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Robots in Elderly Care

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Abstract

Low birth rate and the long life-expectancy represent an explosive mixture, resulting in the rapid aging of population. The costs of healthcare in the grey society are increasing dramatically, and soon there will be not enough resources and people for care. This context requires conceptually new elderly care solutions progressively reducing the percentages of the human-based care. Research on robot-based solutions for elderly care and active ageing aims to answer these needs. From a general perspective, robotics has the power to completely reshape the landscape of healthcare both in its structure and its operation. In fact, the long-term sustainability of healthcare systems could be addressed by automation powered by digital health technologies, such as artificial intelligence, 3D-printing or robotics. The latter could take over monotonous work from healthcare workers, which would allow them to focus more on patients and to have lesser workload. Robots might be used in elder care with several different aims. (i) Robots may act as caregivers, i.e. assist the elderly, (ii) they can provide remainders and instructions for activities of daily life and safety, and/or assist their carers in daily tasks; (iii) they can help monitor their behaviour and health; and (iv) provide companionship, including entertainment and hobbies, reminiscence and social contact. The use of Robots with human subjects/patients raise several sensitive questions. First of all, robots may represent information hubs, and can collect an incredible amount of data about the subjects and their environment. In fact, they record habits such as sleeping, exercising, third persons entering in the house, appointments. Communications may be continuously recorded. Moreover, by connecting with medical devices, they can store medical data. On one hand, this represents a very powerful tool to collect information about the single subject (precision medicine), about disease (thus eventually finding new signs and symptoms through artificial intelligence by machine learning and deep learning) and about his/her habitat. On the other, this powerful instrument may represent a dramatic treat to the privacy of the subjects and their caregivers. Therefore, robotics represents an ethically sensitive field. Care robotics bear the risk of reducing human contact, of increasing the objectification and loss of control of the elderly, of losing the privacy and personal freedom of the individual (especially when robots may perform restrictive interventions). Moreover, the use of robots in elderly care may raise in the risk of confusing between reality and appearance, with a potential risk of deception and infantilization of the elder.

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Introduction

The costs of healthcare in the grey society are increasing dramatically, and soon there will be not enough resources and people for care. Low birth rate and the long life-expectancy represent an explosive mixture, resulting in the rapid aging of population. By 2060, one out of three Europeans will be over 65, resulting in an increase in the ratio between inactive population and workers (from 1:4 to 1:2) (European Union, 2015). At present, Spain and Italy are the oldest societies in Europe with 18.1%, and 20.2% over 65 respectively. The increasing isolation of the elderly requires extra care and monitoring of qualified professionals to ensure the welfare and health. However, it is difficult to ensure the continued presence of professionals. The cost of assistance for the elderly increases daily and will soon become untenable. Therefore, we must reinvent our care system for the elderly, taking advantage of new ICT products and robotics to make more efficient and less expensive elderly care, i.e. to provide better and cheaper assistance. The great challenge that society faces is identifying innovative approaches to help a cohort with chronic illness. In the EU countries, WHO projections suggest that 88 million people will die directly due to a chronic illness. In addition, the number of people over the age of 65 (retirement age) will increase from 90 million in 2012 to 155 million in 2060. There will be also a dramatic increase in the percentage of the population over 80 years from 24 million in 2012 to 70 million by 2060, reflecting the effects of increased longevity, partly due to better health care in EU countries.

This context requires conceptually new elderly care solutions progressively reducing the percentages of the human-based care. An example is given by the research on robot-based solutions for elderly care and active ageing.

Robotics has made remarkable progresses in the last few years, in many different fields of work (see Yang et al. 2018, for a review), and medicine and healthcare are two fields in which their use is becoming mandatory.

Many diseases can be avoided or at least delayed, if certain risks and diseases are detected in early stages. Intelligent technological solutions will enhance human perception and therefore provide conditions for support that will lead to a better quality of life. Connected and combined information on individual characteristics, behaviour and circumstances and related individually-tailored exercise, nutrition and cognitive training can support people to maintain health within their resources and capabilities. Thereby people are empowered to be self-reliant experts for their own health and their desire to live with dignity as long as possible. With the emergence of an aging society the need to prevent long-term care or delay general health deterioration, technical assistance in form of human-robot-interaction (HRI) and socially active robot (SAR) based solutions should be implemented in a familiar setting and used long time before medical or care intervention is needed. By means of developing and using such applications in the living environment of older adults, improved security and support for the preservation of abilities and independence is provided, thus enhancing and maintaining the quality of life of older adults by HRI support for Active and Healthy Ageing (AHA). Active and Healthy Ageing (AHA) concerns optimizing opportunities for health, participation and security to enhance quality of life as people age. It applies to both individuals and population groups. 'Health' refers to physical, cognitive, psychological and social well-being. 'Active' refers to continuing participation in social, economic, cultural, spiritual and civic affairs, not just the simple ability to be physically active or to participate in the labour force (WHO definition).

