Technology that supports dish washing with kitchen robots

1. Overview

The Tokyo University IRT Research Agency has developed a technology that supports dish washing using "kitchen robots." This is one of the core technologies for robots that will support housework and long-term care in Japan's aging society.

2. Details

Since 2006, the University of Tokyo, Toyota Motors Corp., Olympus Corp., Sega Corp., Toppan Printing Co. Ltd., Fujitsu Laboratories Ltd., Panasonic Corp., and Mitsubishi Heavy Industries Ltd. have been participating in the "Special Coordination Funds for Promoting Science and Technology" project, which is supported by the science and technology incentive funds offered by the Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan. The "IRT Foundation to Support Man and Aging Society" project was conceived by President Komiyama, University of Tokyo. This project aims at conducting R&D

activities and developing significant innovations in the next 10 to 20 years. The Tokyo University IRT Research Agency (Director: Isao Shimoyama), which is the leading agency in the implementation of this project, in collaboration with Panasonic Corporation, has developed a kitchen robot that supports dish washing using a dishwasher, while carefully handling dishes placed in the kitchen, by integrating robot technologies into a kitchen environment.

The aging society in Japan is expected to be characterized by an increase in households where housework represents a significant burden; for example, single-person households, or households with seniors requiring long-term care. By reducing the burden of cleaning up dishes after a meal, the recently developed technology will enable people to devote more time to caring for seniors or children, working, or other activities, thereby contributing to the support of housework and long-term care in an aging society. "Cleaning up dishes after a meal" can be divided into four main processes: transporting dishes (clearing the table); disposing of leftovers; washing dishes; and putting dishes away. The newly developed technology for handling dishes is an important elemental technology essential to all four of these processes. In addition to supporting dish washing, as presented here, this technology can be used to automate many other processes, including putting dishes away in cabinets.

This new technology for handling dishes is comprised of two main technologies: (1) a real-time information feedback control technology for information obtained from multiple sensors; and (2) a manual search manipulation technology that uses MEMS touch sensors and an end effector with multiple types of sensors built in.

○ Outline of technology for handling dishes

(1) Real-time information feedback control technology for information obtained from multiple sensors

In order to enable robots to handle dishes and other fragile objects without breaking them, those robots must be able to respond instantaneously to touch information sent from multiple types of sensors, and adjust its actions accordingly. One method of achieving a rapid response is a configuration method in which the robots are programmed to execute a specified action reflexively when a given piece of sensory information is obtained.

Because the systems controlling the actions are frequently interchanged, however, it is difficult to describe the actions required to achieve high-level goals such as cleaning up dishes after a meal. In the case of actions with task goals like cleaning up dishes after a meal, the sensory information to be focused on is limited, so an effective method is to have a facilitator that controls the actions monitor the sensory information in parallel as required, and to gather information while making judgments on the actions to be executed. We have developed a software configuration method for accomplishing complex tasks using the following approach: Processes that requires fast, simple responses are processed in parallel with a separate thread; comprehensive judgments are made based on information with a wide scope of both time and space; and actions are planned accordingly.

(2) Manual search manipulation technology that uses MEMS touch sensors and an end effector with multiple types of sensors built in

By using an end effector with multiple types of sensors built in, we have achieved a manipulation technology that handles dishes with "manual search" by effectively utilizing the unique characteristics of individual sensors. Before the robot touches the dishes, object surface information is obtained using a proximity sensor, and after the dishes are touched, strength information is obtained using pressure sensors and MEMS touch sensors. In the past, strength information was obtained using 6-axis sensors in the wrist, but there was significant error due to hand movement and the effects of weight, and this factor had a negative effect on accurate movements. MEMS touch sensors can measure strength in both vertical and shear directions, so it is possible to adjust the grip strength to control slipping of the gripped object and also adjust the pressing, thus achieving actions that trace the surface of the object.

MEMS touch sensors are comprised of 2 cm x 2 cm ultra-compact MEMS 3-axis touch sensor chips embedded in a flexible rubber material. The University of Tokyo and Panasonic Corporation jointly developed MEMS touch sensors in which each individual sensor can measure weight with an accuracy of 0.3 g. These sensors won the "Most Outstanding Robot" award in the "This Year's Robots" awards sponsored by the Japanese Ministry of Economy, Trade and Industry.

