Design of Novel Feeding Robot for Korean Food

Won-Kyung Song[1], Jongbae Kim[1], Kwang-Ok An[1], In-Ho Lee[1], Won-Jin Song[1], Bum-Suk Lee[2], Sung-Il Hwang[2], Mi-Ok Son[2], and Eun-Chang Lee[3]

[1] Research Institute, National Rehabilitation Center, 520, Suyu5-dong, Gangbuk-gu, Seoul, 142-884, Korea
wksong@nrc.go.kr, jbkim@nrc.go.kr, anko04@korea.kr, lio3596@korea.kr, swjli@naver.com
[2] National Rehabilitation Hospital, National Rehabilitation Center, 520, Suyu5-dong, Gangbuk-gu, Seoul, 142-884, Korea
iambs@nrc.go.kr, nrchsi@nrc.go.kr, sonmiok33@yahoo.co.kr
[3] DesignTV, 1 Fl. 451-5 Dogok-dong, Gangnam-gu, Seoul, 135-855, Korea
thedesigntv@gmail.com

Abstract. During mealtime, a feeding robot allows a person with upper limbs disability to enjoy chosen food with desired time intervals. Although many feeding machines are developed and commercialized over the world, Korean consumers are still hard to find a feeding robot that can handle the Korean food with boiled rice. In order to handle those kinds of food, we design a novel feeding robotic system that consists of two robotic arms: one is a food grasping robotic arm, and the other is a food transferring robotic arm. We expect that the proposed feeding robot could provide easy handling the Korean food with general bowls. In addition, when one caregiver supports the multiple persons, one part of feeding robots, i.e., a transferring robot, could be effectively applied in facilities or hospitals.

Keywords: Feeding Robot, Assistive Robot, Dual-Arm, Eating.

1 Introduction

Improving independence of growing weaker members of a society is one of crucial issues for the quality of life. Specifically, the disabled people who officially registered in Korea are already over two million, i.e., 4.5 per cent of total Korean population, due to illnesses, injuries, and natural aging processes [1]. More than one third of the disabled people are the elderly persons. In addition, the elderly people in Korea are over 10 per cent due to decreasing the birthrate and lengthening the span of their life. Effective caregiving is strongly required within restricted resources. An assistive robot could be one of solutions to tackle that problem in the activities of daily livings.

A caregiver should physically contact the disabled in several caregiving tasks such as changing their clothes, repositioning their posture, transferring, having a meal, bathing, and rehabilitation. These tasks are well known tasks for activities of daily living. Among these activities, having a meal is one of basic activities and this task could be replaced with an available technology if someone prepares a meal for a user.

Y. Lee et al. (Eds.): ICOST 2010, LNCS 6159, pp. 152–159, 2010.

Various assistive robots have been developed since late 1980s. Handy 1 [2] is an assistive robot for the daily activities like eating, drinking, washing, shaving, teeth cleaning and applying make-up. Handy 1 consists of a five DOF (degrees of freedom) robot, a gripper and a tray unit. The major function of Handy 1 is eating. Handy 1 allows a user to select food from any part of the tray. A cup is attached in order to drink water with their meal. The walled columns of a food dish make an important role to scoop the food on the dish.

Winsford feeder [3, 4] is a mechanical system for the self-feeding. Winsford feeder uses a mechanical pusher to fill a spoon and a pivoting arm to raise the spoon to a user's mouth, i.e., a preset position. A rotation of the plate places more food in front of the pusher. The user can choose two input devices: a chin switch and a rocker switch.

Neater Eater [5] has two types: a manual operation type and an automatic operation type. Neater Eater consists of the two degrees of freedom arm and one dish. Couples of foods could be mixed on the one dish. The manual type that has damping factor could be used to suppress the tremor of upper limbs while a user eats food.

My Spoon [6] is suitable to deal with Japanese food. My Spoon consists of a 5-DOF manipulator and a gripper with a meal tray. The meal tray has four rectangular cells. My Spoon combines several preprogrammed motions: automatic operation, semi-automatic operation, and manual operation. The semi-automatic operation allows a user to choose food. The manual operation can change a grasping position on the food as well. The input device could be selected among the chin joystick, the reinforcement joystick, and the switch. The end-effector of a robotic arm has one spoon and one fork that make the grasping motion. While the robot grasps food, the gap between a spoon and a fork changes and thus the end-effector grasps the food. Then, the robot moves to the preset position, and the fork that is located on the spoon moves backward to provide a user with food on a spoon.

Meal Buddy [3] uses a three-DOF robotic arm and three bowls which can be mounted on a board by magnetic attraction. After this system scoops the food, the robotic arm scrapes the surplus food off the spoon by the rod on bowls.

