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RIKEN (The Institute of Physical and Chemical Research)

Tokai Rubber Industries, Ltd.

## **Realization of Transfer Operations by Nursing-care Assistant Robot “RIBA”**

**- Significantly reduces the burden of nursing-care utilizing the robot that can gently lift up a person-**

### **Key points of the research achievements**

- **We have developed a robot which realizes a series of transfer operations including lifting up a person weighing 61 kg from a bed or a wheelchair, transferring and setting down.**
- **The robot is able to respond flexibly to changes of position and posture of care receivers and environment by operating through the tactile sensors.**
- **We have adopted new technologies including the high rigidity interference drive system and the high strength resin material.**

RIKEN-TRI Collaboration Center for Human-Interactive Robot Research<sup>\*1</sup> (RTC, Director of RTC: Shigeyuki Hosoe), established in 2007 by RIKEN (President: Ryoji Noyori) and Tokai Rubber Industries, Ltd. (TRI, President: Yoshiaki Nishimura), has developed a nursing-care assistant robot named RIBA (Robot for Interactive Body Assistance). RIBA is the first robot developed in the world to reduce the burden of nursing-care by performing a series of transfer operations<sup>\*2</sup> including lifting up a person from a bed or a wheelchair, transferring and setting down using human-like arms. This result has been achieved by RTC as a whole especially by Toshiharu Mukai, team leader of RTC Robot Sensor Systems Research Team, and Shijie Guo, team leader of Advanced Soft Devices Research Team.

The Japan's aging society with a falling birthrate has led to growing social concerns over a shortage of caregivers in the future. There are high expectations for utilization of the robot technology to cope with this nursing-care problem. Especially, transferring a person between a bed and a wheelchair is physically a hard work and required many times in a day. As a result, many caregivers suffer from back pain. Nursing-care facilities consider that reducing the burden of transfer operation is one of the important issues to be solved.

RIKEN developed a robot called RI-MAN in 2006, aiming to lift up a person. However, with insufficient RI-MAN's safety, payload, degree of freedom of its joints and motion accuracy, RI-MAN could actually lift up a doll weighing maximum 18.5 kg that was placed in a predetermined position.

RTC succeeded the achievements of RI-MAN research and integrated control, sensor and information processing technologies of RIKEN with material and structural design technologies of TRI to develop a nursing-care assistant robot RIBA, having characteristics including payload<sup>\*3</sup> with one of the world's highest tare weight ratios<sup>\*3</sup> achieved by using the newly developed high rigidity interference drive system and high strength resin, the robot operation function using the high accuracy tactile sensors widely covering RIBA's arms, and the distributed information processing that enables a whole robot controlled motions due to high speed information processing. Furthermore, with soft materials including urethane foam and molding technologies developed by TRI, RIBA's entire body including its joints is covered with soft covering to enhance safety. As a result of these achievements, RIBA can transfer an actual person (weighing 61 kg or less, currently).

RTC will further promote our research on a nursing-care assistant robot based on RIBA, use RIBA in the monitor trial in nursing-care facilities within a few years to organize issues, and commercialize RIBA through TRI. RTC hopes that our robot technology contributes to the aging society.

## 1. Background

With the country's aging society with a falling birthrate, the number of elderly people is increasing and the shortage of caregivers is becoming more serious. To make up for this shortage, there are high expectations for robot technologies. Especially, transferring a person between a bed and a wheelchair is physically a hard work and essential, but required many times in a day. In a nursing-care facility, one caregiver has to do this work about 40 times a day. Consequently, many caregivers suffer from back pain.

In 2006, RIKEN has developed RI-MAN, aiming to lift up a person (News released on March 13, 2006. <http://www.riken.jp/r-world/info/release/press/2006/060313/detail.html>). However, since RI-MAN still had unsolved issues including safety, payload and degree of freedom of its joints and motion accuracy, RI-MAN could only lift up a doll weighing maximum 18.5 kg that was placed in a predetermined position.

