Do robots represent a viable and sustainable solution to the rapidly increasing social and care needs of an ageing population?

An *ActiveAge* Discussion Paper

Scientists and engineers have long been preparing us for a future when the elderly outnumber children and there will be too few 'younger people' to care for the 'older people' and keep society and the economy functioning.

"By 2050 the proportion of elderly-dependent people in Europe is expected to increase to more than 51%. Japan is expected to see the largest rise in their elderly dependent ratio…71% by the year 2050". [1]

A recent study highlights 'the shortage of human capacity to care for older people and a demand led by the baby boomers 'to grow old at home' as the two main reasons for developing assistive technologies to help the elderly'[2].

As a result of these demands governments around the world are seeing robots as one of the key technology solutions to address these issues.

"As the elderly population continues to grow, a great deal of attention and research will be dedicated to assistive systems aimed at promoting ageing-in-place, facilitating living independently in one's own home as long as possible"[3]

The Japan Robot Association predicts that by 2025[4] 'the home' will be the largest growth area for robotics. The 'home' includes *'education, home based virtual training, entertainment-oriented rehabilitation systems, communication tools, household equipment'.*[5]

Whilst robots have worked for humans in industrial settings for many years, helping to ease work tasks that involve manual labour - in industries such as automobile manufacturing there is *'about one robot to every ten workers'*[6]- a move into the home causes some concern. Many do not believe machines will or should ever replace human beings or that they will be capable of adapting to different cultural backgrounds[7].

This apprehension is partly, at least, because robots in our homes seems like totally new territory. However, a brief look back in history shows robots being used in informal settings for entertainment purposes in ancient Greece and assisting with simple chores, such as tea carrying, in 18th century Japan.

[1] *My Friend The Robot*, K. Richardson, The Times Higher Education, published 16.2.07
[2] *Assistive Social Robots in elderly care: a review*, by J. Broekens, M. Heerink, H. Rosendal
[3] A. Tapus, M.J. Mataric, B Scassellati, *The Grand Challenges in Socially Assistive Robotics,* IEEE Robotics and Automation Magazine Special Issue on Grand Challenges in Robotics
[4] Japan Robot Association, 2001, *Summary Report on Technology Strategy for Creating a 'Robot Society' in the 21st century*
[5] ibdn
[6] B.Gates, *A Robot in Every Home*, 2007. Scientific American Magazine
[7] BBC, Robot Carers developed in Bristol Laboratory, 8.11.10

Karakuri mechanicial tea-carrying dolls from 18th century Japan

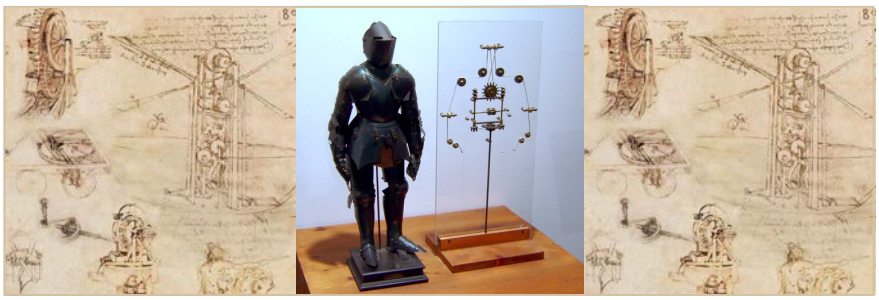
The *ActiveAge* team has been tracking robot developments for over 5 years and is particularly interested in the development of robots for the home, specifically as companions and carers for older people.

Of particular interest is the form home robots will take. Will they resemble human beings or will they be machine-like in appearance? What will their function be? Will they purely assist with domestic chores - or will they take on personalities of their own, forming different types of relationships with human beings? This paper will attempt to address these questions.

Background

This year marks the 90th anniversary of the 'robot'. The word, which came from the Czech word 'robota' meaning *servitude*, *hard work* or *drudgery*, was first popularised by Czech writer, Karel Capek, in his 1921 play, RUR (Rossum's Universal Robots). However, robots had much earlier roots in ancient mythology. The notion of artificial people can be traced to the mechanical servants built by the Greek god Hephaestus[8], clay golems in Jewish legend and clay giants of Norse folklore.