An ageing population places a huge demand on our health care systems, up to a point that it threatens to overwhelm the capacity of the society to take care of the elderly. An ongoing trend is that elderly persons are encouraged to stay in their own residences as long as possible. However, the excellent care facilities that are typically present in senior citizen homes are more remote and less accessible when living at home. Thus, there is a severe risk of people becoming socially isolated and of people not being able to take proper care of themselves. Elderly people eat, drink and move less and worse than they should. Their condition deteriorates, especially if they suffer from a chronic disease and other co-morbidities. Thus, although independent living reduces the demand for care, if not enhanced by accompanying solutions, it also reduces the quality of care. Possible solution to this issue comes from technological developments, such as the robotic ones. Sustainability of active and healthy ageing could be secured by complementing human care by specific activities and support offered through intelligent specialized robots, which may be eventually connected to smart home devices.

Care robotics represent a field of robotics that has been emerging over the last decade as a response to demographic developments in the developed world. Countries like Japan have pursued the use of robots in elderly care for a long time. Europe is now pursuing similar developments, with the European research agenda including care robotics for the elderly as a part of their strategies for aging, and the European Strategic Research Agenda for Robotics in Europe 2014-2020 (SPARC) identifying assisted living robots as part of the growing market of consumer robots. Similarly, the UK Robotics and Autonomous Systems (RAS) strategy RAS 2020 includes reference to health and social care robotics for the elderly population.

On the other hand, it is ethically relevant to ensure that robots introduced into elderly care do actually benefit the elder, and they are not merely designed to reduce the care burden on the rest of society. In fact, amongst the fundamental human rights established in documents such as the Charter of the United Nations and the Universal Declaration of Human Rights, the right to a standard of living adequate for health and well-being is fundamental to the elder; this includes the right to private and family life, and to freedom from degrading treatment and discrimination. Friedman and Kahn (2003) identify and discuss several human values that are implicated in technological design: human welfare; ownership and property; privacy; freedom from bias; universal usability; trust; autonomy; informed consent; accountability; identity; calmness; and environmental sustainability.

Assistive Technologies

If we consider assistive technologies in a broad sense, the human kind developed such devices since several centuries. The wheel-chair was first developed in China in the VI century and was patented in 1886; the first motor wheel-chair was developed during WWII. Much older is the “walking stick”, whose origin goes probably back to the dawn of time. Primitive man used a branch just for support. Today’s walking sticks are equipped with sensors, GPS, alarm systems when are not fully replaced by exoskeletons.

Robotic assistive technologies are now proposed in the care of autistic children, as catalysts of for social behaviour, in elderly care and in stroke rehabilitation (gait training, upper arm recovery, wrist rehabilitation).

Robots might be used in elder care with several different aims. (i) Robots may act as caregivers, i.e. assist the elderly, (ii) they can provide remainders and instructions for activities of daily life and safety, and/or assist their carers in daily tasks; (iii) they can help monitor their behaviour and health; and (iv) provide companionship, including entertainment and hobbies, reminiscence and social contact. Robot can act as a personal trainer, to motivate the subject, and as a companion, if it can have a good one-to-one interaction.

Robots That Provide Assistance

Robot can assist caregivers in specific tasks such as feeding (for example the Japanese Secom “My Spoon” automatic feeding robot) or bathing elderly people, e.g. the Sanyo electric bathtub robot that automatically washes and rinses patients. Robots can provide physical assistance in completing tasks (Sabelli et al. 2011 and Dario et al. 1999).

Also, robots can perform heavy duties: for example, Riken have developed the RIBA robot (Robot for Interactive Body Assistance), which can upraise and move subjects from a bed to a wheelchair. It can also recognize faces and voices and answer to spoken commands. Other robots can perform small tasks such as those performed by guide dogs: in the US, Georgia Tech has developed an assistive robot, EI-E, that can respond to many commands.

