FEEDBOT: A SIMPLE AND SMART DESIGN SELF-FEEDING ROBOT FOR PARKINSON'S PATIENTS AND THE ELDERLY

FEEDBOT: MỘT THIẾT KẾ ĐƠN GIẢN VÀ THÔNG MINH CỦA ROBOT TỰ CHO ĂN CHO BỆNH NHÂN PARKINSON VÀ NGƯỜI CAO TUỔI

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ABSTRACT

The assistance for the elderly and Parkinson's patients has always been utterly demanding, many robots assisted feeding (RAF) are designed to support Parkinson's patients and the elderly. This paper demonstrates the design of a robot that helps disabled people in eating activities since they can barely do this themselves. Visually, the robot consists of three main parts: a food tray, a feeding arm, and a remote control in order to simulate the eating movement of humans. This design aims to design a lightweight robot that operates autonomously and can analyze data based on patients' nutritional recommendations via smartphone monitoring software. Besides, the design is also based on the study of adults' experiences in their daily dining. This work aims to design a robot-assisted feeding and apply it to reality in Vietnam.

Keywords: *Parkinson; Self-feeding robot; Robotic manipulator.*

TÓM TẮT

Việc hỗ trợ cho người cao tuổi và bệnh nhân Parkinson luôn luôn là một nhiệm vụ đầy thách thức. Nhiều loại robot hỗ trợ cho việc ăn uống (RAF) đã được thiết kế để hỗ trợ bệnh nhân Parkinson và người cao tuổi. Bài viết này trình bày về việc thiết kế một loại robot giúp người khuyết tật trong hoạt động ăn uống, bởi vì họ thường khó khăn trong việc tự thực hiện điều này. Về mặt hình thức, robot này bao gồm ba phần chính: một khay đựng thức ăn, một tay cầm đưa thức ăn và một bộ điều khiển từ xa để mô phỏng cử động ăn của con người. Thiết kế này hướng đến việc tạo ra một loại robot nhẹ và có khả năng hoạt động tự động, có thể phân tích dữ liệu dựa trên các đề xuất dinh dưỡng của bệnh nhân thông qua phần mềm giám sát trên điện thoại di động. Hơn nữa, thiết kế của robot này còn dựa trên việc nghiên cứu về trải nghiệm ăn uống hàng ngày của người lớn. Mục tiêu của công việc này là thiết kế một loại robot hỗ trợ cho việc ăn uống và áp dụng nó vào thực tế tại Việt Nam.

Từ khóa: *Parkinson; Robot tự cho ăn; Cánh tay robot.*

1. INTRODUCTION

Parkinson's disease is a disease of neurological which is popular among the elderly, and it can be considered a chronic condition or a source of disability. There is approximately 18.7% percent of the non-institutionalized US population has been living with a disability [1], and 12.3 million require assistance with their activities of daily living (ADLs), for instance, eating, bathing, dressing, and moving [2]. Moreover, depression and disability can be worsened when there are assistances in their ADLs because this is the loss of regular routines that aggravates disability [3]. According to University Medical Center Ho Chi Minh City, 1,089 patients with Parkinson's were monitored and under treatment for a total number of 4,000 treatments per year. Patients who are suffering from upper limb impairments barely find feeding themselves easily. Fortunately, in recent years, there has been much research to apply technology and science to support disabilities [4-5]. There are several remarkable designs of feeding-assistance robots introduced [6-7]. For instance, Abou Haidar, Gaby, et al [6] came up with RFDP consisting of an arm with five degrees of freedom by using blink detection technology; the user selects the appropriate food plate and moves the arm towards it by just blinking the eye. Turgeon, Philippe, et al [7], designed a meal-assisted robot arm that aims to stabilize the movements of people living with movement disorders. In the market, Obi is a robotic arm connected to a food tray of four bowls. A removable spoon is attached to the arm in order to pick up food from the tray. The feeding movement of Obi is relatively identical to other self-feeding robots, although it features Teach mode which users can progressively adjust the arm to a position in front of their mouth and then record the position for further feeding movement. The iEAT feeding robot (Assistive Innovations, 2016) [8], is a feeding device for people who have been living with spasms, tremors, or quadriplegia by rotating its food plate, the spoon can gather enough amount of food to feed the user. These robots share the same design and adjust to suit their demand, they consist of a food tray, and arms with an attached spoon, and can operate in manual or automatic mode. In addition, they are designed to bring state-of-the-art, safe, and easy use. Patients with quadriplegia, spasms, or Parkinson's can benefit from features in their daily eating routines [9]. However, in Vietnam, rice, and soup, considered as primary food, are usually served at the dining table in combination with other dishes. Furthermore, gruel and rice noodles are also everyday food and they are often given to patients because they are delicious food and easy to eat. These made consuming food in this country a lot different from Western countries not to mention dishes for the elderly and patients who are under medical treatment are usually offered meal plans for a healthy diet. In Vietnam, Parkinson's patients are in the final stage, all living activities are carried out by relying on relatives, unable to control their bodies. Besides drug treatment, physical therapy exercises, and logical dining suggested by doctors with outside support, people with Parkinson's disease or Alzheimer's disease are recommended a soft, easy-to-digest, and high-fiber diet [10]. Nutrition has an important role in neuroprotection and neurodegeneration [11]. In many of the observed cases, the patient needs support for feeding. The task of feeding is not too complicated for the medical staff or the patient's family, however, it takes up their time. They also do not feel for themselves which is the most appropriate height of the spoon to feed the food, but only the approximate. Therefore, if the patient can control this height, they