In the 15th century Leonardo Da Vinci sketched plans for a humanoid robot. Da Vinci's notebooks, rediscovered in the 1950s, contain detailed drawings of a mechanical knight now known as 'Leonardo's Robot', able to sit up, wave its arms and move its head and jaw[9].



Leonardo Da Vinci's mechanical knight could sit up, wave its arms and move its head and jaw

[8] Deborah Levine Gera, 2003. *Ancient Greek Ideas on Speech, Language, and Civilization*. Oxford University Press

[9] Leonardo da Vinci's Robots, www.leonardo3.net. Accessed 4.2.2011

In the late 18th century the Japanese craftsman Hisashige Tanaka (1799-1881), who features strongly in the history of robotics[10], developed the *Archer Doll* robot, which was powered by a winding mechanism and gears, with movement controlled by strings. It shot arrows as part of an automated sequence and the face of the robot doll appeared to express joy or disappointment after hitting or missing the target, depending on the angle and light on the robot's mask.

Much of our thinking about robots, past and present, has been influenced by science fiction and the big screen. From as early as the nineteenth century robots were shown in films like *Metropolis* (1927), *The Wizard of Oz* (1939), *Tobor the Great* (1954), *Forbidden Planet* (1956), *The Stepford Wives* (1975), *Star Wars* (1977), *The Matrix* (1999) and *iRobot* (2004).

A poster, left, promoting the 1954 'Tobor the Great' (Tobor being the reverse anagram of Robot) and, right, C-3PO - a protocol droid - in a scene from the 1977 'Star Wars'

The word 'robotics', referring to the study and use of robots in engineering, itself originated in science fiction literature. The word was first adopted by scientist and writer, Isaac Asimov in 1941. In 1950 Asimov produced a collection of short stories about robots, *I, Robot*, which predicted the rise of a powerful robotics industry and introduced the *Three Laws of Robotics*:

1. A robot may not injure a human being or, through inaction, allow a human being to come to harm.
2. A robot must obey any orders given to it by human beings, except where such orders would conflict with the First Law.
3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law[11].

The overlap between science fiction and robotics is, partly at least, responsible for the belief among many that robots are bad, evil or untrustworthy, to be feared rather than befriended. This has caused a degree of suspicion by human beings of robots. Japanese roboticist Masahiro Mori coined the term *'Uncanny Valley'* to describe the phenomenon of human discomfort, which increases as avatars and robots look more and more human[12].

This phenomenon must be overcome if robots are to be accepted as companions or helpers for human beings and truly "user-friendly".

[10] Nicks, V. History of Robotics in Japan – Tanaka Hisashige's Boy Archer Doll, accessed 11.2.11, http://www.suite101.com/content/history-of-robotics-in-japan---tanaka-hisashiges-boy-archer-doll-a267250
[11] I. Asimov, *I, Robot* (2004)
[12] BBC, *Early Origins of Uncanny Valley*, Nov 2009, http://news.bbc.co.uk/1/hi/technology/8344203.stm

Robots and older people

In Japan the development of robots goes hand in hand with the rapidly ageing population. Japan has the World's highest proportion of elderly citizens. By the end of 2010 there were 3 pensioners to every child under 15, and, before long, one in six people will be over 80[13]. 21% of Japan's population is over 65 and, by 2030, this is estimated to reach 25.6%.

Whilst some countries are encouraging immigration to help the ageing problem, Japan has adopted an approach that encourages the development of technological solutions, including robots, to overcome the problems of an ageing society.

One of the most interesting aspects of robot development is their application as carers or companions, providing similar support to that of humans. This is a phenomenon that seems to be attracting attention, not only in Japan but also in the UK and Europe.

Studies on social robots in elder care primarily focus on two different types of robot. The first are robots used as assistive devices to help with everyday tasks, such as eating, bathing, toileting, and support independent living.

Examples of these robots include *Pearl*, the Dutch *iCat* and the German *Care-o-bot*. These types of robots have caught the eye of the UK media.

Developed by Philips Research in the Netherlands, iCat is a prototype of an emotionally intelligent user-interface robot

At the end of 2010 there were a number of articles about the European-wide *Mobiserv* Project[14], which includes input from researchers at The University of The West of England. The project aims to demonstrate that robots can be a positive element in social care, allowing older people to remain independent and stay healthy in their own homes for longer.