RIKEN and TRI has established RTC on August 1, 2007 in order to develop the "human-interactive robot that directly contacts with humans" for practical use by succeeding the achievements of RI-MAN research and integrating control, sensor and information processing technologies of RIKEN with material and structural design technologies of TRI. Putting a robot into practical use requires knowledge in many fields. RTC concentrates knowledge from different fields for our research and development to realize the robot that contributes to the society.

## 2. Research method and achievements

The research team aimed at developing a robot that can lift up an actual human based on the RI-MAN's research achievements in order to realize a practical nursing-care assistant robot. Therefore, the team reviewed all aspects including material, structure, information processing system, sensor, operation method and design to develop the nursing-care assistant robot RIBA (Fig. 1) that ensures safety, power and ease of operation to interact with actual humans.

### (1) Material

Although metal is used for most of the structural materials, high strength resin is used for forearms, taking future weight reduction and productivity into consideration. This helped reduce the weight of the forearms one-half with same strength. In addition, enhanced safety has been realized by covering the entire body including its joints with soft materials

### (2) Structure

Although RI-MAN could only lift up a doll weighing 18.5 kg, RIBA can lift up an actual person weighing 61 kg even though its weight is 180 kg (including a battery). This has been achieved by performing the structural analysis and concentrating on strengthening the necessary parts. This means that RIBA achieved one of the world's highest payloads with tare weight ratio 0.33. Another point that should be stressed is that the high rigidity interference drive system adaptable for heavy weight is developed by modifying the interference drive system<sup>\*4</sup> used also for RI-MAN.

RIBA's movement mechanism has omni-directional wheels that can turn in any direction, enabling RIBA to move in a small space, including in nursing-care facilities and hospitals.

### (3) Distributed information processing

The research team has further modified the distributed information processing through the networks in a robot that was also used for RI-MAN. Increasing the speed of the compact information processing boards (Fig. 2) embedded in various parts of the robot realized the advanced processing. For example, RI-MAN took approximately 15 ms (millisecond: one millisecond equals  $10^{-3}$  second) to process one piece of a tactile sheet (64 elements). On the other hand, it takes only 1 ms for RIBA. This enables more complicated information processing at each place including arms and chest so that the robot as a whole can perform advanced operations.

### (4) Sensor

Although the tactile sensors were installed only inside of RI-MAN's arms, the sensors cover all around the arms of RIBA (Fig. 3) so that they can contact with a lifted person in any angle and the rest of the sensors can be used by the operator for robot operation.

With the improved vision and auditory capabilities, RIBA can recognize operator's voice and face and moves his face toward the operator while moving in the direction of the operator.

### (5) Collaboration between a human and a robot to cope with situations flexibly

With the current technology, it is difficult for a robot to fully automatically transfer a person from one place to another in various environments where people interact. Therefore, the collaboration work system is adopted in which an operator perform recognition and judgment which humans are good at and a robot performs heavy physical work. The robot autonomously works to the extent possible. However, the operator can adjust robot movements and assure entire safety. As it is difficult to order details with regard to the position and posture of the robot having many joints through voice or a remote controller, the research group has developed the "tactile guidance" (Fig. 4) with which the operator's intention can be communicated by directly touching the tactile sensors embedded in the robot and pulling the robot in a desired direction. This realized the intuitive robot control without having any dedicated device.

### (6) Design and quietness

For the actual situation where robots are used, they need to have looks to be acceptable to users. Machinelike is not suitable for the nursing care field. However, a robot half-way similar to a human may look weird. Based on these reasons, the research group adopted the friendly design like a stuffed bear. Additionally, quietness has been largely improved by considering the structure, material and control method. Specifically, when RIBA lifts up a person in the position one meter from its front and one meter high, its operation noise has been reduced to 53.4 dB(A) <sup>\*5</sup> (60.0 dB(A) for RI-MAN). This is the acceptable level for a hospital waiting room.

By integrating these technologies, the research team has completed the nursing-care assistant robot RIBA that boasts payload with one of the world's highest tare weight ratios and has the operation function with the high accuracy tactile sensors covering wide range of the arms, whole body manipulation <sup>\*6</sup> and distributed information processing function. As a result, RIBA can perform transfer operations for an actual human (weighing 61 kg or less, currently) (Fig. 5).