These robots can help the elderly to maintain independence in their own homes, but their presence could lead to the risk of leaving the elderly in the exclusive care of machines. The elderly needs the human contact that is often only provided by caregivers and people performing day-to-day tasks. On one hand, these robots maybe very helpful, since they can provide physical assistance at reasonable costs, maintaining the independence of the individuals who can live at their homes. On the other hand, this might reduce the amount of human contacts, and, when used insensitively, it could increase senior citizens’ feeling of objectification and lack of control over their lives. Such robots could make elderly people feel that they had even less control over their lives than when they depend on human nursing care. Dignity of the elder could potentially be ameliorated through robotic technology developed with the aim of increasing the autonomy and

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decreasing the dependence on other people. Therefore, robots could empower the aged frail person and increase his independence.

The question also remains on how much control, or autonomy, should an elderly person be allowed by the robot. To what extent it should depend on medical assessments of their mental capability? One must find the right balance between empowering elderly people by making them mobile and protecting them from the dangerous situations resulting from their regained motility.

Table 1. Some examples of robotic technology in use and under research in elderly care.

Domain	Need	Current solutions	Technology in use	Robotic care under research
Daily activities	Eating	Home nurse, designed instruments	Robotic manipulator, intelligent spoon	Intelligent home
	Medicine administration	Home nurse, medicine containers	Intelligent dispenser	Robot reminder
	Cleaning	Maid, vacuum cleaners	Cleaning robot	
	Shopping	Caregivers	Internet shop	Intelligent home, robot
	Personal hygiene	Domotics, caregivers	Bathing robot	
Physical	Physical activity (tracking and stimulation)	Caregivers, physiotherapists	Smart TV, apps, medical devices	Assistive robot
Cognitive	Memory loss	Caregivers, diaries, notice boars	PC, mobile apps	Robot, intelligent home
	Cognitive exercise	Caregivers, exercise on paper	PC, mobile apps	Robot
	Reduced vision	Spectacles, voice indicators in devices	Software	Guidance robot
	Reduced hearing	Hearing aid	Speech recognition software	Robot
Psychologic	Mood	Caregivers	Face/speech analysis software	Face/speech analysis robot
Social	Loneliness	Caregivers (nurses, family members), TV, internet, email	Robot companion	Robot companion, emotional robot (SAR: socially assistive robot)

Monitoring the Elder

Active monitoring of the elder can be very important to follow his health conditions, and to check the compliance to the recommendations of the caregivers. Pearl, developed at CMU (Pollack et al. 2002), is a “nursebot” that reminds seniors about routine activities (e.g. eating, drinking, taking medicine and using the bathroom/toilet), and that can guide them through their environment. RP-7 is a tele-operated robot that is used to facilitate doctor-patient interactions at distance. CareBotTM, a personal robot equipped with multiple vital sign sensors, that can follow an elderly person in their home. RoboSoft, a French robotics and automation manufacturer, introduced RoboLAB10, a home-assistance robot designed to assist in home care of the elderly. Remote Presence robots (RP-6 and RP-7) are made by the Californian company Intouch Health. An extension to the NAO robot, denoted as RIA, is being developed at the Engineering Institute of Coimbra (ISEC). The RIA is not only built for a social interaction with the elderly but also as an autonomous tool to promote professional care through the analysis of health and environmental parameters (Vital et al. 2013). Robots can have cameras which can record and transmit videos of the subject and, being mobile, can follow him. Also, they can be connected to several medical devices to check blood pressure, oxygen saturation, frequency, mobility, and act as a hub for the caregivers. Eventually they can be connected to each other in a cloud, thus learning from each other for example new words and new expressions. Besides being very important for the care of the single elderly person, monitoring can be very relevant to follow the subjects through time and detect new signs and symptoms of disease.

Falls and their consequences are a major risk especially for elderly people who live alone where immediate assistance is needed. The Kinect sensor has been used to introduce a mobile robot system to follow a person and detect when the target person has fallen. In addition, the mobile robot was provided with a cell phone that is used to send an SMS message notification and make an emergency call when a fall is detected (Zaid et al. 2014). The FP7 project CompanionAble starts from situation-specific, intelligent reminding (e.g. taking medication or drinking) and cognitive stimulation, via mobile videophony with relatives or caregivers, up to the autonomous detection of dangerous situations, like falls, and their evaluation by authorized persons via mobile telepresence (Gross et al. 2011).

