Robots in the Home: A Novel Suite of Interactive Devices for Assisting with Disease Prevention and Meal Preparation

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***Abstract*—We describe the design, prototyping and testing of five robotic elements for in-home use. The robots are designed to be inexpensive and relatively simple. The set of elements is comprised of a robotic mosquito net system, an adaptive gripper, and several elements to assist in food preparation. Collectively, the elements form part of a wider *home*+ system being developed to aid people in everyday tasks within their own homes. Results from initial testing with prototypes of the robot elements are discussed.**

***Keywords*—robotics, home health, aging in place**

I. Introduction

As robotics transitions from industrial settings to the wider world, it is likely to revolutionize the daily lives of ordinary people around the globe. Inexpensive in-home robots such as the Roomba [4] already show the potential of relatively low-cost, simple robot elements performing domestic tasks.

In this paper, we introduce and describe a set of simple in-home robots collectively aimed at disease prevention and food preparation. Key design metrics for these robots included low cost (hundreds instead of thousands or tens of thousands of dollars), ease of construction, and rapid prototyping (inside one month from design concept to realization of prototype).

This work forms part of a wider effort, which we term *home*+ [3],[6] aimed at creating and evaluating a suite of relatively simple and inexpensive robots focused on domestic tasks within the home. The underlying philosophy is that the robots work with the human occupants to augment their capabilities, rather than doing everything for them, as might (more capable but more expensive and as yet not realizable) humanoid servants [7].

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The paper is organized as follows. The design concepts and process for each of the new robotic elements is described in section II. Section III contains the results of prototyping and testing of each of the designs. Discussion and conclusions are provided in section IV.

II. Robotic Elements - Design

A. Robot Mosquito Net

According to the World Health Organization, hundreds of millions of cases and several million deaths are caused each year by mosquito-spread malaria, yellow fever, and dengue [8]. Mosquito nets are a primary defense against mosquitos [2]. The mosquito net element introduced herein is designed to provide in-home adaptive protection, placing its net without taking up extra usable space. This is particularly important for people who are vulnerable, ill, or frail, and for whom manipulating such nets is difficult.

The design (Figure 1, section III.A) is an over the bed system with integrated lighting, extending horizontally before net deployment, and when not in use retracting and folding the net.

Figure 1. Left: Net system design concept. Right: realized system from underneath, net deployed showing integrated lighting.

B. Adaptive Gripper

The typical gripper (a.k.a. end effector) on industrial robots is a parallel jaw gripper. While suitable for the highly structured environment and predictable engineered parts typically handled by robots in factories, the design lacks the adaptability and compliance desirable in the home, where objects of a wide variety of shapes, sizes and masses need to be grasped.

Therefore, we designed a gripper with flexible fingers (Figure 2, below). Actuated by low pressure pneumatics, two or three flexible fingers, fixed to solid base, bend to enclose a grasped object, adapting their shape to it. A simple IR sensor is used to inform binary grasp/ungrasp control of the gripper.

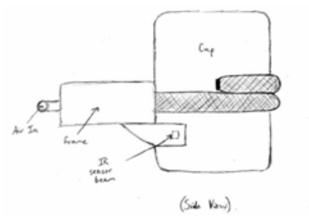

Figure 2. Flexible gripper design concept.

Realizations of the above design, augmented with a wheelchair as an adaptive cup holder and for handling operations in food preparation, are discussed in section III.B.

C. Spice Rack

Motivated by the needs of people in wheelchairs, whose ability to reach articles in the kitchen are limited, we next introduce a robot spice rack element. The requirement is for the robot element to work with the human, moving the spices in the rack to locations low and close to the edge of the counter.

The resulting design features a directly actuated rack base, with rotating shelves in which the spice containers are placed. The rack is counterweighted with dual torsion springs to assist with raising and lowering the structure. The shelves are free-rotating, using gravity to maintain the spices in a vertical posture regardless of the angle of the rack. The design prototype is discussed in section III.C.

D. Robotic Slicer

For many people, food preparation is both a time-consuming and tedious task. For infirm people or those with disabilities, it can be impossible, significantly reducing quality of life. The fourth element in the robotic set is a system for cutting, removing, and placing food, focused on slicing cakes.

