Smart Spray-on Clothing for Disabled and Older Adults in AAL Settings

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ABSTRACT

This paper envisions a futuristic scenario with smart clothing for disabled and older adults using spray fabric combined with nanosensors. First we show the importance of assisting older adults and disabled people with the task of dressing themselves. Then, we briefly survey some technologies already developed which can be applied in our proposal. Smart clothes can be a great aid in dressing up, but can also be used to automatically collect information about the well-being and behavior of their users. We also present other possible scenarios that could benefit from our proposal.

CCS Concepts

•Human-centered computing → Ubiquitous and mobile computing systems and tools;

Keywords

Dressing assistance; people with disabilities, spray-on clothes; ad-hoc nanonetworks

1. INTRODUCTION

Technical advances reinforce the optimism from researchers to envision a future where older adults, people with disabilities and/or with cognitive decline can perform their daily living activities independently. Currently, the efforts in Ambient Assisted Living (AAL) strive toward solutions for assisting a person's daily living and working environment to enable them to stay active longer, remain socially connected, and live independently into old age. The developments of this area provide support to older adults by using intelligent and pervasive computing, for example by designing systems capable of monitoring and notifying about risky scenarios, like fall detection systems, or to provide assistance to complete daily activities [24].

The most common daily activities requiring assistance are bathing (showering) and dressing [18]. According to the U.S. National Science Foundation (NSF), "Physical disabilities due to illness, injury, or aging can result in people having difficulty dressing themselves, and the healthcare community has found that dressing is an important task for independent living". For that reason, the NSF has designated near to $1.2 million USD to research on robots to dress the elderly [3].

The current market provides different options of assisting devices that leverage specific tasks when dressing, for example by helping to put on buttons, to lace shoes easily, using clips for pullup trouser and sticks to push/pull socks without having to stretch or bend over [1]. But these devices still need abilities that can be inappropriate for older adults, people with dementia or with injuries.

Work is being done on the design of robots for dressing assistance, but this is still an open field for robotics with different challenges, like handling different fabric materials and the varying posture from persons during assistance [15]. In this paper, we propose an scenario where people are dressed through fabric in spray, a technology already in development.

The Fabrican company [2] presented in 2010 the product ©Spray-on fabric which consists in liquefied fibers that allow textiles to be sprayed out of a can or spray gun. As the video in [4] shows, the fabric is sprayed straight onto a body, and when the solvent evaporates, the fibers will form a garment. This technology can be used in more applications besides fashion because of its properties, like its feature of being sterile allowing its use as bandage, and its feature to absorb oil that can be used for cleaning purposes.

Our proposed futuristic scenario is given by combining the liquefied fibers along with smart nanotextiles that will be used to assist in dressing, but additionally will monitor the users in others activities. Nanotextiles is a new technology that can be used to sense locally different aspects, for example health indicators like pulse, temperature and humidity. Also, these textiles can feel if and how they are being touched, so they can act as switches, antennas, etc.[30]. We propose to take advantage of the properties of nanotextiles to communicate with each other, so they act as motion capture technology in order to infer daily activities [29].

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A clear advantage of this technology would be its flexibility to adapt to different complexions and physical disabilities. However, there are still challenges to be solved for its viability. In section 2 we show the current technologies related to this idea. Section 3 shows a future scenario using this proposal, along with more possibilities and challenges detected so far. Section 4 indicates some final remarks.

2. RELATED WORK

The devices developed in [1] comprise a wide range of advances, from simple zip pullers, buttoning aids passing and dressing sticks to rapid dressing assessment kits, all of them mainly focused on assisting older adults with their dressing tasks.

