NYAM: The Role of Configurable Engagement Strategies in Robotic-Assisted Feeding

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Figure 1: Robot-assisted feeding with a real patient in a hospital. First, the caregiver can personalise the robot's behaviour. Then, while feeding, the robot may actively engage the person by choosing among three different strategies.

ABSTRACT

In some contexts, like geriatric hospitals, the number of patients requiring assistance with feeding is very high and robots may be an effective tool for caregivers to provide better assistance. This article introduces NYAM, a robot designed to aid in the feeding process for individuals. Our robot is equipped with a mechanism to effectively recapture the person's attention whenever necessary. The mechanism is easily adjustable by the caregivers, allowing the straightforward customisation of the feeding service. The approach was evaluated, within a geriatric hospital, with 9 patients who used the robot for 5 consecutive days. We argue that incorporating enhanced social aspects into the robot is imperative to enhance the effectiveness and acceptance of this solution.

CCS CONCEPTS

• **Computer systems organization** → *Robotics*; • **Social and professional topics** → **Assistive technologies**.

KEYWORDS

Assistive Robotics, Human-Robot Interaction

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1 INTRODUCTION

Feeding is a fundamental self-care skill for humans, but it can be challenging for those with physical or neurological impairments. An estimated 142 million people worldwide have severe disabilities and may require assistance with eating due to conditions such as cerebral palsy, muscular dystrophy, amyotrophic lateral sclerosis, or spinal cord injuries [17]. Feeding another individual who is unable to feed themselves due to a medical condition or disability is referred to as assisted feeding. Traditionally, caregivers have provided this assistance, but this approach is not always consistent or sustainable long-term. Robotic feeding systems show promise as an assistive technology, aiming to improve users' quality of life, autonomy, and dignity by enabling self-feeding. However, key challenges remain in building robots that can safely and effectively handle a variety of foods, utensils, and feeding motions involved in everyday meals while adapting their movements to each person's abilities and interacting naturally with the user. The community (users and caregivers) play an important role in designing this new generation of robot tasks that can be seen as community-centred relational services [2].

Although different proposals exist in the market, they present important shortcomings. For example, some are restricted to specific types or formats of food, while others have limitations in the use of utensils or regarding autonomy, control or interaction with the user allowing only pre-programmed trajectories [1, 10, 12, 15]. Some authors have been interested in producing natural and easy-to-adapt robot motions [4], but the robot used was bulky and the evaluation was limited to lab conditions. Recent studies have advanced in user control, allowing the detection of an open mouth to adapt the trajectories [6] or improving the recognition and manipulation of different types of foods [7, 13, 16]. The community has also studied how personal preferences, such as robot speed, approach direction or the amount of talking, should be taken into account when feeding [5, 11] and the type of preference adaptation that is most appreciated by users [3]. Engagement can be considered a facilitator between emotional well-being and caregiving tasks, either using verbal or embodiment cues [8].

Still, these approaches have in common that the robot cannot take the initiative. Thus, none of these approaches has investigated the active-robot interaction dimension and the role of the caregiver in it. Additionally, most of these works have been tested in laboratory environments and not with real patients.

Post-stroke patients or people having mild dementia usually require assisted feeding not only because they have physical limitations, but also because their cognitive condition often causes them to forget that they are in the middle of a meal and become distracted. In care environments, the caregiver assisting with feeding is responsible for reminding the user that they are eating and insists on continuing with the meal.

This assisted feeding problem presents an additional dimension in settings such as hospitals and nursing homes, where due to the routines of daily life, healthcare personnel are faced with a large number of patients requiring assistance with meals within a brief timeframe. All meals are delivered from the hospital kitchens simultaneously, and it falls upon the nursing and other healthcare staff to support and supervise feeding all patients in a very short time interval, while also attending to various other tasks and emergent needs. Despite being a predictable and daily recurring workload, finding a simple solution proves challenging. The optimal resolution to this issue, having additional personnel during meal times, not only poses clear economic limitations but is also significantly constrained by the current historical context and future projections, notably affected by the shortage of nursing staff[14]. In this high-pressure environment, stress can be induced in workers, potentially leading to a decline in the quality of patient care.