The selected design (section III.D) integrates two off-the-shelf consumer products: a passive cake turntable, and a slicer. The slicer is designed to be moved (rotated to orient with the cake body), raised and lowered vertically (to cut, and remove slices). In combination, these motions combine to raise a cut slice, rotate it over a plate, and lower for placement. The design features an extra actuator to maintain sufficient pressure on the consumer slice to maintain grip on the slice.

E. Kitchen Assistant Station

The final robotic element extends the goals, and some of the robotic solutions, of the other elements, to realize a kitchen assistant workstation that can work with a human (possibly, but not necessarily, wheelchair-bound) to prepare a meal from basic ingredients. Specifically, we consider the case of preparing a salad, a task that requires fetching of the ingredients (done either by the human or another mobile element of *home+* [3],[6]), followed by local transport and chopping of some ingredients, the addition of spices, and mixing of the salad. This is an interesting and challenging case of human/robot interaction.

The design features a table top robot manipulator, with its end effector a three-fingered version of the adaptive gripper. A conveyor belt transports ingredients to and from the robot arm. The gripper can be manually replaced, with a chopping tool (a consumer chopper). The human interfaces with this system, and the spice rack element, at the side of the kitchen counter, to produce the meal, as shown in section III.E.

III. Robotic Elements – Prototyping and Testing

In this section, we present results from prototyping and testing of the five elements.

A. Robot Mosquito Net

The main base for the system was constructed from laser cut wood, with six radially oriented scissor mechanisms constructed of laser cut acrylic with 3D-printed rivets. A single motor rotates a timing belt, which rotates a center crank to actuate the scissors simultaneously. An aluminum frame serves as both support for the system and (at the top) rail guides for the scissor mechanisms. See Figure 3.

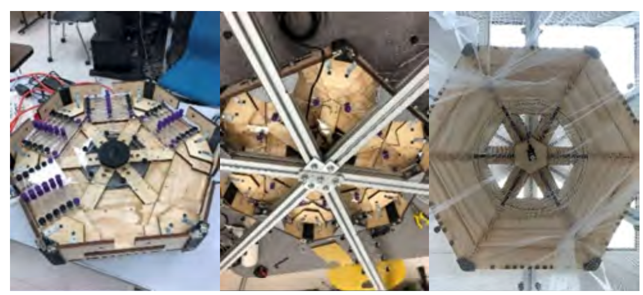

Figure 3. Net deployment system hardware details.

Figure 4 shows the system deploying the net. The goal of the design is to sense the inhabitant(s) as they approach or leave the bed, and automatically deploy the net. Presence of people is detected using IR motion sensors. A JIBO robot serves as the surrogate human in the experiment shown, with the JIBO providing motions indicating when the net deployment system should deploy and stow.

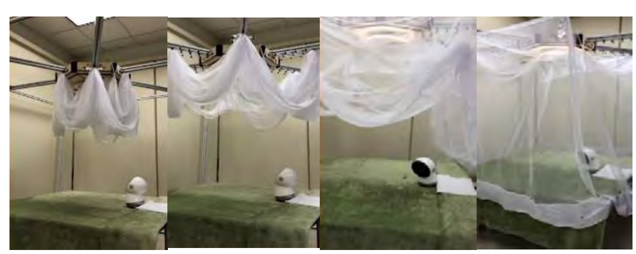

Figure 4. Mosquito net deployment.

B. Adaptive Gripper

Prototypes of the gripper, with two and three fingers, are shown in Figure 5. The bases were 3D printed to include conduits for the finger pneumatic lines and a central mounting interface. The fingers were made from single McKibben pneumatic muscles [5], with the covering braid sewn along the inner side to constrain them to bend inwards [1].

Figure 5. two- and three- fingered gripper versions.

A two fingered version of the prototype was first integrated with a wheelchair to create an adaptive cup holder. The IR sensor was mounted at the base of the cup holder, with the fingers actuated when the cup was sensed within 1/8 inch of the cup holder base. The gripper worked very well, grasping cups of a wide range of sizes, shapes, and materials, without spilling their contents (deficiencies of existing fixed size wheelchair cup holders) See Figure 6.

Figure 6. Gripper grasping large metal/small flexible paper cups

Application of the three fingered gripper in the meal preparation station robot element is described in section III.E.

C. Spice Rack

The prototype spice rack is illustrated in Figure 7.

