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Morphological Switching Robots to Support Independent Living for Older Adults

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***Abstract*— Robots have the potential to augment the care provided by humans in enabling older adults to lead a healthy and independent lifestyle. However, to be ubiquitous, robots must build trust with older adults and provide a safe interaction environment, while still maintaining functionality. Current robots built using rigid links, actuators, and sensors provide accurate movements and can handle large loads, but the benefits of these features are compromised by cost as well as retrofitting safety features, and a complex control policy. On the other hand, the new field of soft robots is inherently safe but suffers from reduced load bearing ability, speed, and accuracy. This work proposes a new concept called *morphological switching* that can overcome the limitations of external rigid and soft robot configurations. Morphological switching is the ability of the robot to morph its structure from a rigid configuration to a soft continuum configuration. We present the challenges to translate the concept of morphological switching for adult care and support tasks.**

I. Introduction

The world population is aging – the WHO estimates by 2050 there will be 2.5 billion over age 60 ("Population Reference Bureau," 2020). Though aging may be accompanied by impairment in mobility, perception, and/or cognition, most older adults still prefer to remain living independently and maintain as much autonomy as possible. However, 35% of older adults still require support with Instrumental Activities of Daily Living (IADLs) such as maintaining the home, preparing meals, and health self-management [1]. Such care was traditionally provided by families or professional caregivers [2]; however, increasing work, personal obligations, and cost have rendered this source of support less viable. Consequently, older adults continue to try to carry out these tasks themselves – many of which require reaching in high places or bending down low – both of which can lead to falls and the subsequent need for surgery, rehabilitation, or relocation. The National Institute on Aging estimates that one in three older adults falls every year [3] – this rate could be reduced with robotic assistance.

It is widely recognized that robots have the potential to assist adults with IADLs in their own homes. Our recent studies have reaffirmed the adults' willingness to accommodate robots in their lives [4, 5], but long-term use and effectiveness still depend on building trust between robots and humans. Understanding and modeling trust is complex and dependent on the context, preferences, and attributes of the human [6]. Trust may be increased through a combination of reliable and precise robotic assistance combined with safety and adaptability, especially when a robot is in close proximity with a human (e.g., object retrieval). In this work, we present a novel robot design that addresses these concerns. We also describe the different challenges that need to be effectively solved before this technology can be successfully deployed and our preliminary thoughts and available resources to tackle them.

II. Morphological Switching Robots

Structures that can morphologically switch between rigid and soft configurations [7] can lead to unique service robots that are ideal for assisting adults. Morphological switching implies that the robot structure can toggle between a conventional jointed configuration that provides extreme levels of accuracy and precision, and a soft continuum configuration that exemplifies adaptability and dexterity. This concept maximally overcomes the limitations of designing robots with either purely conventional joints or soft continuum links by seamlessly spanning the space of rigid and soft attributes. The ensuing robots are compact, cost effective (< $3,000), require fewer sensors and can be potentially deployed with simplified controls. In our preliminary work, we demonstrate a possible embodiment of a morphological switching configuration where a pneumatically actuated soft continuum arm (SCA) is nested inside a rigid link known as Variable Length Nested Soft Arm (VaLeNS) (Figure 1) [8]. The VaLeNS is mounted on a mobile platform to increase its capabilities.

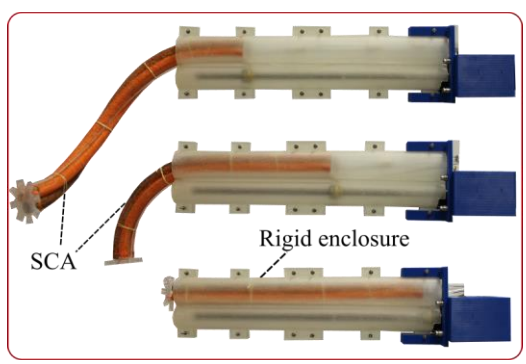

Figure 1: Example of a morphological switching robot: Variable Length Nested Soft Arm (VaLeNS) prototype

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In a simple scenario of an adult losing his/her glasses on the floor (Figure 2), the robot demonstrates sufficient precision to pick up the glasses (Figure 2(a)), and considerable safety and adaptability (Figure 2(b)-(c)) in handing them to the adult.

