A Vision of the Patient Room as an Architectural-Robotic Ecosystem

Anthony L. Threatt[1], Jessica Merino[2], Keith Evan Green[1], Ian D. Walker[2], Johnell O. Brooks[3], Sean Ficht[2], Robert Kriener[2], Mary Mossey[3], Alper Mutlu[2], Darshana Salvi[2], George Schafer[1], Pallavi Srikanth[2], Peng Xu[2], Joe Manganelli[1], Paul Yanik[2]

Abstract— **Healthcare is becoming more digital and technological, but healthcare environments have not yet become embedded with digital technologies to support the most productive (physical) interaction between medical patients, clinical staff and the physical artifacts that surround and envelop them. This shortcoming is an opportunity for the architecture and robotics communities to interface with each other and the everyday users of healthcare environments. Our extended lab focused ten weeks on "sketching in hardware" a robotic, patient-room ecosystem we call home+ with the help of clinicians at the Roger C. Peace Rehabilitation Hospital of the Greenville Hospital System University Medical Center [GHS]. This early prototyping effort represents our vision for the larger robotic patient room, and identifies opportunities for more focused work on an Assistive Robotic Table (ART).**

I. Introduction

One of the current challenges in the healthcare industry is the cost of care. Insurance companies want accurate billings that meet the requirements for treatment at the lowest cost, requiring providers to spend limited time with multiple patients each day. Meanwhile, technologies in the room are numerous, some beeping and many with unrecognizable displays, causing patients unease. Researchers must be cognizant of the factors related to a patient's willingness to accept new technologies [1] because their quick adaptation is important when cost is a prime consideration, while still ensuring a careful balance between independence and engagement [2]. Our approach to aging in place [6], [7], [8] represents a significant departure for robotics in healthcare.

The Assistive Robotic Table (ART) is one component of "home+," the robotic, patient-room ecosystem which aims to augment the interior to become a more inviting, responsive and accommodating environment to increase the quality of life for people aging in place. Given the complexity of our ambition at room-scale, our research team of architects, electrical and computer engineers, and human factor psychologists elected to focus ten weeks on developing the home+ vision for the patient room as an architectural-robotic ecosystem, rather than intensively focusing our efforts on the ART component in isloation. We focused on a small set of design parameters and, similar to [9], quickly prototyped our architectural-robotic interventions as an integrated vision.

[1]School of Architecture, Clemson University, Clemson, SC 29632 USA `anthont, kegreen@clemson.edu`

[2]Department of Electrical and Computer Engineering, Clemson University, Clemson, SC 29632 USA `jmerino, iwalker@clemson.edu`

[3]Department of Psychology, Clemson University, Clemson, SC 29632 USA

Under recently awarded funding, fundamental ART research involving hardware, sensing and usability is being conducted by the Clemson University investigators in a multi-year cycle of iterative design and evaluation informed by our observations, interviews, surveys, card-sorting and Modified Delphi methods aided by the help of clinicians and the use of the home+ lab within GHS. ART is being designed with attention to a host of parameters, such as safety, performance, usability, aesthetics, robustness, cleaning-ease and cost. We are currently developing ART's capacity to foster a companionable, social relationship with users as stated by [3] and [4], using a reward-based system to cultivate a higher degree of interaction, increasing the rate of recovery and providing patient and clinician with a higher-rated user experience. Not all of these could be considered in the short-term of the home+ vision presented in the video.

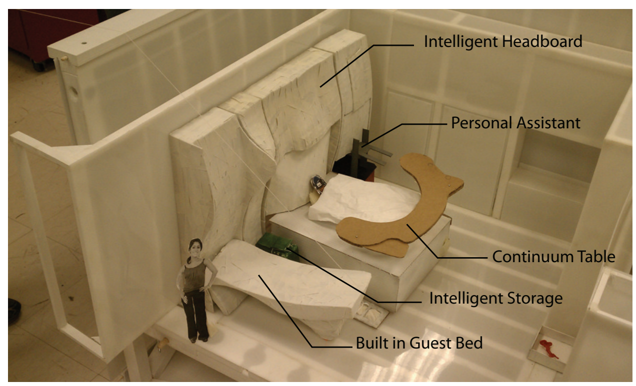

Fig. 1. A Vision of the Patient Room as an Architectural-Robotic Ecosystem

II. Definition and Envisioned Patient Room Ecosystem

In our 10-week focused effort, we envisioned the architectural-robotic ecosystem, home+, having four key components (Figure 1):