This use of robots to monitor elderly people can result in a reduction in human contact and companionship. Moreover, there is a risk that it could impact on the right to privacy. Monitoring can also lead to restrictions of the activities of the elderly. If the robot is programmed to autonomously take steps to prevent dangers, e.g. turning the cooker off, or even restraining the elderly person (gently) from carrying out a potentially dangerous action such as climbing up on a chair. However, restraining a person to avoid harm could be the first step towards authoritarian robotics. Robot could decide to lock the door or call the staff. Such loss of freedom could represent an unethical aspect of robotic care.

Companionship

It has been known since a long time that elderly people affected by mild cognitive impairment or dementia can take advantage from the “doll and/or pet therapy”. Dolls or pets, in fact, may represent psychotherapeutic tools to enhance positive feelings and reduce aggressive behavior of the patient, reducing the need for psychotropic drugs. In this sense, robots can represent an alternative to dolls or pet, and even enhance the quantity and the quality of the social interaction of the elder, even with their fellows.

There is an increasing number of robot toys, some of which have been have been proposed as companions for the elderly. They are robots that provide communication services, i.e. nonphysical assistance (Tapus et al. 2007). Communication robots, such as Pearl (Pollack et al. 2002), stress the importance of social interaction in assistive robotics as a means of providing effective healthcare. Paro, a fur covered robotic seal, was specifically designed for therapeutic uses with the elderly. The appearance of a seal has been chosen to be accepted by the elder, who would easily suspect to be deceived by a false cat or dog (which are pets easily identifiable by everybody, contrarily to a seal). Developed by AIST, PARO responds to petting by moving its tail and opening and closing its eyes. It reacts to sounds and can learn to respond to its name. It makes seal-like sounds, and is active in the day, and “sleeps” at night. It can detect light and dark by means of a light sensor, and recognize when it is being held, stroked, or hit, by means of posture and tactile sensors.

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Figure 1. PARO robot.

Sony's AIBO robotic dog, developed as an "entertainment robot", has also been used in robot companions research. It has a metallic dog-like form, and can walk, or chase a ball. It has sensors that can detect distance, acceleration, sound, vibration and pressure. It can express six "emotions" (happiness, anger, fear, sadness, surprise and dislike), by means of its tail, body movements, and the color and shape of its eyes.

NeCoRo (OMRON) is a robotic cat covered in synthetic fur. Its behavior depends on the history of its interactions and it can 'learn' to recognize its name.

Figure 2. AIBO robotic dog.

There are some concerns about the efficacy of the robot companion. According to the study of Wada and Shibata (2007), who conducted a study to understand how people use and accept robots, PARO robot encourages social interaction and strengthen social ties: urine stress hormones dosages are decreased. On the other hand, people living in a shelter home in solitary confinement might benefit from being given a robot companion, but they would benefit far more if they were offered a friendly social environment. For instance, there is research that suggests that an extensive social network offers protection against some of the effects of aging: being single and living alone has been shown to be a risk factor for dementia (Fratiglioni et al. 2000). Saczynski et al. (2006), in a study of 2513 Japanese-American men, found that decreased social engagement from midlife to late life was associated with an increased risk of dementia. Some reports claim that residents "liked the ifbot for about a month before they lost interest". Robot companions such as Paro the seal, are marketed as pets because they are soft and cuddly and are designed to imitate some of the features of pets, such as purring when touched--they are exploiting human zoomorphism. They are being touted as a solution to the contact problem, but these are still toys that do not alleviate elder isolation, even though they may relieve some of the guilt felt by relatives or society in general about this problem. The success of these robots may stem from people being systematically deluded about the real nature of their relation to the devices.

At present, robots are far from being real companions. Their conversational ability is still extremely limited. They could be used to alleviate the family's guilt about living the elderly alone. Related to deception is the concern that encouraging elderly people to interact with robot toys has the effect of infantilizing them. predicated on the idea that those with dementia are going through a second childhood, and that this notion is dispiriting and encourages a rigid authoritarian, deficit-based approach to care. It is a malignant way of caring for those with dementia that leads to disempowerment, disparagement and infantilization. more cheerful and talkative; an attractor for visitors. anthropomorphize machines (Mutlu and Forlizzi 2008).

Figure 3. Robin of the Giraffplus project.