experience the most favorable eating and also lose the feeling that others have to serve them. Thus, in terms of product design, a robot for feeding provides both the best experience in the patient's physical activity and mental comfort for the elderly with poor movement ability. The purpose of the design is to automatically adjust and match each patient, and the robot is suitable for Vietnamese people's nutrition. The design of this self-feeding robot enables bowls to be inserted into each tray food tray, hence these bowls can be separated for better cleaning and hygiene. It is designed suitably for types of common food in Vietnam, such as rice, soup, or gruel. Moreover, it introduces the nutritional data (including nutriment and quantity of foods) collection feature, the accompanied software can be used to record the nutritional needs of the patient through a smartphone and give the recommendation to the user. These types of information can be easily observed and controlled via the internet; thus, this enables family members to have a better overview and easily the condition of the patient.

2. ROBOT-ASSISTED FEEDING SYSTEMS

2.1. Target user

This research aims to assist the elderly and individuals who are diagnosed with Parkinson's disease. This debilitating condition is known to decrease a person's ability to move, making it challenging for them to use their fingers, legs, and other extremities. Bradykinesia, or slowness of movement, is a prevalent symptom among Parkinson's patients, and it often leads to pain and discomfort. In addition, Parkinson's disease can cause involuntary shaking of the hands and feet or muscle stiffness, which can cause resistance to muscle relaxation, making it challenging for patients to perform daily activities [8]. People who suffer from muscle disorders frequently encounter poor muscle activity around their elbows and shoulder joints, even though they can lift their hands and have minimal motor functions. Furthermore, the elderly often experience difficulties with the motor functions of their upper body, and those who are frail or have disabilities require assistance with basic activities of daily living. Such activities may include feeding oneself, which can be extremely challenging for some individuals. Therefore, this research aims to develop solutions that can aid these individuals, making it easier for them to complete daily tasks and maintain their independence.

2.2. The expectation of a self-feeding robot

The design is expected to support the patient throughout their eating routines. Most of the elderly are using wheelchairs to move around, which helps them approach the device easily. First, the robot can serve foods in both liquid and solid forms. A removable spoon attached to the arm is designed to reach all areas of the bowl and is programmed to shake lightly after scooping in order to prevent food from falling out of it while eating. Second, this system is designed for serving Vietnamese foods including rice, soup, and gruel. The movement of the arm needs to be suitable for eating those foods that are scooped around the edge of the bowl first. Third, this design is accompanied by a dedicated application that can be used on smartphones. This software sends and receives information with the robot via Bluetooth and the internet, the information includes nutrition facts and meal quantity of meals and is stored for medical check-ups. Fourth, the self-feeding robot is mainly used for feeding purposes, that's why sanitation of the device is also a noticeable ☞

factor. The cleanliness brings the user a reliable sensation from the robot, it makes the food look more delicious, and to some extent, it helps patients consume food if they are losing appetite. Finally, since other self-feeding robots, which were commercially introduced to the market, are quite high-priced, this design is supposed to be low-cost and approachable to many users. These features make this robot well-researched globally shortly.

3. DESIGN

As mentioned above, the RAF robot can be approachable to many types of users, especially the elderly and people with Parkinson's. The arm(s) of the robot should be modeled to simulate human hand casual movement while feeding elderly people, users shouldn't have to force themselves to move or have a hard time leaning over to eat food.