### 3. Expectations in the future

We will continue developing a nursing-care assistant robot based on RIBA in the future. In addition to the transfer operations, the research team has already started studying application to the rehabilitation where force is exchanged between a human and a robot. The team aims to develop the robot that is easier to use by promoting our research to create a robot that can carry heavier object with safety and can deal with various situations, and by increasing its autonomy in accordance with the technological advances. We also plan to increase ease of maintenance and productivity, use RIBA in the monitor trial in nursing-care facilities within a few years to organize issues and commercialize RIBA through TRI. RTC hopes that our robot technology contributes to the aging society.

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## <Footnotes>

### \*1 RIKEN-TRI Collaboration Center for Human-Interactive Robot Research

RIKEN and TRI established this collaboration center on August 1, 2007 based on the system called “Research Collaboration with Industry Program” set by RIKEN in 2007. The collaboration center is working toward practical use of the “human-interactive robot that directly contacts with humans” that is actively integrated into nursing care fields by succeeding the achievements of the human life assistant robot RI-MAN. With knowledge on the motor systems control theory and sensing theory of RIKEN and new functional material technology and know-how of commercialization combined of TRI, our research should help overcome the shortage of caregivers through science and technology.

### \*2 Transfer operations

In the nursing care field, moving from one place to another, for example, from a bed or floor to a wheelchair or from a wheelchair to a toilet seat (or the other way around) is called transfer operation. At a facility that RTC surveyed, one caregiver performed an average of total nine transfer operations a day for one care receiver: three times for meals, once for a snack and once in two days for the bath. Additionally, since one caregiver takes care of about five care receivers, he/she performs more than 40 transfer operations a day. This imposes physical strain that is one of the main reasons for back pain.

### \*3 Tare weight ratio and payload

The tare weight ratio is a value comparing robot weight itself with payload. Which part of the robot has to be included differs. In the case of RIBA, weight of parts necessary for operating the robot as an autonomous system including a battery and computer is included in the tare weight.

In general, the payload of a carrier is the weight of things that it can carry. However, definition of “capability of carrying things” depends on the robot functions. The payload described in this article is used for operations of lifting up a person from a bed or a wheelchair, transferring and setting down to a bed or a wheelchair.

### \*4 Interference drive mechanism

As for the RIBA’s arm joint, differential motion of two motors utilizing the bevel gear mechanical has enabled a set of two bending and twisting movements. This mechanism can output force of two motor torque combined when either one of the bending or twisting movement is required so that RIBA can show its competence when raising its arms and bending and stretching elbows that requires a great deal of power for lifting operation. Since each arm has three sets of this mechanism, which equals to six motors in total, and by driving them, small but high output powered arm movements are realized.

### \*5 dB(A)

The perceived magnitude of a stimulus of a human is proportional to the logarithm of the physical stimulus intensity. The human perception of sound differs depending on frequency. dB(A) is a unit of expressing the magnitude of sound taking the above into consideration and is widely used to express noise.