Several assistive robots aim to fulfil all these needs by the elderly. For instance, GyraffPlus and the robot Robin (http://www.giraffplus.eu/). From the website of the project: "GiraffPlus is a complex system which can monitor activities in the home using a network of sensors, both in and around the home as well as on the body. The sensors can measure e.g. blood pressure or detect e.g. whether somebody falls. Different services, depending on the individual's needs, can be pre-selected and tailored to the requirements of both the older adults and health care professionals. At the heart of the system is a unique telepresence robot, Giraff, which lends its name to the project. The robot uses a Skype-like interface to allow e.g. relatives or caregivers to virtually visit an elderly person in the home."

Pepper robot by Softbank (https://www.ald.softbankrobotics.com/en/robots/pepper) is a humanoid robot, designed to represent a true companion for different purposes. It has the aspect of a young boy, and is provided of a camera, can move gently the arms and dance (even though it has no legs), can answer to questions posed by the individual in front of it, and has a touchpad on the breast. In elderly care, it can both collect data from the elderly (by the camera and the microphone), even posing direct questions to the subject, and provide games (therefore also cognitive games) and solicit physical exercise or act as a drug reminder or connect with caregivers using the screen. It can speak different languages (it is sold around the world) and can learn new words since it is connected in cloud with other Pepper robots.

Figure 4. Pepper robot.

Requirements for an Assistive Robot

The Multi-Annual Roadmap (Robotics 2020, Multi-Annual Roadmap for Robotics in Europe) has identified a number of issues, some of which are of particular relevance to health care:

- Dependability, i.e. the ability of the system to perform its given tasks without systematic errors – In general end users literally depend on the proper functioning of the robotic service. AHA and/or care organizations can only transfer tasks to robots if they are equally dependable, but they typically do not have highly trained personnel to operate robots. To ensure safety and user acceptance the robotic system needs to be extensively tested in relevant environments.

- Social interaction ability (i.e. the ability of a robot to interact with humans, by understanding their individual social signals and cues and responding appropriately) and user acceptability – In healthcare applications robots need to interact closely with humans. These are primarily end-users who receive assistance from the robot but also family members and friends, the general practitioner and the care organization, if any. User acceptance requires high-level social interaction skills and natural human-robot interaction. This is especially the case in healthcare because the people involved are not trained in working with robots and expect easy and natural interfaces.

- Human-Robot Interaction ability – Current robotic systems are typically limited to execute pre-defined actions autonomously when interacting with users. To support caregivers a robot must be able to recognize when it can or cannot perform a task autonomously so that it can choose to perform simple tasks autonomously and safety-critical tasks partially teleoperated.

- Decisional autonomy – Real environments are uncertain and dynamically changing, which requires robust technology that can deal with uncertain data. Probabilistic reasoning and learning algorithms have a huge potential, but they typically lack the robustness for long-term tests. Evaluating systems in realistic scenarios is needed to analyse decision failures and to certify decision making algorithms in safety-critical situations.

Assistive robots can aim to integrate AHA activities into the daily life of the elderly. This comprises 1) communication, 2) health, 3) safety. The solution must be configured to the specific user needs of primary and secondary users, such as physiotherapeutic exercises which are prescribed by therapists/doctors, social communication capabilities and entertainment functions. The treatment must be personalized and modifiable according to user's progress. The elderly, informal and professional caregivers could benefit by sharing and analysing health and behaviour-related data among the relevant actors. Informal caregivers can be informed on health changes, divergent everyday routines and not fulfilled tasks from a big distance. Professional nurses can intervene in form of individually tailored therapeutically interventions and instructions. Caregivers can quickly react to changes and develop tailored medical interventions. The goal of the robotic care is to improve and support the individual User capabilities. This implies that the system must be driven by the user's requests and needs. It must be adaptive in a way, so that it can recover from errors and learn from experience.

Assistive robots could provide security and smart living to manage daily life activities related to home automatization and smart living (incl. privacy awareness, control and trust). Also, security-related events could be tracked (e.g. water, fire, entrance control). In addition, the robot can stimulate physical exercise (fall detection and prevention) and cognitive training (learning therapy) together with activities of daily living (ADL) training.

Assistive robots should also fulfil some requirements: they should be able to investigate human behaviour, to navigate and maneouver in the home environment, to recover errors and adapt to the situations. A major technical aspect is that of autonomous recharge, and the duration of the batteries. In fact, notwithstanding the claims by the manufacturers, the duration of batteries is often short if the robot is in activity.