In recent years, robotic assistance for dressing has been under development [6, 19] although it is still considered an open problem. Some challenges faced in this area, are the interaction with non-rigid clothing materials and the adaptation to changes in posture from the person being assisted [15]. A key aspect when dealing with robots, which represents a complication, is recognizing and exploiting the degrees of freedom necessary to accomplish the proposed tasks. For example, the degrees of freedom in the context of non-rigid objects poses challenges that are significantly different from the rigid case [27]. Additionally, even tough robots have demonstrated to be helpful in daily living activities [17], there is still some reluctance from older adults to adopt the technology as a support in their daily activities [28].

Another proposal for dressing assistance consists in giving instructions via verbal indications; such system uses a vision module to monitor the person motion and determines if the user is following the instructions, while it infers mobility limitations [14].

On the side of monitoring, which is also a proposal in this paper, the sensors play an important role because the information they capture is analyzed to provide intelligence [13]. Some examples of sensor devices that have been proposed in the literature are: smart watches, activity trackers, healthcare devices and many others. However, it is desirable that the devices be less cumbersome, more transparent and adapted to different users while keeping low prices. Wearable sensors [21] are a good approach to keep a tradeoff between intrusiveness and monitoring.

Research in nanotechnology is pushing the evolution of wearable sensors, making sensors less obtrusive, and allowing them to be incorporated into wearable devices with the purpose of monitoring physical variables for medical purposes [16]. Despite the efforts in the development of nanotechnology in clothes, there are still barriers, for example the difficulty of the integration of electronic and textile materials and the poor durability of smart capabilities [30].

3. ASSISTING CHANGING BOOTH

For our proposal, we assume that several of the technological challenges previously mentioned have been surmounted; for example, the integration of nanosensors in fabrics, and a good performance of these nanosensors to capture and transmit information. We also assume that the technology of spray-on fabric has evolved and the materials can be reused after a procedure of re-liquifying the fibers.

Our proposal consists in a space, that we call a *changing booth*, where a person enters and is dressed using the spray technology. Additionally, the fabric is mixed with nanosensors that will be used the whole day to monitor the activities of the users. Next, we show an example of an scenario using our proposal followed by some health problems that could be solved. Then we show some challenges identified.

3.1 Futuristic scenario

Mario is an older adult of 84 years old, he has difficulty to move and has mild dementia. He wakes up from bed and enters the *assisting changing booth*, where he will be dressed. He takes the position shown in Figure 1 with his arm a little raised. Two robotic arms will spray to his body a garment as depicted in Figure 1. The previous clothes used by Mario will be entered in a recycling compartment for further use.

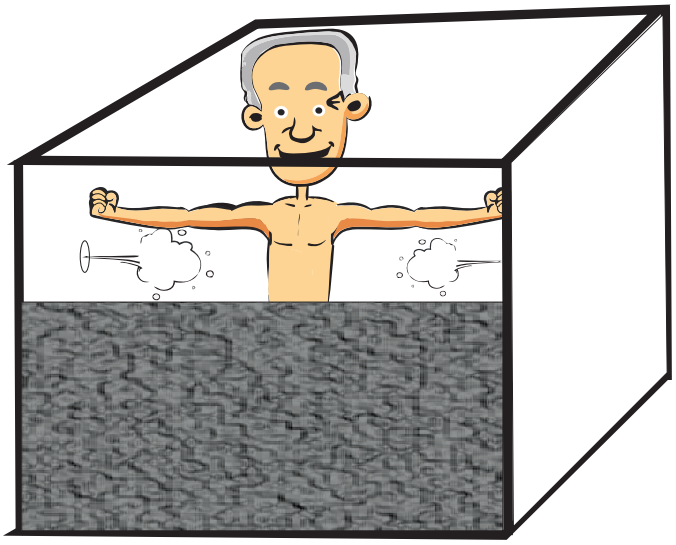

Figure 1: An older man being dressed using spray with nanotextiles

As soon as he has finished using the changing room, the nanotextile sensors start finding neighboring sensors to form an ad-hoc network such as the one depicted in Figure 2; this includes finding the relative position of each nanodevice within the network as well as to Mario's body. For instance, those located near Mario's heart will sense a stronger signal coming from his heartbeat, so it will be easy to infer their position, and take this as a reference point. Other pieces of clothes will also have their own reference points to know where each node is located; for instance, the pants could have the knees as reference points, as the movement and bending will be very characteristic and easy to be identified by sensors. Therefore, each piece of cloth will form its own ad-hoc network, which will be extended by connecting to the contiguous networks in the adjacent pieces of cloth. A smarter, more powerful device (as an smartphone) could provide communication to external networks, e.g. the Internet, for monitoring and visualization purposes.