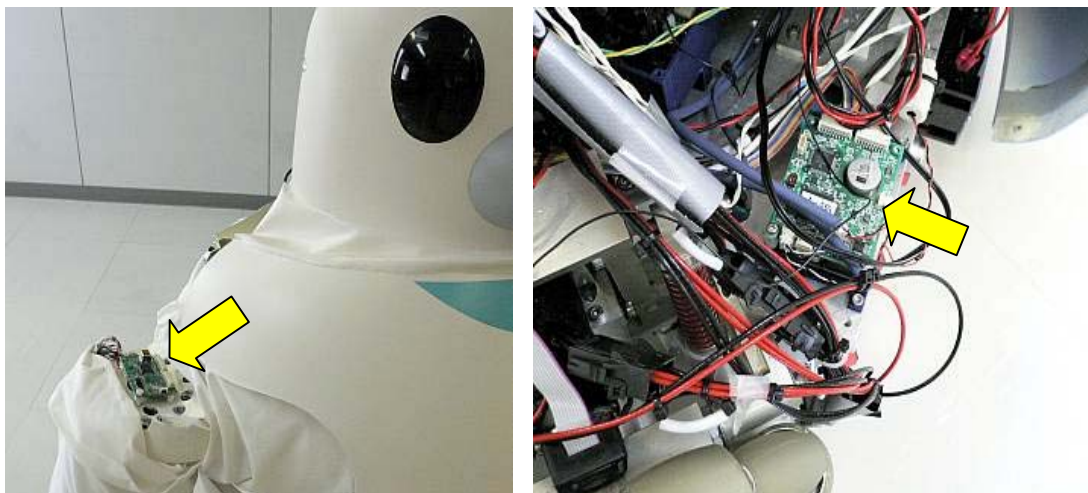
### \*6 Whole body manipulation

Normally robots use finger tips called robot hand to operate objects. In contrast, the whole body manipulation uses not only the finger tips but also the whole body including forearms, upper arms and chest to operate objects. Although the whole body manipulation requires new element and control technologies including tactile sensors, it can produce greater output than the manipulation only with robot hands.



**Fig. 1 RIBA**

RIBA is approx. 140 cm tall, weighs approx. 180 kg (including a battery) and has a winsome appearance. RIBA's whole body is covered with soft materials including urethane foam. The degrees of freedom for each arm is 7, 3 for head (currently, only 1 is used), and 2 for waist. RIBA moves with the base which has omnidirectional wheels.



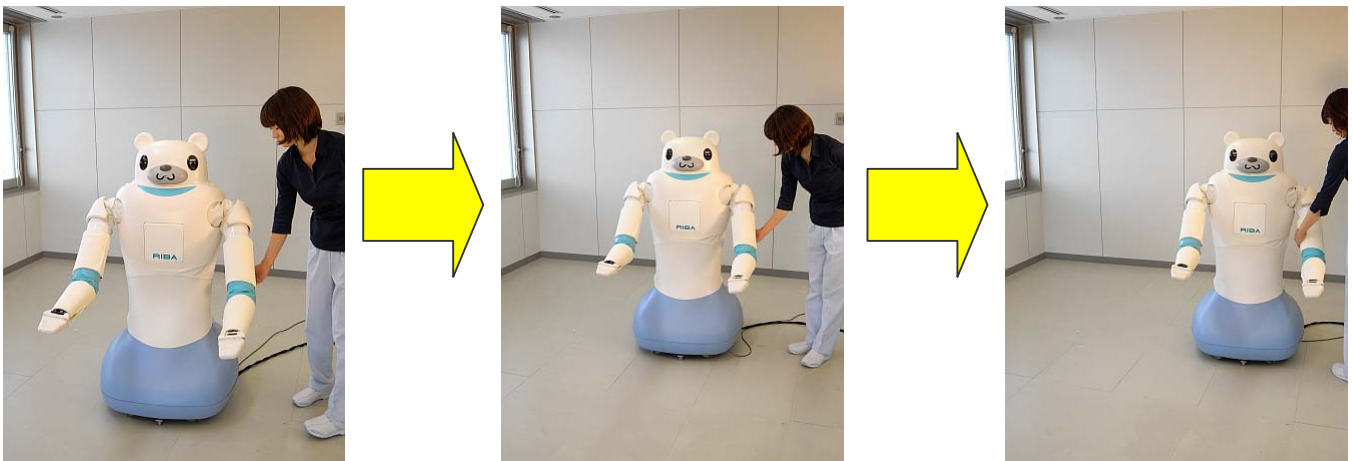
**Fig. 2 Compact information processing boards embedded in RIBA**

More than 20 pieces of this compact information processing board are embedded in RIBA to configure an internal network. Distributed processing contributes reduction of load on personal computers and simplification of wire routing.