3.1. Concepts

There are typical concepts for a self-feeding robot, these concepts are likely inspired by previous designs. These concepts are considered uncomplicated while being the most effective and approachable. The proposed robotic system is specially designed to enhance the dining experience for individuals, with a circular tray serving as the base for a pair of robotic arms. The tray is equipped with the advantage of rotation, providing two key benefits. Firstly, it ensures that food is accurately given to the correct robotic arm at the perfect time, preventing any spills or accidents during mealtime. Secondly, the tray can be easily removed for cleaning, sterilizing, and storing in the kitchen area without impacting the rest of the robotic-assisted feeding (RAF) system. n terms of technical design, the robotic arm has two degrees of freedom in perpendicular directions, height, and width, making it highly flexible (as depicted in Figure 1). This design allows for better customization to the individual's unique needs and preferences. Additionally, in Vietnamese culinary culture, people typically require the use of different types of spoons during dining, and robotic arms are well-suited for this purpose. With the ability to accommodate two spoons, each arm can function for different dishes, thus enhancing the dining experience and aligning with Vietnamese culinary culture.

The robot's ability to rotate also allows for better accessibility and ease of use, especially for individuals with mobility limitations. The design of the robotic arms provides improved dexterity and control, enabling precise and accurate movements while feeding, thus minimizing the risk of any accidents. Furthermore, the system's modular design allows for easy maintenance, upgrades, and customization to better suit individual needs and preferences.

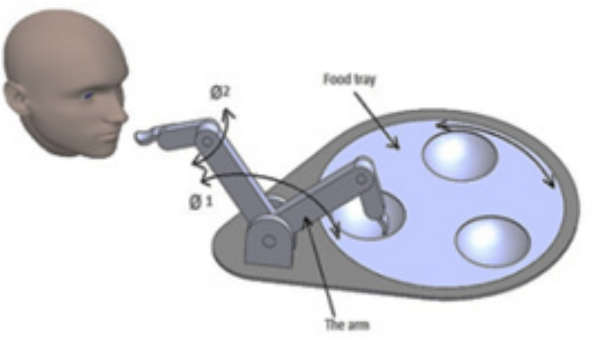

Figure 1. Concept 1 for Feedbot.

The second design proposes a more convenient method for choosing foods. Each button in the controller is assigned to the corresponding food tray. The robotic arms are independent and there are more degrees of

movement in this concept than in concept 1. The arm and the food tray are not connected by any link, which suggests the placement of these be fixed. Otherwise, the robot cannot scoop food properly. This concept shares the same common with concept 1 as the same the eating activity of humans (Figure 2). Simulating human movement helps the patients in familiar with the robot easily as it serves them frequently. It is designed based on user experience, which is established in technology as consumers' experience [12]. This approach initiates in the elderly with mentality, a will for cooperation, and design, and it simulates skillful human arms. However, this design, in a sense, disables the caregivers and nurses with its immobility and fixed position.

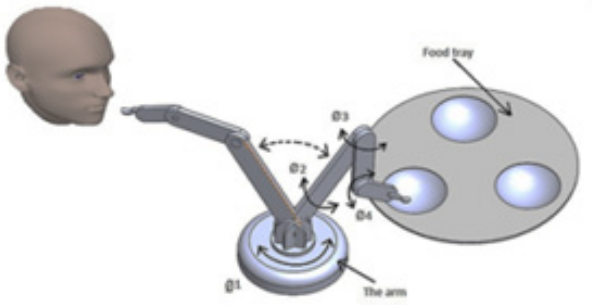

Figure 2. Concept 2 for Feedbot.

The third concept shown in Figure 3 includes two arms, one is equipped with a gripper and the other uses a spoon as usual. This concept takes inspiration from the expectations of users as the foundation of the design [13]. This design aims to simulate both hands of humans, thus it can pick different types of cultural foods and bring pleasure to users in an interaction with the character both serving and repeating how humans would use them in the same context [14]. However, it repeated the same disadvantage of the second design which is not being conducive for caregivers or nurses to place the food tray and the arms accurately.

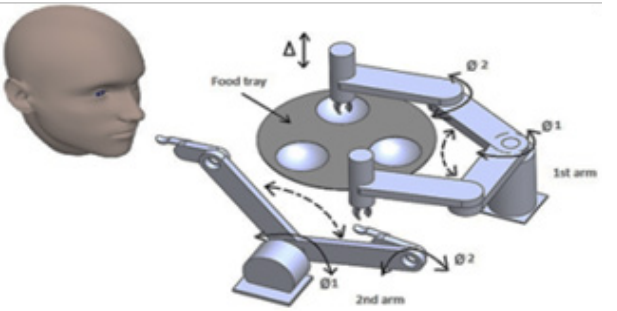

Figure 3. Concept 3 for Feedbot.