Figure 2: Original Obi device (left) and robotised version (right) able to perform tool change (not used in this work), including RGB-D camera, screen and security button.

This paper introduces a robot designed to assist in feeding people. The robot is endowed with an attention-grabbing mechanism to recapture the person's attention when needed. We designed this mechanism to be easily configurable by caregivers, allowing them to adapt the operation of the feeding service effortlessly. In designing our robot, we observed several caregivers (both formal and informal) assisting with feeding in a geriatrics-specialised hospital. From these observations, we realised that caregivers employ different active attention mechanisms to keep people engaged. The preliminary experiments, conducted with real patients in a hospital, demonstrate that the robot offers interesting features for both the caregiver and the patient. We argue that incorporating better social aspects into the robot is necessary to enhance the utility and acceptance of such a solution.

2 ROBOT DESCRIPTION

To address the challenge of human-robot interaction, collaborative design sessions were conducted with healthcare staff from the *Parc Sanitari Pere Virgili* Hospital. The team comprised physicians, nurses, nursing aides, occupational and speech therapists, a nutritionist and a psychologist. The commercially available Obi device (Fig. 2, left) served as the starting point for demonstrations of assisted feeding, and potential enhancements were discussed. Obi, previously tested and validated for feeding individuals, underwent both software and hardware modifications based on the insights gained from these sessions (Fig. 2, right).

One important feature was the ability to adapt to the user, so an RGB-D camera was added to detect the user's facial location and identify the mouth status and its positional orientation. Social capabilities were considered important, so we integrated a display screen and speaker to provide feedback to the user. The display features a facial representation to add expressiveness to the uttered verbal communications. The robot's verbal statements are designed to encourage the user to continue eating and to reinforce focus on the activity in case of user distraction. Additionally, the entire control system has been reprogrammed with new trajectories and dynamics for food collection, encompassing scooping and removing excess food.

Regarding safety, the Obi device tool is attached using a magnet that allows the tool to detach in case of a collision. We additionally programmed a torque control watchdog that stops the robot in case maximum torque thresholds are surpassed. Finally, the Ethical

Committee required us to add an additional safety layer by including a safety stop button.

The team also aimed to provide more flexibility in the robot's operations. A panel with additional tools was added including a tube for liquid intake, several spoons, and a napkin. The robot can change the tool, taking advantage of the magnetic attachment used also for safety. This capability is not evaluated in this paper.

2.1 Engagement strategies

The experiment involves a comparative analysis of the robot with three behaviours:

(A) **Button-Controlled Robot**: The robot features a single button responsible for managing patient feeding. The operational sequence is as follows: upon button press, the robot scoops food from the plate and offers it to the user. After a certain time, the robot retreats and stands by for the next button press. This version is the most similar to the original Obi device behaviour.

(B) **Gesture-Controlled Robot**: The robot uses the integrated RGB-D camera to monitor the position and orientation of the patient's face throughout the process. The operational flow is: when the patient gazes at the robot, it retrieves food from the plate; when the patient opens the mouth, the robot approaches the food. After eating food (which is identified by the detection of the user's face approaching and then retreating), the robot returns to its stand-by position, repeating the cycle. The trajectory used for feeding in each instance is selected from a set of pre-recorded trajectories (for safety), with each trajectory optimally positioned relative to the user's mouth.

(C) **Robot with Robot-Human Verbal Interaction**: The robot can trigger verbal and/or gesture interactions. The flow is the same as the gesture-controlled robot with the following modifications: (1) a timeout system to trigger the different behaviours (see next paragraph) that the caregiver can customise; (2) the integration of a facial expression display system on the screen; (3) the introduction of gestures using the robotic arm; and (4) adaptability to vary its level of interactivity based on the patient's behaviour.