Mealtime Partner Dining System [7] locates in front of the user's mouth. Three bowls can rotate around the user's mouth. The spoon picks up the food, and then moves the preset location with short travelling distance. This system reduces the slip chance of wet food because the spoon's bottom wipes out after scooping. The user does not need to lean toward the feeder because the system locates in front of a user's mouth.

The food has a bite size in common. However, scooping sticky boiled rice is not an easy task. Most of feeding systems are scooping the food with a spoon, and those systems are not suitable to treat boiled short-grain rice. My Spoon has the grasping function to pick up food. However this system is hard to serve rice due to fixed grasping strength of a gripper.

The feeding robot allows a user to enjoy dishes independently during mealtime. At first, the feeding robot needs to prepare the dishes through a caregiver. After preparing the dishes, a user and a caregiver can directly solve following problems via a feeding robot.

- What does a user want to eat?
- When does a user want to eat?

The user can independently choose dishes and select a serving time of dishes.

In this paper, we present the requirements of a feeding robot for Korea food. Then, we propose the novel feeding robot for Korean dishes especially boiled rice. In Section 2, we will mention the requirements of a feeding robot for Korean food. The specific design results will be presented in Section 3. Finally, we will make the conclusion in Section 4.

2 Requirements of a Feeding Robot for Korean Food

The major users of a feeding robot are persons with upper limbs disability such as people with C4 (cervical 4) complete spinal cord injury, cerebral palsy, and muscle diseases who cannot move their shoulder. Those users are not large. However, if we include the number of senior citizens who have difficulties in the motor function of upper limbs, the overall population of target users will be growing in the near future.

We survey the requirements of a feeding robot through a focus group. The focus group includes people with spinal cord injury and a person with cerebral palsy. In addition, we collect the opinions of occupational therapists and medical doctors. We discuss the requirements of feeding robots in the group meetings and interviews. Their opinions are as follows.

First of all, a user can control the feeding interval for desired food. In case of care giving, one of common problems is hard to control the feeding interval. The people with spinal cord injury can talk quickly when the feeding interval is too short. However, the people with cerebral palsy are difficult to represent their intention quickly such as short talking.

Second, the specialists and the user candidates believe that the feeding systems for western style food are not suitable for Korean food. Korean food basically consists of boiled rice, soup, and side dishes like kimchi. The general procedure of having a meal is as follows: at first a user eats one of side dishes, and then eats boiled rice. Or someone eats boiled rice, and then eats one of side dishes. Those steps perform repetitively during mealtime. In comparison with foreign boiled rice, the Korean boiled rice hold together very well after cooking. One of problems is handling the sticky boiled rice. In addition, the Korean soup includes meat, noodles, and various vegetables, and thus existing feeding robots are hard to handle Korean foods.

Third, a feeding robot could be applied to private homes and facilities. In view of an economical point, a feeding robot is effective in facilities that have many persons with upper limbs disability. Those kinds of facilities do not have enough caregivers for feeding. The feeding is one of heavy time consuming tasks. Thus a robot reduces the burden of caregiving for feeding. On the contrary, a feeding robot could be applied in the ordinary home in order to improve the quality of life of consumers. The member of a family can face each other and freely enjoy talking. The other members of the family can go out without the burden of feeding during couples of hours.

Next, the location of bowls or a tray is one of important factors. According to Korean culture, the location of bowls or a tray is strongly related in the dignity of a person. Some senior user candidates hate the bowls rightly in front of a mouth and they prefer to eat the food like ordinary persons. Thus we mainly use a tabletop tray. However, if the bowls are located in front of a user's mouth, we are easy to make a simple structured feeding system.

Other comments of user candidates and specialists are as follows: simple machines that can serve simple dishes with water are required. When a caregiver goes out for a while, a user needs to eat corn flakes with milk through a machine. The water service machine should be located aside a user's body. The cover's meal tray is required in order to prevent dust contamination. The price should be reasonable. For example, the price should be between US$1800~2700. The feeding robot should deal with noodles. The feeding robot could consider the posture of a user because some persons recline on a wheelchair. A feeding robot should be lightweight.

On the basis of requirements, the system that supports the activities of daily living depends on a user's culture and environments. Especially Korean food consists of several dishes: rice dishes, meat & poultry dishes, stew & soup-based dishes, and seafood dishes. The Korean food is based on the rice. How to handle boiled rice is an important problem. In general, the rice is sticky, and thus a user is difficult to pick up the rice. Sometime, a user is difficult to release the scooped boiled rice.

We should choose how to handle rice. First, the rice is naturally loaded in a bowl or a tray. In this case, rice has no special shape, and is similar with rice of a general meal. Second, the caregiver prepares rice as several lumps of rice. The lump of rice has a bitable size in a mouth. By the focus group interview, we decide to use rice without reshaping in a bowl or a tray. The user candidates said that the complex preparing process of rice makes a caregiver or a user avoid using the assistive feeding system. Thus we put boiled rice in a bowl for a feeding robot generally.