The FeedBot is designed to serve people in Vietnam, who have different eating traditions from Western countries. In Vietnam, the meal usually consists of rice, soup, and different dishes in combination. This influenced the design of FeedBot as it has an arm that can scoop rice or soup on the tray in bite-size and a food tray with three hemispherical rooms for food bowls of different sizes. The outside of the robot is covered in bright white, bringing the user the feeling of sanitation and trustworthiness of their meal. With the mission, the manufacturing cost of the Feedbot is reduced so the design must be simple but must meet the proposed functions, Table. 1 shows a comparison of concept design about design complexity.

Table 1: Comparison of concepts

Concept	No. DoF of Arm	No. Arms	No. actuator overall
1	2	1	2
2	4	1	4
3	5	2	5

Among these concepts, the integration of the feeding manipulator and the food tray onto the same base is a thoughtful design choice that offers several benefits. One significant advantage is the compactness of the system. By placing both components on the same base, the device's overall size is reduced, making it more manageable and practical to use in different environments. Additionally, the system's neatness is improved, giving it a more professional and refined appearance. Moreover, the user experience is enhanced by this design. Caregivers can easily place food on the tray and position the device on a table, enabling the patient to eat comfortably without any physical discomfort. This feature saves time and effort while also making the feeding process less stressful for both the caregiver and the patient. The feeding manipulator arm, which has two degrees of freedom, is another key aspect of this design. The arm's flexibility allows it to move in multiple directions, which simplifies the device's calculations and control. This capability also reduces the cost of the equipment, making it more affordable for those who need it. In conclusion, the integration of the feeding manipulator and food tray onto the same base as in Concept I is a smart design that offers numerous benefits. From improving the system's compactness and neatness to enhancing the user experience and reducing equipment costs, this design is a significant advancement in the field of feeding assistive technology.

3.2. Anthropometry

The self-feeding robot is designed for Vietnamese users, whose body measurements are considered. As the height of Vietnamese people varies between men and women and among areas of the countries, the dimensions of the robot should follow corresponding anthropometric figures [15]. This device is used by a particular group of people, Fozard (1981) and Stoudt (1981) research the anthropometry of the elderly, stating that as their age increases, the anthropometric value also differs from other age groups. These data cannot be used interchangeably among countries and ethnicities [16-17].

Anthropometry is one of the determining factors in any design of a robot for well-being. Such values are:

- Sitting height of a person in a wheelchair;
- Sitting mouth height of a person in a wheelchair;
- Distance from crown to mouth;
- Distance from mouth to spoon (also head reach).

They directly influence the dimension of the robot and a design for the elderly should certainly be specifically convenient. Because stature is the most affected anthropometric characteristic and according to the National Institute of Nutrition of Vietnam in 2010, the average height of Vietnamese people is 164.4 cm for men and 153.6 cm for women, which belongs to the low average group. The data of the Vietnamese's average sitting height is 84.4 cm and 79.5 cm for men and women, respectively. The head of the man according to the ratio of development of the body is usually larger than the head of the female, and the head height is shown at face length from the forehead to the chin, with an average gender varying from 1 cm to 1.5 cm. The ratio of head height and body height varies from 1/7 approximately. This means the head height of a man is 23 cm and 21.7 cm for a woman. These values are

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essentially taken into account when it comes to designing furniture because chairs and tables are two objects that will be used for a long time. This means they must be proportionally designed to help users, particularly the elderly to work and move with ease and comfort. And with the height of the table in Vietnam has been standardized to be 75 cm from the ground while the chair is 42-45 cm. All measurements are made by the same person for all the participants. The measurer was given training in the use of anthropometric instruments in the laboratory. Before the data collection is started, several trial runs are conducted in the laboratory to make sure that the measurer fully understands all procedures of measurement and follows them consistently throughout data collection. The measurements made by the measurer in the trial runs are checked by another person to determine the accuracy and consistency of the measurements.

3.3. User Experience

The self-feeding robot's design was evaluated practically by patients with Parkinson's disease, in a series of research and surveys conducted in nursing homes and healthcare centers for the elderly in Ho Chi Minh City, Vietnam. The need for such a robotic system arises from the fact that in nursing homes and healthcare centers, nurses usually assist patients with their eating every day. However, patients who are elderly or have Parkinson's disease take longer to eat than others, and each nurse or caregiver is often assigned to look after more than one patient, which can result in a lack of attentive care. This highlights the crucial role that this robot can play in enhancing the well-being of patients.