During the day, Mario performs his activities while the nanosensors are capturing his pulse, the amount of perspiration, the chemicals released from his perspiration, his type of breathing, the pressure against objects, etc. Additionally, as the sensors are arranged in a mesh and its location is known respect to Mario's body, they can be used to detect his positions and movements, like sitting or walking, as

depicted in Figure 3.

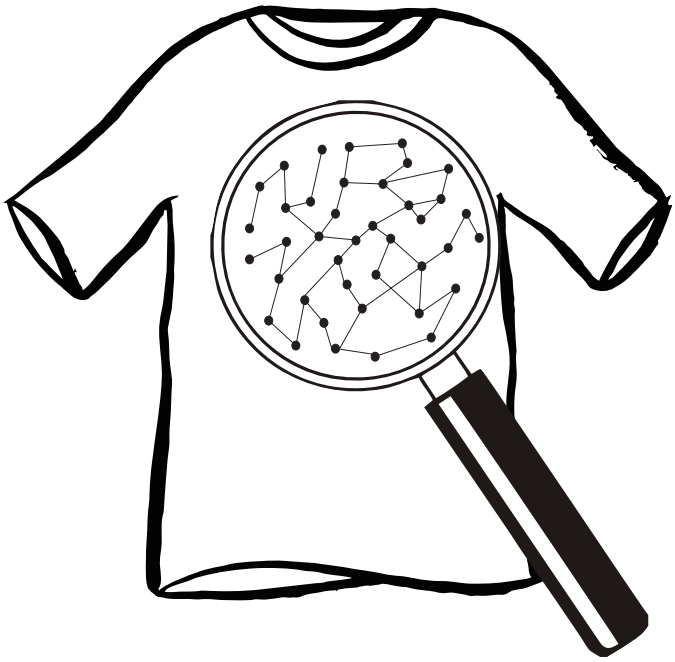

Figure 2: Nanosensors connected in the garment.

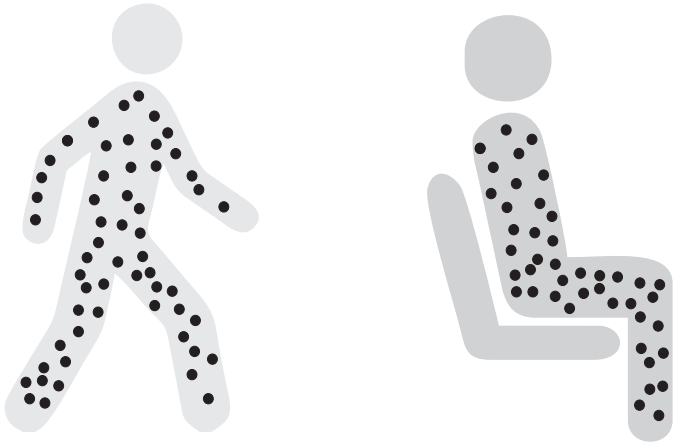

Figure 3: Movement caption through nanosenors.

At night, Mario starts breathing faster and tries to get up because he suffers a reflux attack. An analysis using the data captured by the sensors, included in his pijamas, identify this situation by the movement of his chest and the movement from his intention to get up. This produces an alert that notify this situation to her daughter, who is sleeping in the next room, to come to attend and calm him.

3.2 Further possibilities

In this section, we indicate some aspects where our proposal could be beneficial and provide advantages in other health scenarios.