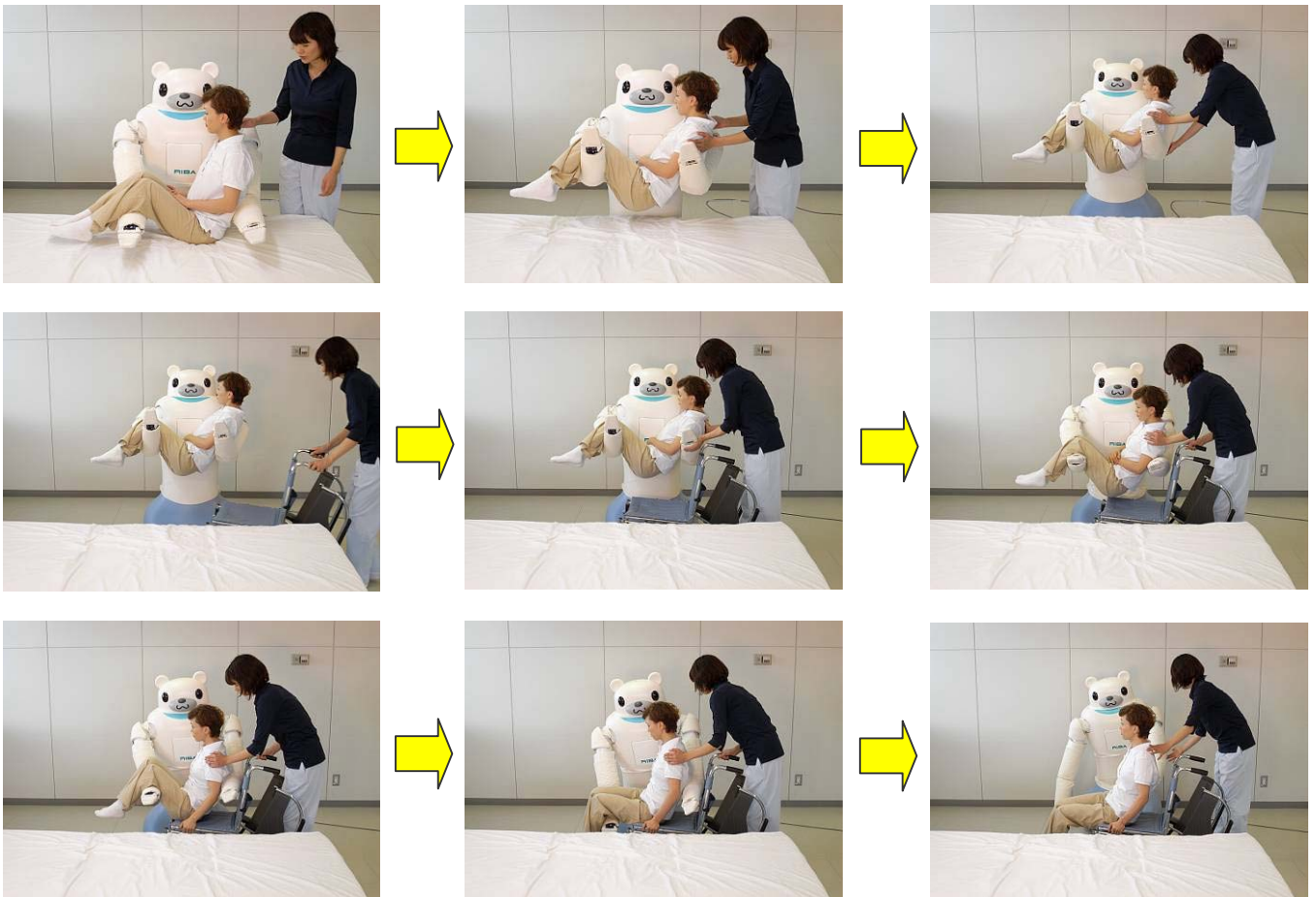
**Fig. 3 Tactile sensors covering all around the arm**

The sensors can detect load distribution of a lifted person and operator's intension.



**Fig. 4 Tactile guidance**

An operator can operate RIBA to move and lift up a person by touching the tactile sensors and pulling RIBA in a desired direction.



**Fig. 5 RIBA holding a person**

RIBA can lift up a person from a bed or a wheelchair, transfer and set down a person.