We concentrate on the rice handling. We disregarded the soup into the bowl at first version. We pour water or soup in cups. We will handle the Korean soup in a next version's design. Instead of handling a Korean styled soup, we will provide the cup with a straw for intake water or soup.

Technically, we take into account four candidates of a feeding robot in order to grip and release boiled rice effectively. First, couples of bowls are located in front of a user's mouth, and the food is presented by the spoon with short travelling. For example, if the number of bowls is three, one bowl has rice and two bowls have side dishes. However, two side dishes are not enough to enjoy the food. In general, Korean persons eat three or four side dishes with boiled rice at a time. So we need the four or five bowls.

Fig. 1. Design concepts of a feeding robot

Second, the bowls are located in upper front of a user's mouth, and then the food drop from the bottom of a bowl. The food is located in the spoon by dropping, and then the spoon approaches a user's mouth. This method needs the mechanism of food dropping on the spoon. This method could be suitable for a bite-sized rice cake.

Third, the system with a food tray is located on a table. The robotic arm picks up food, and then the robotic arm moves the food to a user's mouth. These tasks are divided into two tasks: one is picking up food and the other is moving the food to a user's mouth. Two arms can be used to perform above two tasks, respectively. A user candidate talks about the easy installation of the feeding robots, especially a dual-arm manipulator, because caregivers could be senior people and are not familiar with brand-new machines.

Finally, one bowl is located in front of a user's mouth. The mixed food with rice is loaded in that bowl. Some users do not like the mixed food even though they prefer a simple feeding system.

We decide the third candidate that is located on a table in accordance with opinions of specialists and user candidates.

3 Design of Feeding Robot

We design a simple robotic system that has a dual-arm manipulator in order to handle Korean food like boiled rice with an ordinary food container effectively. Arm #1 transfers the food by a spoon from nearby a container to a user's mouth. Arm #2 picks up the food on a container and then loads up the spoon of Arm #1 with the food. If two arms have different roles, the end-effectors of two arms can be effectively designed. That is, the end-effector of Arm #1 has a spoon and the end-effector of Arm #2 has the gripper to pick up food. For the picking up the food, we can use an odd or sharp shaped gripper because that gripper does not approach nearby a user's mouth.

The two arms with two different end-effectors mimic Korean caregivers' behavior. In the cultural point of view, Korean uses a spoon and chopsticks during mealtime. The Korean caregivers usually pick up food with chopsticks, and then put food on a spoon in order to serve food to users such as children and patients. In the designed system, the gripper of Arm #2 and the spoon of Arm #1 make roles of chopsticks and a spoon, respectively. In that sense, the feeding system that has two arms stems from those feeding procedures.

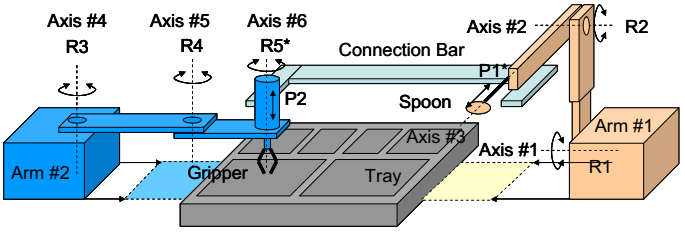

Fig. 2. The concept of a feeding robot for Korean food. P1 (Prismatic Joint #1) and R5 (Revolute Joint #5) are optionally applicable joints.

Arm #1 should have one or two degrees of freedom in order to transfer food on the spoon without changing an orientation of the spoon as shown in Fig. 2. If a revolute joint R1 connects to a revolute joint R2 through a belt, R1 and R2 have one degree of freedom. However, the prototype of Arm #1, we provide separated motors with R1

and R2. If Arm #1 does not use the belt between Axis #1 and Axis #2, we can change of the length between Axis #1 and Axis #2 manually and thus we can reduce the overall size of a system when a user is not in use. People with cerebral palsy are difficult to eat food on a spoon in front of their mouth. The feeding robot could add the additional prismatic joint P1 toward a user's mouth as shown in Fig. 2. Therefore, the robot effectively puts the food into their mouth.

Arm #2 should pick up food on a container, and two revolute joints and one prismatic joint are adopted for the effective motion along a food container. The revolute joint R5 could be added in order to control the gripper's rotation. The gripper that has a sharp tip is suitable to separate and grasp food.

In preliminary experiments on treating boiled rice, we observe that releasing rice is important like picking up rice. According to the temperature of boiled rice, the stickiness of rice is changing. The slightly cool rice is difficult to release rice from the gripper. In order to solve this problem, the feeding robot optionally put the gripper of Arm #2 in the water for a while. That process makes a layer of water on the gripper that can reduce the adhesive strength of rice. In that case, we can easily release sticky food as well.