Urinary incontinence.

Aging usually brings health decline such as cardiovascular diseases, kidney failure, dementia, unconsciousness, etc [26]. The outcome of many of these diseases is the use of an urinary catheter. Elderly people are required to use these urinary catheters for longer periods of time, which causes difficulty in wearing clothes [25]. Using our proposal for dressing would permit to design clothes that will not touch or cover the catheter if necessary.

Pressure Ulcers.

When elders can not move freely anymore, they usually spend long periods of time in one same posture [7]. This causes circulation issues and eventually ulcers appear. Our proposal can reduce the pressure over ulcers by sensing pressure and reducing friction with clothes. Also the state and evolution of the ulcer can be analyzed through humidity and temperature measurements.

Arthritis.

Elderly arthritic people often have trouble finding appropriate clothing that fits well and is easy to put on and take off because of the physical changes associated with the disease [12]. Moreover, the continuous tracking of movements through nanosensors in clothes can provide more information about disease's evolution for physicians.

Rehabilitation.

Fractures of upper and lower extremities occur at any age. When people suffer an injury or surgery of their extremities, dressing and undressing becomes difficult and sometimes depend on other people to assist them. The continuous dressing and undressing to perform daily activities such as toileting, taking showers, etc. represents a very hard task. The fabric in combination with sensors can ease the caring work and enable new forms of rehabilitation and physical therapy [22].

Muscle weakness.

It has been demonstrated that electric pulses can be detected in the skin to predict movement intentions and can help in coordinating feeble or weakened muscles for use in exoskeletons [8]. The converse has been also tried, applying mild electric currents in the skin to stimulate a weakened muscle [23]. The detection of electric pulses can be made through clothes equipped with nanosensors and then activate an exoskeleton assisting older or disable people. On the other hand, clothes can also beam electric pulses using the nanosensors embedded in fabric to stimulate muscles.

3.3 Challenges

Our proposal considers the use of already existing technologies, some in full production, although others still at early stages. Nonetheless, we have outlined some remaining challenges to make our proposal a reality:

- Nanonetworking. The nanosensors embedded in the fabric of clothes will be able to communicate using nanonetworking techniques. However, as discussed in [5], there are still many open issues regarding the integration of nano-components, communications in terahertz bands, formation of opportunistic nanonetworks, and others.

- Big data. The integration of different sources of data, its standardization, its continuous generation, analysis and storage are still challenges in the big data field as mentioned in [9].
- Artificial intelligence. While spraying on the body might require less critical fine and precise movements is still necessary more development in robotics of these topics in order to provide better assistance. The performance of the spray clothing will depend on the ability from the system to recognize the shape of the body and the position from the users through an effective vision module.
- Privacy. Due to the amount of sensors attached in fabric, and to its personal nature, the data and information generated should be treated and preserved following user constrains about use, access and storage of data [20].
- Feasibility. Economic and financial concerns would arise. As any new product the price and quantity should be adjusted according to the law of supply and demand. Environmental concerns are also considered, although as demonstrated it is possible to create reusable fabrics.
- User acceptance. Usability tests and proofs of concept should be ran to refine design and develop a final industrial design [11, 10].
- Public perception. The approach could limit or encourage creativity among population. Fashion designers could lose work opportunities. But in the other hand, people could have access to design and create their own clothes and vestment perfectly fitted.

4. FINAL REMARKS

With the world population aging at a faster pace in the upcoming years, automated solutions to health monitoring, assisted living, etc. are seen as viable possibilities for attending the needs from the older population. In this context, we propose smart clothes equipped with sensors, as a technological aid for assisting in the process of dressing up. Although most of the basic technologies needed are already in existence, some are still in the early stages of development, and also the integration of all of them is not a trivial task. However, we believe that the enhancement in the quality of life of the users of such proposed system is worth the efforts to overcome the challenges for making it a reality.

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