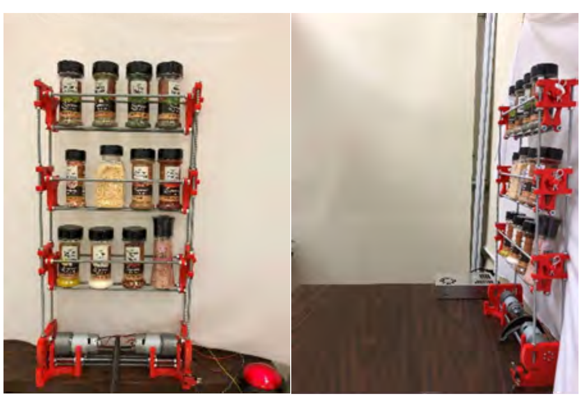

Figure 7. Spice rack prototype.

The rack performed its function as designed, with the counterweighting system proving particularly effective. Figure 8 shows the rack in operation. Notice in the left image in Figure 8 that the rack is triggered (by a press switch) by the end effector of a mobile robot (h+lamp, another element of the *home+* set of robots [6]). This illustrates a key feature of the robot elements presented here, that they be usable by either human or robotic occupants of the home environment. While the gravity-based rotation aligned the spice jars as designed, one issue encountered was that although the spice jars at the tip and middle of the rack were easy to grasp by the wheelchair-bound user, the ones near the base were still at an awkward distance away. This issue could be addressed in future versions (with higher mechanical complexity) by adding a translational element to the rack.

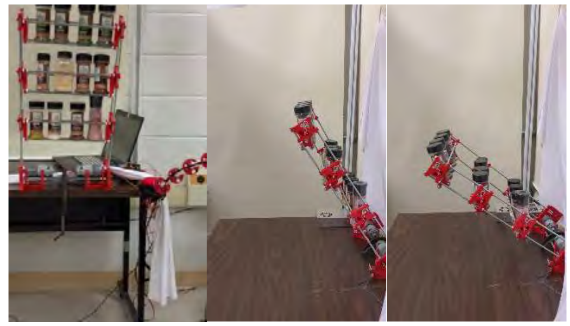

Figure 8. Spice rack in operation.

D. Robotic Slicer

The prototype integrates the two off-the-shelf consumer products (passive cake turntable and slicer) with a robotic tower with 3D-printed links to provide the necessary motions (Figure 9). Stepper motors were used to rotate both the cake and the cutting utensil. A linear servo was integrated to provide the slicing and lifting/lowering of the cake slice. Presence of the cake was detected by a force sensitive resistor.

Figure 9. Robot structure with slicer, turntable, and cake.

The resulting system was able to consistently sense, rotate to the appropriate part of, and cut and remove a slice of the cake. See Figure 10.

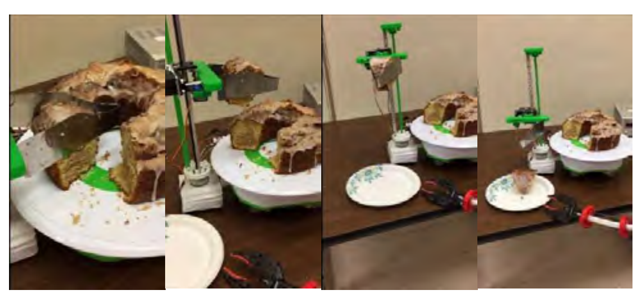

Figure 10. Slicer in operation.

E. Kitchen Assistant Station

The manipulator selected for the kitchen assistant station was a KUKA KR 6 R700 sixx (Figure 11). The three-fingered gripper had the fingers arranged at 120 degree angles around its "palm" (Figure 11), which open and close in unison actuated by a single pressure line. A vision system senses and tracks objects on the conveyor belt.

Figure 11. KUKA and conveyor – the core of kitchen assistant.

An example of collaboration between the kitchen assistant and a human to prepare a salad is illustrated in Figure 12. The human brings the ingredients, places them on the conveyor, changes the end effector to chopper, retrieves the chopped ingredients, interfaces with the spice rack element, and eats. The robot system performs the grasping, chopping, and transport operations.