Reference: http://www.robotaward.jp/prize/01/ [in Japanese only]

(Note 1) "Creation of IRT Platforms to Support People in an Aging Society" Project

Japan is relatively advanced in these issues , and its aging and shrinking population is becoming an issue for the whole society, including not only the generation in need of nursing care, but also those about to retire, and those of working age through to children. In an aging and shrinking society , there are many causes of concern, such as labor shortage due to declining numbers of workers, increasing health concerns and social security costs due to increasing number of seniors, increasing domestic workload due to increasing single-person and elderly households, and increasing nursing-care workload due increasing number of people requiring nursing care. The use of robots will aid in addressing these concerns.

The creation of the "new industries in support of people and society" through the collaboration of universities and industries holds great promise for the introduction of household robots. By integrating IRT with the Social Sciences, the "IRT Foundation to Support Man and Aging Society" project will create new innovation to support people and society and help Japan maintain its level of prosperity in light of an aging and shrinking population.

The goal of this project is to produce leading-edge, joint creations and new industries through collaboration between industries and universities, to follow after automobile and computer industries.

(Note 2) According to the Basic Science and Technology Plan, an innovation is defined as a new thing or method that brings about new social and economic value by combining scientific discoveries and inventions, paving the way for further developments. (Ref: MEXT homepage http://www.mext.go.jp/a_menu/kagaku/kihon/main5_a4.htm）

3. Contact Information

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TEL: +81-3-5841-1625   E-mail: IRT-office@irt.i.u-tokyo.ac.jp
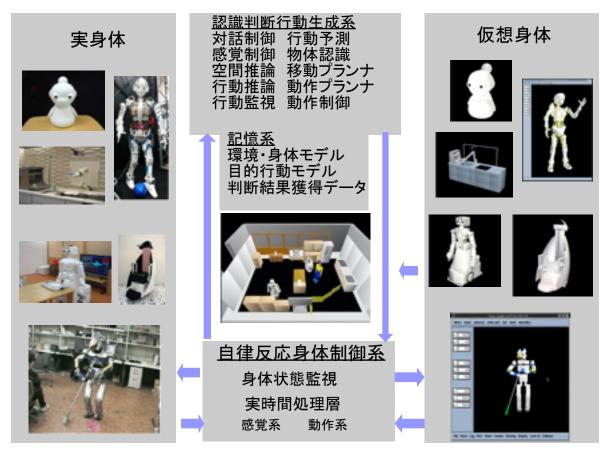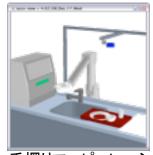URL: http://www.irt.i.u-tokyo.ac.jp

報道発表用画像

東京大学
THE UNIVERSITY OF TOKYO

(技術解説資料)

(1)多種センサ情報の実時間フィードバック制御技術

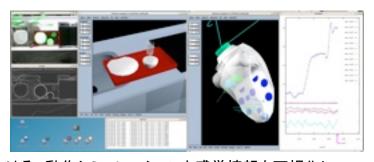## 1-1) ロボットを記述し認識行動制御を行なうソフトウェア

多種のロボットの仮想身体形状，構造，感覚系，動作系を記述する仮想身体とその実身体の両方を共通に操作する高機能記述ソフトウェア環境. 高機能ソフトウェアと実時間制御システムとの連携機能を備えたIRT基盤ソフトウェア環境.

実身体

認識判断行動生成系
対話制御　行動予測
感覚制御　物体認識
空間推論　移動プランナ
行動推論　動作プランナ
行動監視　動作制御

記憶系
環境・身体モデル
目的行動モデル
判断結果獲得データ

仮想身体

自律反応身体制御系
身体状態監視
実時間処理層
感覚系　　動作系

1-2) ロボット行動シミュレーション及びオンラインモニタリング環境

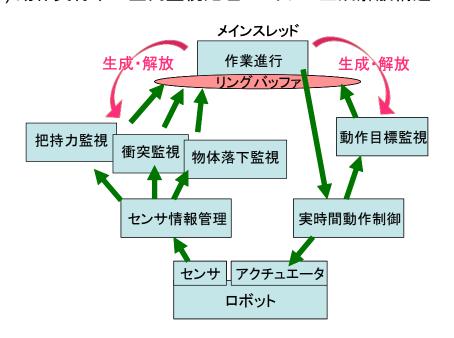
手探りマニピュレーションにおける，動作シミュレーションと感覚情報を可視化しオンラインでモニタリングするシステム記述例