1. A **Continuum Table** gently folds, extends, and reconfigures to support therapy, work, and leisure activities.

2. A **Personal Assistant** retrieves objects that are stored around the room and away from the bed. The robot uses a vision-based recognition system via wireless communication to ensure the robot retrieves the correct item.

3. **Intelligent Storage** manages, stores and delivers personal effects, including medical supplies, and communicates to caretakers when eyeglasses and other belongings are not

moved over a period of time. It accommodates audio and touch screen computing technologies.

4. An **Intelligent Headboard** adapts to the profile of the patient. The morphing surface periodically changes the patients position to ensure against bed sores.

These four aspects of the ecosystem recognize and communicate with each other in interaction with humans and, we envision, with other home+ components. Note that figure 1 and figure 2 are merely sketches of how the system might look and behave. Consequently, these figures represent not a fixed, pre-determined design, but instead, the current state of our research team's continuing iterative design and evaluation development of the system.[1]

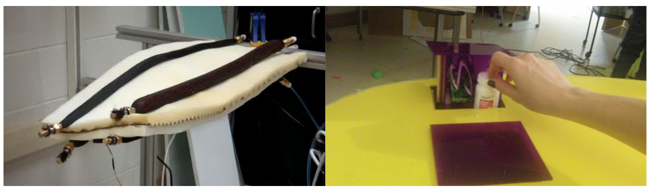

Fig. 2. Left-Pneumatic Muscles; Right-Intelligent Storage

III. ART's Continuum Robotic Surface

The focused efforts to prototype the room-scaled architectural-robotic environment, aligned with our human factors investigation in the hospital, helped the team determine that ART's integrated, reconfigurable, continuum surface technology is most important to rehabilitating stroke victims. The compliant, continuum-robotic surface is made up of pneumatic muscles (Figure 2) with embedded temperature, force, and proximity sensors that control actuators. The table's robotic surface provides patients immediate sensor feedback and encourages off-hour therapy sessions.

IV. A Scenario

Lucille has had a stroke and has right hemiplegia (paralysis of the right extremities). To complicate matters, the stroke has caused her to develop aphasia (speech and language problems): Lucille is frustrated when she's unable to recall the smallest memory. When Lucille enters the hospital room for the first time, she is entering an intelligent suite of robotic-embedded furnishings that "grow" with her changing needs. Lucille is unsure of herself and her new surroundings; but within a few hours, her intelligent home+ suite is able to learn her preferences and those of the hospital staff to best support her recovery. The home+ ecosystem is designed to help Lucille regain her speech and language capabilities as well as functioning for her right side. Lucille uses the table each day, placing her arm on the table's continuum surface, finding the lights on the right side, recognizing the color changes, and reading passages off of the table's touch screen. These activities help Lucille improve more quickly.

The headrest positions the cushions around her appropriately. Lucille has a place to store her glasses, watch, and cellphone. Larger items are retrieved for her by a mobile robotic assistant. The table sits by her side, providing her comfort and off-hours rehabilitation services. While medical staff routinely attend to Lucille, what's constant in Lucille's treatment and recovery is her intelligent home+ suite featuring ART.

[1] http://youtu.be/a9Jt36Q8H9c

V. Conclusions

Our research team has previous experience in creating architectural-robotic environments [10], [11], and has used the focused effort reported here to envision the home+ ecosystem and to springboard intensive, funded research of one of its components, ART. This paper and accompanying video suggest how robotics researchers responding to complex challenges as found in healthcare can envision the larger ambition, the robotic "ecosystem," towards identifying and contextualizing more discreet research undertakings.

Acknowledgment

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