First, robots should be safe, and, on the contrary, should not be put in danger by the elderly and the caregiver. Since the beginning of robotics, robots should follow Asimov's laws of robots:

- A robot may not injure a human being or, through inaction, allow a human being to come to harm.
- A robot must obey the orders given it by human beings except where such orders would conflict with the First Law.
- A robot must protect its own existence as long as such protection does not conflict with the First or Second Laws.

This means that the robot should be able to discriminate the good and the evil for the elder and to adapt these concepts to the specific situation. Moreover, it should not represent a danger by itself, for example being too heavy and unstable, thus risking to cause traumas or fractures to the elderly people, who are frail and more prone to accidents. Sometimes, for example, traumas can be provoked when fingers of the elderly are trapped between the joints of the robots (arms, neck, etc.).

On the other hand, the robot should be designed to prevent damages by the elderly: for instance, cases were reported in which the elderly tried to feed humanoid robots with biscuits, or buried Paro when the batteries were down, believing that the animal was dead.

Also the appearance of the robot is a relevant feature. Humanoid robots can represent the best way to communicate with the elderly and stimulate imitation when performing exercises. The appearance of a pet can stimulate empathy and communication. On the other hand, we have already described above about the risks of deception and illusion of the elderly, therefore some robots are designed to be easily discriminated from human and animal beings.

Mentalization

Mentalization is a process which allows to consider someone else's behaviour as the result of mental states similar to ours; thus, we make sense of each other and ourselves, implicitly and explicitly, in terms of subjective states and mental processes. Therefore, it is crucial, for human-

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robot interaction, to investigate how the robot is perceived in terms of mental states by the individual.

The sight of a robot may have a bewildering effect on elderly people: it often has a human aspect, but its movements are not completely natural and similar to human. Ikeda et al. (2017), in a fMRI study, found that the visual observation of the android, compared with that of the human model, causes greater activation in the subthalamic nucleus, suggesting that it detects the subtle unnaturalness of its movements. Motor resonance towards a humanoid robot, but not a human, display of facial emotion is increased when attention is directed towards judging emotions, indicating different reactions (Chaminade et al. 2010). Chaminade et al. (2012) studied subjects using fMRI during interactive games while believing their opponent was a fellow human, a humanoid robot endowed with an artificial intelligence, or a computer playing randomly: participants' subjective reports indicated that they adopted different stances against the three opponents.

It was also demonstrated, studying the selectivity of the human action perception system, distinctive responses to the mismatch between appearance and motion in androids (mechanical movement, biological aspect) than in robots (mechanical aspect and movement) (Saygin et al. 2012). Also, fMRI found different areas of activation when seeing human-human interactions (left temporal parietal junction) than human-robot interactions (precuneus and ventromedial prefrontal cortex). This latest finding seems to be the neural correlate of a phenomenon called "uncanny valley", a feeling of weirdness and bewildering (Wang and Quadflieg 2015).

Therefore, further studies are needed to investigate mentalization in humans, and more specifically in elderly people, when interacting with a robot, especially when humanoid. Also, we should define if we aim that assistive robots are perceived as humans by the elderly people or not.

Industrial Impacts

From a general perspective, robotics has the power to completely reshape the landscape of healthcare both in its structure and its operation. In fact, the long-term sustainability of healthcare systems could be addressed by automation powered by digital health technologies, such as artificial intelligence, 3D-printing or robotics. The latter could take over monotonous work from healthcare workers, which would allow them to focus more on patients and to have lesser workload.

The way automation cuts out repetitive and monotonous tasks from the human work schedule fits into a decades-long (or even centuries-long) global trend thriving to make people's lives easier and more comfortable. The global medical robotic systems market was worth $5.48 billion in 2011 and is expected to reach $13.6 billion in 2018, growing at a compounded annual growth rate of 12.6% from 2012 in several areas among which: Surgical Robots, Non-Invasive Radiosurgery Robotic Systems, Prosthetics and Exoskeletons, Assistive and Rehabilitation Robots, Non-Medical Robotics in Hospitals and Emergency Response Robotic Systems (https://www.transparencymarketresearch.com/medical-robotic-systems.html). Even though surgical robots are expected to enjoy the largest revenue share, Robotic Companions already see several companies pushing the boundaries of interaction to a new frontier, most promising ones.

From an industrial point of view, Honda Robotics's ASIMO,and Luvozo PBC's SAM stand as example of robot companions – regardless whether human or animal shaped, smaller or bigger – to enable elderly and other people without the necessary social support to connect with the world.

