, enabling experimental validation of how multiple forms of Ultimate Embodied Intelligence interact and co-emerge.

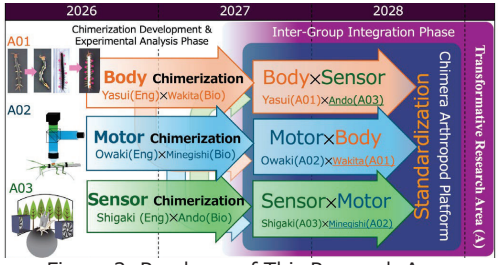

Figure 2. Roadmap of This Research Area

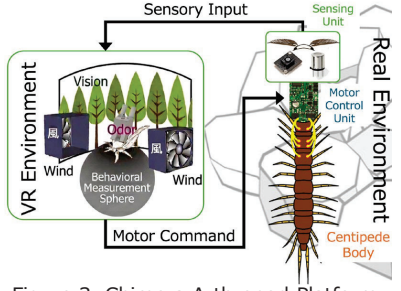

Figure 3. Chimera Arthropod Platform

●Expected Research Achievements

This research will have transformative impacts across domains:

- ✓ In robotics, Ultimate Embodied Intelligence will enable flexible, resilient systems for open environments, including applications in extreme settings such as disaster sites.
- ✓ By revealing self-organizing principles under chimeric reconfigurations, it will advance Embodied Ultimate AI, capable of generating strategies based on physical embodiment and context.
- ✓ In insect science, a chimeric arthropod simulator will support virtual reconstruction and design-based validation, with applications in pest control, pollination, and predicting behavior under climate change.

Website(s)	https://chimerization.jp