Most patients in these facilities use wheelchairs to move around, making it challenging for them to feed themselves independently. In response to this challenge, the robot is designed to be placed on a table right in front of the user, with the trays filled with food. This placement ensures that patients can easily access their food without having to struggle or require assistance from caregivers, providing them with greater independence and control over their meals. The self-feeding robot's design is well-suited for individuals with Parkinson's disease, who often experience difficulty with their motor functions, particularly in their hands and fingers, making it challenging for them to use cutlery. The practical evaluation of the robot's design by patients with Parkinson's disease is critical in ensuring that the system is effective and meets the unique needs of its target audience. The feedback and insights provided by patients can be used to refine and improve the robot's design further, enhancing its usability and performance. Additionally, the ability to conduct practical evaluations in nursing homes and healthcare centers provides a valuable opportunity to test the robot in real-world scenarios, ensuring that it can meet the challenges and demands of daily use. The arm of the robot simulates the activity of a human hand while eating routine. The simulation in this study is an independent manipulator, a rotating food tray that is easily controlled, a highly integrated smart recommendation based on the medical index, and lightweight plastic fiber. During the meal, the mechanism allows the user to scoop food in the tray simply by only 2 simple buttons, it moves up to the user's mouth. The patients only need to lean over a little bit to take food on the spoon. Furthermore, the robot is also programmed to serve rice, soup, or gruel effectively through the agency of variable angles its hand can rotate. The users also notice the shaking motion of the arm after ☞

scooping food so that the food stuck outside the spoon falls back to the tray and does not fall out when the arm moves up to the user's mouth. It is worth noticing that the quantity of scooped foods also affects the user experience and quality of the meal. Depending on the kind of food being served, the amount is scooped differently. Watermelon, rice, and rice porridge are being served in this experiment. Ultimately, most of the participants were satisfied and fascinated by the assistance of this robot.

4. RESULTS AND DISCUSSIONS

The design concept I shows the advantages for users in the experience aspect. Therefore, these product design brings about important tools in the future since user experience is increasing satisfaction and sales of consumers by providing maximum convenience, benefits, and enjoyment for last users [18]. The goal of the design is around the user and their interest in the culinary culture. Vietnamese people have a plan for meals differently from other ethnicities and races; each dish bears different properties, so the mode of scooping, spooning, and handling is also different. Vietnamese anthropometry can be used to collate the design and measurements of each part. The actual Feedbot and the interface are shown in Figure 4 with the specification presented in Table 2.

Figure 4. The actual software and Feedbot.

Table 2: The specification of Feedbot

Feedbot	
Size	408 x 367 x 390 mm
Weight	1.0 Kg
Power supply	9 VDC

In the future, the design will improve the smart recognition of food and for seat height to advance to its fullest design features and precise serving. Development of sensation into the arm of the RAF is a possibility, granting the machine the ability to awareness and memory storage, then self-adjustment to the suitable height of users.

The integration of the physical properties of food allows the robot to select the appropriate spoons and to further increase precision in serving. The users are those that require assistance in movements, they acquire physical care, helping them in daily activities. Moreover, they also need mental, as well as emotional, care in serving and cultural habits in activities and usage of the technology. Thus, further progression of the Feedbot in the future in quantity and quality is necessary. The plan ideas and models for care gadgets depended on the extraordinary necessities of the elderly and difficult impediments in their eating abilities. The conduct of the elderly the difficulties of both senior individuals, and the parental figures in the feasting region while eating are firmly explored in both the ordinary consideration unit and the extraordinary consideration unit of the nursing home. Additionally, the dedicated software can function as overall healthy diet management, which is important for tracking nutrients in food as well as the number of meals. These data are recorded and they are synchronized through smartphones via internet connection. The proposed design is an elegant

departure from the previous models. It comes with a sleek design and a brighter color scheme that does not become mucky overtimes. Moreover, the dimension of the robot can be reduced for convenience.

5. CONCLUSIONS

In this study, a self-feeding robot is proposed with improvements for people in Asia, especially in Vietnam such as cheaper cost, suitability for traditional food, and ease of use. This study is carried out with the advice of doctors, nurses, and caregivers to adjust the mechanical mechanisms suitable for the elderly and Parkinson's patients. This robot uses software to record the information of each meal, this is the document to doctors or patients' relatives can track via the internet. Future research can address the subsequent issues such as force control and user safety, the addition of compliant devices to cut back the chance of injury to users, expanding or optimizing the image processing algorithm for other varieties of foods, seamless integration of the robotic and vision system, the addition of other user interfaces in response to the vast range of user needs, then testing and evaluating the product on users is carried out to improve the quality of the service of Feedbot.

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