The case of ASIMO, the humanoid robot created by Honda in 2000, shows how complicated was to develop robots in the past. In fact, Honda engineers set out to create a robot that could walk already back in 1986. Two decades later, they presented ASIMO, a full humanoid robot, able not only to walk but also to run, climb steps and even carry a tray or push a cart. ASIMO can also comprehend and respond to simple voice commands and has the ability to recognize the face of a select group of individuals. Using its camera eyes, it can map its environment and register stationary objects (http://world.honda.com/ASIMO/).

Figure 5. ASIMO robot.

Luvozo PBC, on the other extreme, was founded only in 2013 to focus on developing solutions for improving quality of life for older adults and persons with disabilities. In July 2015, it started testing its flagship product — Sam, The Robotic Concierge — in a leading senior living community in the Washington D.C. area. Now on the market, the human-sized, smiling robot combines the very best in cutting-edge technology and human touch to provide frequent check-ins and non-medical care for residents in long-term care settings. By doing so, it reduces the costs of care, while raises patient satisfaction index by simply being there for the elderly all the time. (http://luvozo.com/sam/).

According to the Consumer Robotics Survey 2015 Summary, the consumer market is ready – people are ready to accept consumer robots. It also illustrates the criteria for Personal Robotics expectations, which reveals that 58% customers expect the personal robot to understand and react to voice commands. Therefore, there is a consumer ready market, and clearly defined need. SoftBank Robotics Europe as world leader in Humanoid Robots, is actively working in introducing robots to everyday life for supporting the well-being of people, such robots are capable of interacting through voice commands. However, for such robots to be a successful companion and assistant in long term, it is crucial to have the robot equipped with smooth and natural human-robot interaction capabilities customized according to social and cultural norms. From the industrial perspective, there is a great need to push research in the direction of grounding and shaping the multi-modal behaviour of the robot according to cultural situation. The number of everyday situation a robot has to cope with in the human-centred environment in different cultures is huge and there is a need to equip the robot with autonomous adaptation capabilities, which is possible only through development of a generic system in which culture is a parameter. The system developed in the project will redefine the behaviour generation of the robot by developing cultural-aware system. The fact that such a system will also be able to improve itself through IoT and cloud-based data sharing, will increase the robot's capability to adjust in different environment, in different situations, without being reprogrammed. All these will reduce the cost of deployment of the robot as well as enable adaptability capabilities of the robot about how it can interact with people in more interesting, engaging and dynamic manners, and achieve the task. Both the open platform service concept and the intended APP store for robot-based AHA (and care) services enable the implementation of new business models and of new value chains. The basic infrastructure effort will be shared and will depend on the committed cost model of the involved companies. Public stakeholders and end users have to pay only once for infrastructure cost and benefit from lower production and operating costs. A platform concept enables AHA organisations and informal networks (without technical resources) to use the IoT and Robotic-based services. The open modular structure and the associated APP store allow other companies (esp. SMEs) and intervention suppliers (e.g. NGOs) to use the platform and to provide their own services like in a market place.

Conclusions

The use of Robots with human subjects/patients raise several questions. First of all, robots may represent information hubs, and can collect an incredible amount of data about the subjects and their environment. They can work in cloud, which a clear advantage since they can learn together, improve their vocabulary and eventually detect new signs and symptoms of diseases. In fact, they record habits such as sleeping, exercising, third persons entering in the house, appointments. Communications may be continuously recorded. Moreover, by connecting with medical devices, they can store medical data. From one side, this represents a very powerful tool to collect information about the single subject (precision medicine), about disease (thus eventually finding new signs and symptoms through artificial intelligence by machine learning and deep learning) and about his/her habitat. On the other hand, this powerful instrument may represent a dramatic treat to the privacy of the subjects and their caregivers and poses enormous ethical problems which must be considered.

Therefore, robotics represents an ethically-sensitive field. Care robotics bear the risk of reducing human contact, of increasing the objectification and loss of control of the elderly, of losing the privacy and personal freedom of the individual (especially when robots may perform restrictive interventions).

One major side effect of the use of robots in elderly care consists in the risk of confusing between reality and appearance. Moreover, there is a potential risk of deception and infantilization of the elder.

Nevertheless, the market is ready to use this new instrument and, as far as the population which was grown in the computer and internet era ages, the number of potential users and the chance of taking advantage of these new tools will increase exponentially, leading to a real revolution in health care.

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