1-3) 多種センサ情報の実時間フィードバック制御のためのシステム構成

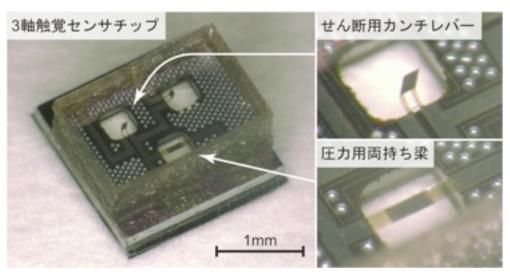メモリ自動管理機能を備えた環境・行動の三次元モデルを利用する高レベル処理記述層と，ロボット身体上の多種センサ情報に基づく感覚動作の実時間処理記述層を連携可能な形で統合し，高レベルの実時間フィードバック制御が可能

幾何モデル　センサシミュレーション
物体発見　形状認識　動作計画生成
手探りセンシング
分離操作生成
センサ監視
接触力制御
センサ情報管理
フィルタリング
センサ情報取得
動作制御
（RTLinuxリアルタイム空間）
センサ情報取得　位置制御
カメラ　H8マイコン　センサ　アクチュエータ
器用なハンド
ロボットハードウェア

1-4) 動作実行中の並列監視処理スレッドの生成解放構造

メインスレッド
作業進行
リングバッファ
生成・解放　生成・解放
把持力監視　衝突監視　物体落下監視　動作目標監視
センサ情報管理　実時間動作制御
センサ　アクチュエータ
ロボット

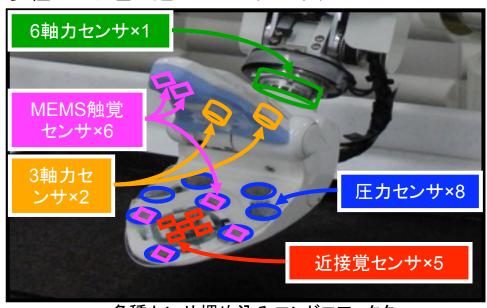行動シミュレーション，動作感覚系オンラインモニタリング機能を備えたIRT基盤ソフトウェアにおける，動作実行中にさまざまな監視機能を必要に応じて生成管理する機能

(2)MEMS触覚センサ及び多種センサ埋込エンドエフェクタによる 手探りマニピュレーション技術

2-1) MEMS触覚センサ

直立したピエゾ抵抗カンチレバーを柔軟ゴム材料に
埋めた超小型MEMS3軸触覚センサチップ

2-2) 多種センサ埋め込みエンドイフェクタ
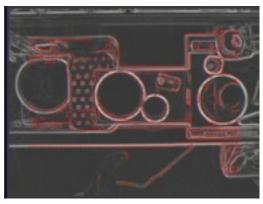

多種センサ埋め込みエンドエフェクタ

2-3) 標準食器の手探りマニピュレーション

食洗機用標準食器：透明なコップ，白いお椀と白い皿で，食洗機に何枚入るかを調べるための食器．

透明ガラス，反射などのため視覚では食器のおおよその初期位置のみを認識し，その後は手の感覚で手探りで確認をしながら食器を操作（マニピュレーション）する

2-3-1) 画像による食器の発見，初期位置の認識

上から見たカメラ画像

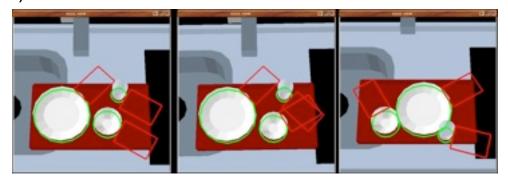境界線の局所方向検出画像

トレイ領域内の標準食器の候補を検出
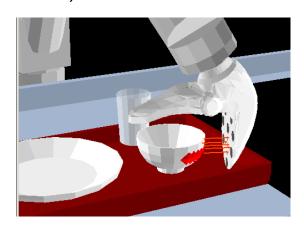

標準食器の幾何モデルの
初期配置予想認識結果

2-3-2) 食器の把持アプローチ方向の計画

食器を把持するために手を近づけることが可能な方向を見つける

2-3-3) 近接センサによる食器の形状ならい

各近接覚センサの計測距離情報に応じて食器の表面に沿ってロボットを動かし、食器表面形状情報を獲得

2-3-4) 食器の高さ確認，把持確認，設置確認

各動作における各種埋め込みセンサの利用：
接触アプローチ（左）、把持確認（中）、把持物体ごしの設置確認（右）

(技術解説資料)

2-3-5) 3種類の標準食器を食洗機へしまい，食洗機を操作する

1) 食器配置認識	2) お椀を確認	3) お椀を把持
4) お椀をすすぐ	5) お椀を置く	6) 次を見る
7) コップへ近づく	8) コップを置く	9) 皿へ近づく
10) 皿を持ち上げる	11) 皿を置く	12) トレイを押す
13) 扉を閉める	14) スイッチを押す	15) 完了・待機