The interaction actions available for robot behaviour C are:

- **Start of the meal**: the robot introduces itself, greets and grabs the spoon.
- **Offer food (Level 0)**: the robot does not interact with the person.
- **Offer food (Level 1)**: the robot indicates by voice that it is necessary to continue eating, in an attempt to grab their attention.
- **Offer food (Level 2)**: the robot prompts again the user to continue eating, this time with a side-to-side movement in addition to the verbal indication.
- **Approach (Level 3)**: the robot announces that it will move closer to the person as a last resort to grab their attention.
- **Finish feeding**: The robot indicates that the dish is over and gives feedback to the patient on how the meal went compared to previous meals

3 EXPERIMENTAL SETTING AND PATIENT DESCRIPTION

The participants of this proof of concept evaluation were 9 patients from a hospital. All required mealtime assistance due to factors such as bed confinement, muscle weakness, or limited range of motion in the upper limbs, provided they possess adequate trunk and/or cephalic stem mobility to engage with various feeder robot prototypes.

The Ethical Committee linked to the hospital has approved the experimental procedure. The inclusion criteria for participation are: the patient is presently receiving nutrition assisted by a caregiver, the patient exhibits a high level of cooperation, and they can manoeuvre their trunk to approach the feeding spoon.

The participants were divided into 3 groups in a between-subjects approach, one group per robot behaviour type (Section 2.1). Each participant experienced their assigned version for 5 consecutive days. This allowed participants to get used to the robot and to reduce the novelty effect. The robot was used for 9 consecutive weeks (1 week per patient) to help during the afternoon snack with dairy-like food. While this sample size is small, it allows us to perform a preliminary study and evaluate the viability of the robot's behaviour and customisation features.

For each feeding session, we have gathered the following data:

- **Feeding timestamps (s)**: sequence of time points (duration since the beginning of the feeding session) in which the user has received food from the robot.
- **Number of spoonfuls**: number of times the robot has fetched and offered food.
- **Frequency of engagement levels**: the frequency of each engagement level (only for version 3).

Regarding the customisation options that we offer to the caregivers, the robot in any of its versions can be customised in several ways. The nurse, patients and/or family can use a graphical interface to tune the following parameters:

- **Trajectory speed**: this parameter can be set to match the patient's eating speed without startling them. It is adjusted as a factor of the trajectories original speed.
- **Time limit for food offering position**: the time before the robot retreats after offering food for version 1 and for versions 2-3 when the user's face is occluded by the spoon.
- **Wait time before engaging**: time before the robot considers the user to be distracted and tries to grab their attention (only for version 3).

4 EXPERIMENTS

The participants in all 3 groups were very cooperative and eager to participate. They appreciated the control over the robot, whether using a button (group A) or gestures (groups B and C). The caregivers, including both family members and healthcare professionals, who witnessed the experiments, were supportive of this technology. They regarded positively the customisation options. On several occasions, the trajectory speed of the robot was adjusted as per the request of the healthcare personnel or the patients themselves. Generally, patients preferred the robot to move faster, as it matched their normal eating speed much better.

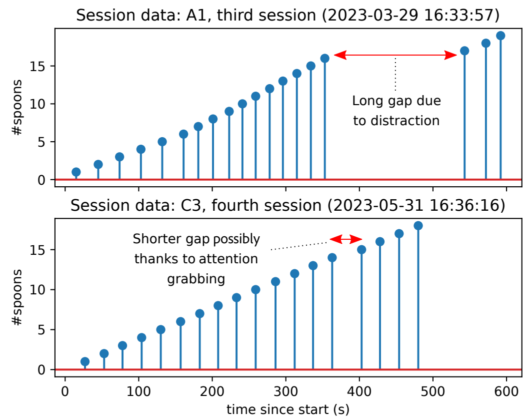

Figure 3: Time between consecutive spoons. Thanks to the engagement strategy, the time to recover from a distraction for patient C3 is much shorter than for patient A1 who does not receive any engagement.