Mobiserv's robot was designed to help older people carry out daily activities, stay healthy and communicate with others. It is able to move around the home, as instructed by the user, and communicate with them through speech recognition technology. It also enables the user to communicate with family and care professionals through video conferencing and can receive information about the user's health through cameras and sensors embedded in their clothing. This information is then conveyed to the older person or to care professionals.

[13] *Solving Japan's Ageing Problem*, March 2010. The Guardian "http://www.guardian.co.uk/money/2010/mar/20/japan-ageing-population-technology"
[14] Mobiserv Project website, http://www.mobiserv.eu

The robot's appearance and functionality is similar to other telecare systems and products already in the marketplace. As such, any user is unlikely to see this device as a robotic companion but rather a practical assistive device with a robotic appearance.

Kompaï has been designed to assist dependent persons at home. This robot can speak, understand what is said to it, find its way around the house and, with just a word, access internet services.

The second type of robot, a social robot, designed for elder care has companionship as its sole purpose.

"In the context of socially assistive robotics, the first efforts have focused on robotic pets, companions that attempt to reduce stress and depression"[15]

These social robots are designed to fulfil the role of pets without the effort involved. Examples include *Paro*, a Japanese robotic seal and *Aibo*, a robot dog designed by Sony.

Other robots that may indicate the future direction of social robotics include *geminoids* and *humanoid*s, discussed in more detail below.

Paro, above left and right, is a seal mimetic mental-committed robot that imitates animal behaviour, interacts with human beings and responds to light, sound, temperature, touch and posture.

Aibo, right, is one of several robotic pets designed and manufactured by Sony. Able to walk, see and recognise spoken commands, Aibo was discontinued in 2006.

[15] A. Tapus & MJ Mataric, July 2006. *Towards Socially Assistive Robotics*, International Journal of the Robotics Society of Japan

There are believed to be a variety of positive affects associated with assistive social robots for older people. These include increased health by decreasing levels of stress, more positive mood, decreased loneliness and increased communication activity with others.

In summary, there are two approaches to the development of robots for older people. The first approach is based on machine-like, assisting robots for helping with everyday tasks, which are usually distinct from human beings in appearance.

The second approach is where the robot is designed for companionship. These robots are often pet-like in appearance but can also be human-like in appearance. Geminoids, for example, which are discussed below, have been designed by Japanese scientists to look exactly like human beings.

Robopsychology

It is important to recognise that our relationship with robots is changing.

Robots today are used in various settings, from industry to pharmaceuticals, but the most notable growth area in the next twenty years, as stated above, will be in the home. This inevitably means closer interactions between robots and human beings.

Whereas, in the past, mechanical creatures were evaluated on their engineering merit and ease of completing manual tasks, they are now being given more humanistic values having their own distinct individuality and perhaps even being judged on their 'personality'.

"From a psychological point of view robots are capable of playing different roles, appearing as a human companion, educator, explorer, entertainer, rehabilitation or medical assistant or even a psychological therapist"[16]

The study of person-robot interactions is carried out in two fields recognized as Robotic Psychology and Robotherapy. The former, which is probably more relevant to *ActiveAge*, focuses on compatibility between humans and robots whilst the latter concentrates on using interactive robots as therapeutic companions for people.

Those who study Robotic Psychology are known as *Robosychologists*. They divide robots into two categories: *Interactive Simulation Robots* (ISRs) and *Assisting Robots* (ARs)[17]. This is a similar distinction to the one above, between assistive robots and social robots for elder care.

ISRs are the Robopsychologist's primary concern but both are of interest to *ActiveAge*. ISRs and ARs are further divided into sub categories. It is worth noting that the Robopsychologist's research does not specifically relate to robots for older people but to the relationship between people and robots in general.

In fact the application areas of socially assistive robotics have been identified as including, *"care of the elderly, care of individuals with physical recovery, rehabilitation and training needs, and care of individuals with cognitive and social disabilities"*.[18]

[16] A. V. Libin & E. V. Libin, 2004. *Person-Robot Interactions from the Robopsychologist's point of view: The robot psychology and robotherapy approach*, proceedings of the IEEE, Vol. 92, No. 11
[17] ibdn
[18] *The Grand Challenges in Socially Assistive Robotics*, IEE Robotics and Automation Magazine Special Issue

Assisting Robots include industrial robots, medical and research robots, military and rescue robots and service robots. *Interactive Simulation Robots* include social and recreational robots, educational robots, rehabilitation robots and robots with therapeutic potential

Interactive simulation robots are designed for the purpose of communicating with human beings on a personal level. Personalized robots are also often called 'artificial partners'.[19]

One of the main issues with interactive simulation robots is their acceptance, or lack thereof, by human beings. In many instances robots illicit fear in human beings, especially when they are seen as alternatives to human companionship. Therefore, if robots really are to fill the gap of a lack of human capacity for elder care, we need to understand the psychological issues linked to human-robot relations. This is necessary before robots stand a chance of being accepted as carers and companions.