The overall number of DOF could be four to seven excluding the gripper. A connection bar is applied between Arm #1 and Arm #2 because we need to connect electrical signals and fix the posture with respect to each other.

The feeding robot could use two kinds of containers. First of all, we could use the meal tray in the ordinary cafeteria. The tray could be located between Arm #1 and Arm #2. Second, we can use bowls that are usually used in a hospital. The bowls are hard to fix on the table when a robotic arm contacts with food in bowls. We can use a tray adaptor that can hold bowls in desired position. The tray adaptor removes the transferring food from original bowls to other trays. A caregiver only puts bowls in sockets of a tray adaptor. In order to position the lapboard on a bed in a hospital or a facility, Arm #1, a tray, and Arm #2 should be aligned in a line because of the restricted with of a lapboard.

In view of the practical application of a feeding system, a caregiver can support multiple users. At that time, a caregiver has a role of Arm #2 such as picking up and releasing food. Under the proposed concept, one caregiver can support couples of users by using Arm #1 that can deliver the food from the table to a user's mouth. The caregiver picks up the food on a dish and then loads the food on the spoon of Arm #1. Users need several tens of seconds in order to chew the served food. During one user is chewing the food, the caregiver can provide other user's spoon with food.

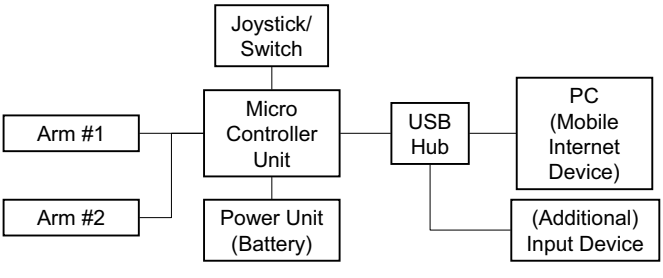

Fig. 3. Block diagram of feeding robot

The feeding robot uses a microcontroller unit to control the Arm #1 and Arm #2 as shown in Fig. 3. We add one small-sized PC with a touch screen in order to get the entertainment and to test various kinds of user interfaces. During mealtime, a user can enjoy the multimedia such as a movie or music. In addition, the small sized PC has a Windows operation system, and we can effectively add assistive devices for human computer interaction, i.e., switch, joystick, and bio-signal interface devices.

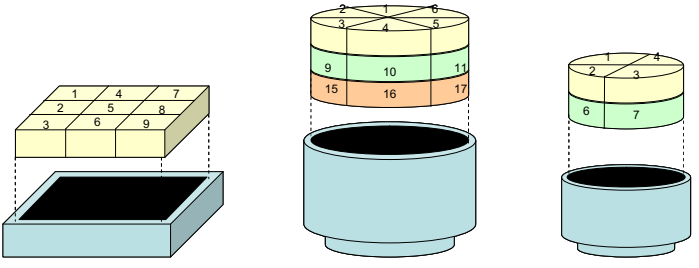

Fig. 4. The definition of grasping volume in containers

Fig. 5. Designed feeding robot for Korean food. Arm #1 (lower left-hand side figure) for transferring food and Arm #2 (lower right-hand side figure) for picking up and releasing food.

In the microcontroller unit, we allow a user or a caregiver to set the following items: an operation mode (automatic/manual), the shape and size of food containers, a mouth's location, a robot's speed, time to stay in front of a mouth, and so on. According to dishes, a user also selects the divided grasping region in each containers and the strength of a gripper of Arm #2. Our system will be open to select the above parameters. A user may make the parameters of various dishes and share with their colleagues through the internet. We hope that the user's community could exchange their own parameters for each cooking.

Grasping regions of boiled rice in a bowl could be specially defined in 3D space because a general bowl should have around 50 mm in height. The grasping volume of dishes could be defined as shown in Fig. 4. Our team is making the prototype of the proposed feeding robot now. Fig. 5 shows the estimated appearance of the system.

4 Concluding Remarks

Research Institute of NRC in Korea has been designed the novel feeding robot that suitably manipulates Korean dishes, e.g., sticky rice, in a general tray or a hospital's tableware. We are constructing the system now. According to the preliminary study, we observe that the basic operation works well through a dual-arm manipulator that has two end-effectors. We will make in experiments on the basis of the novel design soon and then analyze usability of the system. We will customize the system through users' evaluation. In addition, cost-effective user interface devices will be considered.

Acknowledgments. This Research was supported by a grant (code #10-A-01) from Research Institute, National Rehabilitation Center, Korea. The authors acknowledge the input of consumers, Mr. Hongki Kim and Mr. Kwangsup Lee, and specialists of physical medicine and rehabilitation in Korea National Rehabilitation Center in this study.

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