【Grant-in-Aid for Scientific Research (S)】

Comprehensive Data-driven Learning, Prediction and Generation of Whole-body Contact Motions based on Cyber-Physical Human Model

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Project Information	Project Number : 22H05002 Keywords : Motion optimization, Cyber-Physical Human, Humanoid, Learning	Project Period (FY) : 2022-2026

Purpose and Background of the Research

●Outline of the Research

In our daily life we naturally do such **complex contact motions** as "setting on a chair by placing hands on the table," "pushing a cart carrying heavy object," or "passing a narrow space with supporting contacts between body parts and handrail or walls." However, it is still a difficult problem for a humanoid to perform them automatically because **discrete changes of contact constraints are applied to dynamic continuous motions** of a complex anthropomorphic system, making the possibility of combined motions increase exponentially. In contrast, Humans are supposed to generate **optimal contact motions** among numerous possibilities based on **their somatic sensing and accumulated experiences**.

This research aims at solving this problem by approaching from the both aspects of **model-based robotic analysis** and **machine learning** and revealing the **underlying mechanism of contact motion** so that a humanoid can **automatically synthesize** such motions.

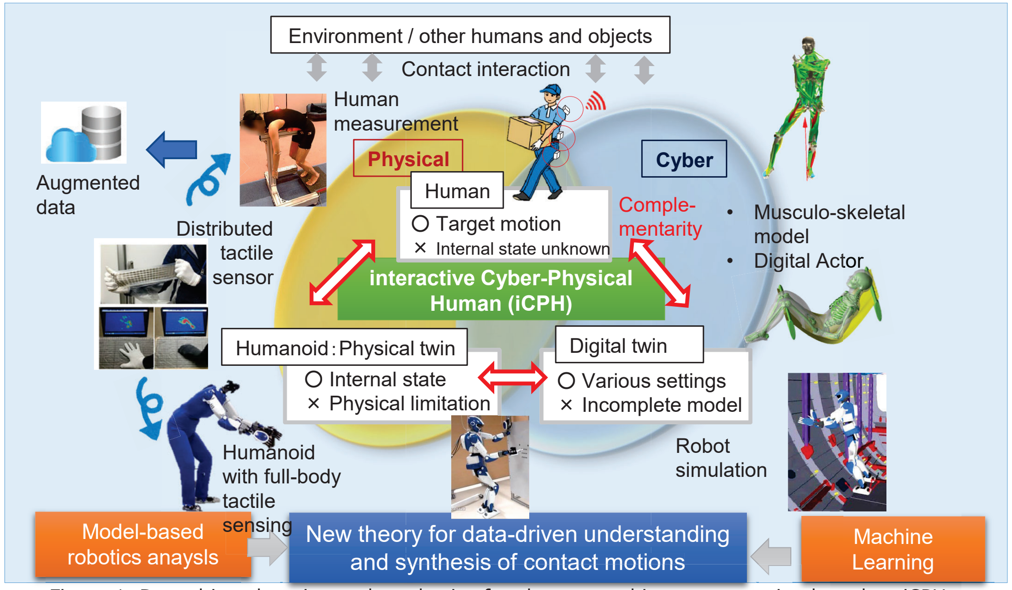

Figure 1. Data-driven learning and synthesis of anthropomorphic contact motion based on iCPH

●Data acquisition and utilization by interactive Cyber-Physical Human (iCPH)

Internal control signal of humans is still hardly measurable. Humanoid robots and digital actors can therefore be leveraged together in a complementary manner as iCPH that provides richer data of contact motions by augmenting them with simulations and experiments.

Expected Research Achievements

In this research, we plan to (1) collect data by iCPH and devise a **generic descriptor** of contact motions, (2) develop methodology for continual learning of **contact motion network** connecting successful motions and (3) establish a framework to synthesize various contact motions by extracting **symbols** expressing motions like a high-level language system. With those findings we tackles challenges such as understanding human motion strategy and automatic generation of humanoid contact motion in unknown environments (Figure 2).

(1) Data collection by iCPH and proposal of "general descriptor"

Humans' contact motion data are collected by using such devices as distributed tactile sensors (Figure 1). The iCPH will be utilized to augment data through simulation with digital twin and to experimentally validate the research with a humanoid as physical twin. Along this line, a **generic descriptor of contact motions for anthropomorphic systems** is derived.

(2) Continual learning of "network" of successful contact motions

By applying "model-based" analysis to the data, we estimate "optimization cost function" bringing contact motion transition. Through a compact expression combining this cost and (1) descriptor, a network of successful contact motions shall emerge. The **efficient optimization computation** that we developed in our past Kakenhi serves as a **bridge between machine learning and model-based analysis** towards **continual learning of contact network**.

(3) "Symbols" for predicting and synthesizing contact motions by symbols

We extract **symbols** from the network by further abstraction of contact motion, which compose a sort of **language system**. We aim at building an intelligent system **predicting future situations** and **synthesizing optimal contact motions** by combining the symbols.

Expected outcome include disclosure of data and application to societal or industrial issues such as difficult-pose tasks by humanoids in large-scale assembly, physical load monitoring of workers, or remote human-robot collaborative contact tasks by avatar in virtual space.

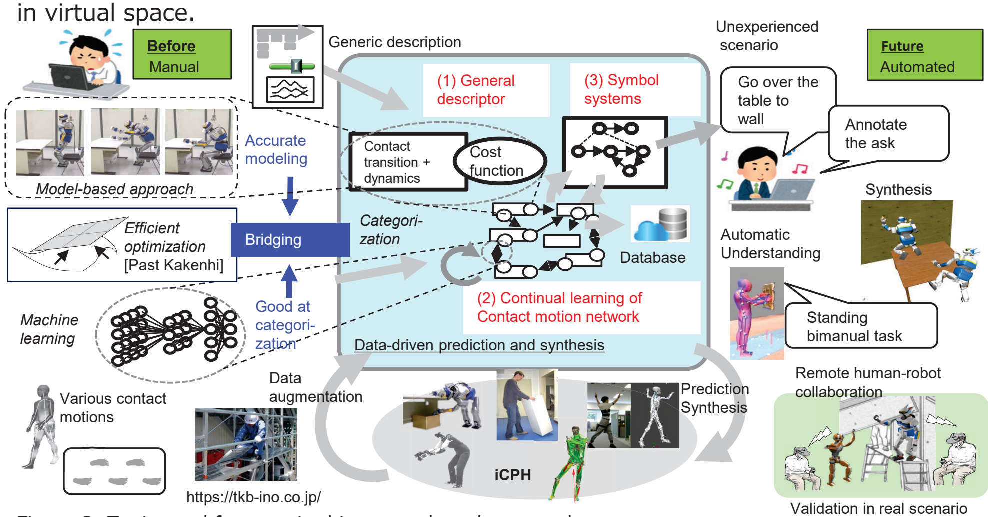

Figure 2. Topics and features in this research and expected outcomes

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