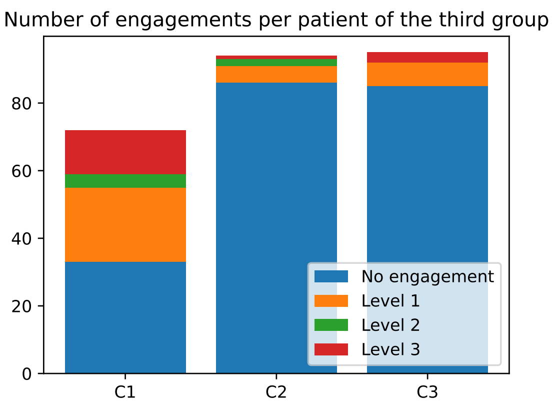

Figure 4: Number of times each engagement level has been triggered for each patient of group C. Observe that patient C1 required different engagement levels more often than the others.

The observed distractions are particularly interesting. The existence of such distractions is very evident upon close inspection of the data, even in groups other than C. For instance, see Fig. 3. The top part of the figure depicts a feeding session for a participant from group A who was distracted for a long period of time, as shown by the long gap between two spoonfuls towards the end of the session. The bottom part of the figure, on the other hand, depicts a distraction for a participant from group C. This time, the participant was distracted for a much shorter time possibly due to the robot's ability to recover their attention. Similarly, more distractions were observed with different patients from groups A and B that could be handled better with version C.

Let us focus now on distractions in group C, which employed the robot version with attention-grabbing capabilities. Figure 4 shows the accumulated times that each robot behaviour was used for each one of the three participants in group C. Participant C1 was easily distracted while participants C2 and C3 were not. It is observed that to grab patient C1's attention, the robot exhibited a lot of different engagement behaviours, switching between them as explained in Section 2.1. For the other two patients, the engagement strategies were required only occasionally, and the third level was not required. This is, naturally, the expected behaviour. From a total of 261 spoonfuls for the three patients of group C, 57 required some level of engagement equal to or greater than 1. However, 39 of these interactions took place with patient C1. Patients C2 and C3 seldom required calls for attention, and when they did, an engagement level beyond the first one was rarely used. A simple verbal prompt was enough to regain their attention.

Although the mechanism to change the level is very simple, it allows us to validate the usefulness of the engagement strategies, which is the objective here. This encourages the development of better decision-making algorithms that can decide at every moment the most appropriate engagement strategy.

5 CONCLUSIONS

In this paper, we have discussed the development and evaluation of a robotic feeding system that aims to support users' quality of life, autonomy, and dignity by allowing self-feeding, while also serving as a tool for caregivers. We conducted a study with 9 real patients in a hospital environment who used the robot for 5 consecutive days, testing different interaction approaches.

One key takeaway from this work is the importance of incorporating enhanced social aspects into the robot's interaction to improve its effectiveness and acceptance. The outcomes of the engagement strategies catching back the attention of users and the positive feedback from both healthcare personnel and patients, indicate the potential for this technology to significantly impact the lives of those in need. This potential is especially relevant for users with additional cognitive problems, who are more prone to distractions or losing track of the feeding activity.

The general opinion was that the robot was very helpful. The study has been very useful in gathering very promising ideas for improvement. These include different HRI strategies (e.g. encouragement or acknowledging and addressing the presence of family members in the room), better handling of food (e.g. taking into account meals with different textures, or introducing the spoon directly into the patient's mouth), and more customisation options for caregivers (e.g. switching robot versions to match the preferences and capabilities of the patient).

We observed that distractions usually occurred because the TV was on, but also due to visits from the health personnel or social interactions between roommates or family members. The robot should recognise the latter and taking into account the ethical implications involved in developing personalised cognitively assistive robots [9] balance the benefits of actively engaging in these situations.

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