The rigid link is used for operations that require precision and force transfer (such as opening a kitchen cabinet door in Figure 2(d)-(f) and the SCA is extruded when greater reachability and adaptability is required (such as reaching for a fragile ceramic from the interiors of the cabinet in Fig.2(g)-(i).

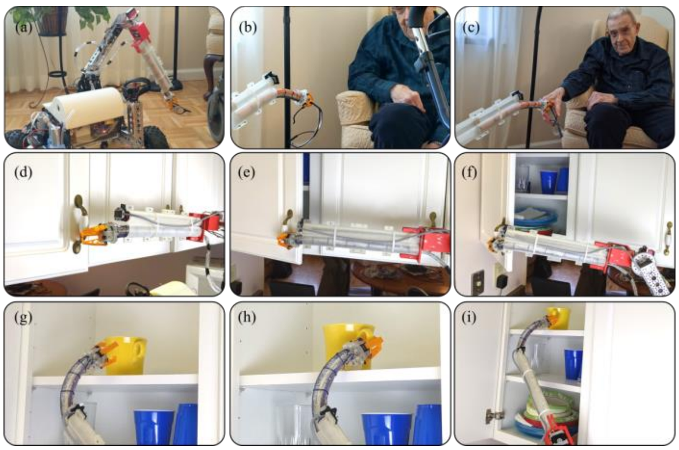

Figure 2: Our preliminary work shows the promise of morphologically switching robots in adult care. VaLeNS arm that can be extruded depending on adaptability and safety of the task required.

All the above demonstrations are controlled by a human user (not the older adult) using a graphical user interface (GUI).

III. Challenges

Translating the concept of morphological switching into functional service robots that can assist older adults with IADLs involves multiple complex tasks and a combination of thoughtful robot design and robust control. In addition, user preferences with respect to robot autonomy must be understood.

The work will benefit from a participatory design/user centered iterative design cycle in the CHART apartment [9] and the McKechnie Family LIFE Home, [10] which provide simulated home environments for research. Evaluating robots in these contexts will not only enable us to improve the robot design to fit the needs and preferences of older adults, but also provide a range of older adults with opportunities to learn about and experience this potentially useful technology.

Acceptance of soft robots as assistive devices for older adults: Human-robot interaction research has primarily focused on older adults' preferences when interacting with a rigid link robot. We will demonstrate the working of soft robots through different methods, such as pre-recorded videos, online survey, and interviews that will elicit older adults' needs and preferences for morphologically switching robots in their personal/ domestic environment. Open research questions relate to safety versus precision; specific tasks for which users prefer soft robots vs. rigid robots; novel use-cases where morphologically switching may occur during the task, when interacting with an older adult.

Development of an appropriate user interface for older adults: In certain contexts, older adults prefer to retain high-level control of the robot rather than permit full autonomy [11]. We will develop a direct input method using a visual interface with input keys that will directly indicate the corresponding motion of the robot. In addition, we will have the view of the camera on the robot and the camera that is at the end of the soft continuum arm. Care will be taken to maintain readability with large fonts on the command buttons to accommodate users with limited vision. The user interface will be iteratively developed and tested with older adult target users to improve usability and user trust.

Assessing control and interaction preferences: We will directly assess the ability of older adults' with and without mobility disabilities to interact with the robots performing different tasks such as removing obstacles from the floor, searching and inventorying items in the pantry, and emptying the dishwasher. We will observe (and video) interactions in the simulated home spaces to identify different contextual needs. We will identify the challenges in using the robots for a variety of older adults with ranging physical capabilities. In addition to observing older adults interactions with our morphologically switching robot, we will interview participants about their perceptions of the robot proximity, safety concerns, trust factors, and willingness to use it in their own homes. We will develop deployment recommendations for these contexts and user groups that will include training and education needs for potential users.

In summary, we have presented a novel design concept known as morphological switching and demonstrated its feasibility to perform IADLs. The proposed work has a direct impact on US healthcare as the morphologically switching service robots have multiple benefits such as augmenting support during social distancing, reducing falls risk, and enabling independent living..

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