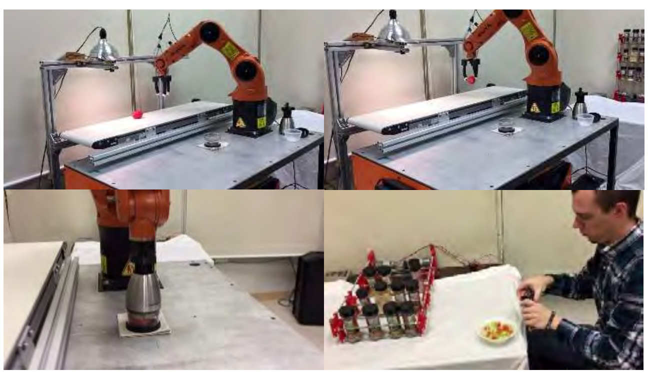

Figure 12. Salad preparation using the kitchen assistant. Top left: tomato entering system on conveyer. Top right: robot arm grasps tomato with three-fingered adaptive gripper. Bottom left: robot chops tomato with chopping tool. Bottom right: human uses spice rack element to season salad.

IV. Conclusions

We have introduced a suite of simple robots intended for in-home tasks. Generally focused on food preparation, the suite also includes a robotic mosquito net system. The design and prototyping process for these robots, along with results from initial testing with the prototypes, were presented.

The prototypes indicate the potential for producing low-cost, restricted-function robots to assist with domestic activities within the home. While the KUKA robot at the core of the meal preparation station is ultimately not a candidate for in-home application due to both cost and safety issues, it was used herein due to its availability in our laboratory. Alternative lower cost and safe manipulators are currently available, and even more inexpensive versions are expected to become commercially available in the next few years. The other components of the robot elements are relatively inexpensive, and either off-the-shelf or easily manufactured.

The results of the demonstrations show how simple robots can perform useful domestic tasks. The current prototypes, while not at a level suitable for commercialization, are illustrative of the wider potential for in-home robots, and are informing our ongoing research in teams of domestic robots, working with humans and each other. Our target audience is not only the elderly, invalids, and those with disabilities, but people in general whose condition and capability changes over (potentially long) periods of time. While all these categories may be able to use most of these devices, identifying the most high-priority requirements from each of these groups is an ongoing focus. Our current research is focused on the creation of the next generation of such *home+* elements.

References

[1] H. Al-Fahaam, S.T. Davis, S. Nefti-Meziani, and T. Theodoridis, "Novel Soft Bending Actuator Power Augmentation Hand Exoskeleton Controlled by Human Intention", Intelligent Service Robotics, pp. 1-23, https://doi.org/10.1007/s11370-018-0250-4, 2018.

[2] A.K. Bradley, A.M. Greenwood, P. Byass, B.M. Greenwood, K. Marsh, S. Tulloch, and R. Hayes", "Bed-Nets (Mosquito Nets) and Morbidity from Maleria", The Lancet, Vol. 328, Issue 8500, pp. 204-207, July 1886.

[3] C. De Aguiar, R. Fateminasab, C. Frazelle, R. Scott, Y. Wang, M. Wooten, K.E. Green, and I.D. Walker, "The Networked, Robotic home+ Furniture Suite: a Distributed, Assistive Technology Facilitating Aging in Place", Proc. 12th IEEE International Conference on Automation Science and Engineering (CASE), Fort Worth, TX, pp. 1067-1072, 2016.

[4] J. Forlizzi and C. DiSalvo, "Service robots in the domestic environment: a study of the roomba vacuum in the home", Proceedings HRI '06, 1st ACM SIGCHI/SIGART conference on Human-robot interaction, pp, 258-265, Salt Lake City, USA, 2006.

[5] B. Tondu, "The McKibben muscle and its use in actuating robot - arms showing similarities with human arm behaviour", Industial Robot: An International Journal, Vol. 24, Issue 6, pp. 432-439, 1997.

[6] S. Verma, P. Gonthina, Z. Hawks, D. Nahar, Y. Wang, C. de Aguiar, J.O. Brooks, I.D. Walker, and K.E. Green,"Design and Evaluation of Two Robotic Furnishings Partnering with Each Other and Their Users to Enable Independent Living", Proc.12th EAI International Conference on Pervasive Computing Technologies for Healthcare, ACM, New York City, NY, pp. 35-44, 2018.

[7] I.D. Walker and K.E. Green, "Architectural Robotics: Unpacking the Humanoid", Proc. 11th International Conference on Ubiquitous Computing (UBICOMP'09), Orlando, FL, pp. 28-29, 2009.

[8] World Health Organization, "Mosquito-borne Diseases", https://www.who.int/neglected_diseases/vector_ecology/mosquito-borne-diseases/en/