The Intelligent Robotics and Communications Laboratories in Japan are undertaking a project called *'Communications Robot'* to look at the features required for a robot to be well accepted by many different people.[20] By accumulating experimental research the laboratory hope to create a robot that can support human beings in their everyday lives.

A question of interest to *ActiveAge* is whether the acceptance of robots as companions boils down to their appearance and whether they look like human beings or not. This question is being addressed by a handful of teams around the world where they are developing lifelike android robots for research purposes. *ActiveAge* has been following the work of several of these. Some of the most notable developments in this field are taking place in Japan and, in particular through Professor Hiroshi Ishiguro, at The Intelligent Robotics and Communication Laboratories (IRC) in Kyoto, who has been developing what he calls *'Geminoid Androids'*.

Geminoid is a remote-control 'doppelganger droid' designed by Professor Hiroshi Ishiguro, of Osaka University and ATR Intelligent Robotics and Communication Laboratories.

A *Geminoid* is a person-based android robot. This is a new category of robot, which appears and behaves just like the person it is modelled on, and is tightly connected to its original model by information paths[21].

All the movements and expressions of a Geminoid are remote controlled by an operator with a computer who uses a motion capture system that tracks facial expressions and head movements. When the original person moves his

[19] A.V. Libin, E.V. Libin, 2004. *Person-robot Interactions From the Robopsychologists' Point of View: the Robotic Psychology and Robotherapy Approach*, Proceedings of the IEEE, Vol 92, No 11
[20] Intelligent Robotics and Communications Laboratories http://www.irc.atr.jp/en/research_project/humanoid/com_robo/
[21] Geminoid Overview, http://www.irc.atr.jp/Geminoid/overview.html

head, mouth etc, the Geminoid follows suit. Geminoids would fall under the category of interactive simulation robots that look like human beings.

The purpose of the Geminoid is to advance research in two areas: the development of effective tele-operation interfaces for the generation of more human-like movement in robots. The other area is the cognitive aspect i.e. the investigation of human presence in robots. The overall goal of Geminoid development is to create an advanced robot close to humankind. Part of this research includes an investigation of some of the cultural differences in the perception of robots.

Human-robot interaction studies at IRC focus on appearance. Most robots designed for interacting with humans are not android types (they don't look like human beings). They are more likely to be humanoids such as ASIMO.

It is believed a robot's appearance strongly influences whether it will be accepted or rejected by human beings. Research undertaken at IRC suggests that *'a robot partner, ideally, would have a human-like body. A robot with a humanlike body allows people to intuitively understand its gestures, and in turn causes people to behave unconsciously as if they were communicating with a human"*[22]

This research suggests that if robots are to become companions and carers for human beings they will necessarily need to be more humanlike in appearance and character. However, there seems to be a very fine line in terms of human discomfort with robots.

Masahiro Mori's *'Uncanny Valley'* theory - mentioned at the top of this paper - describes the repulsive response human beings have when a robot's appearance and motion lies between 'barely human' and 'fully human'. Uncanny Valley captures the idea that a robot, which is "almost human", will seem overly "strange" to a human being and thus will fail to evoke the empathic response required for productive human-robot interaction[23].

One of the key aspects of IRC's research is to discover the core elements of 'personal presence', that being the sense of being around/with a particular individual. IRC believes this research is crucially important if robots are ever to replace face-to-face communication and take on caring roles for human beings. Research at IRC suggests that robots need to be capable of showing emotions similar to those of humans if they are to be accepted. If the Uncanny Valley theory is accurate this would suggest that robots need to be indistinguishable from human beings or look nothing like them at all.

Another example of research in the field of android robots is at Hanson Robotics, a company founded in 2003 with the aim of awakening intelligent robotic beings and granting them sparks of true consciousness and creativity in order to distribute them into the world[24]. The Hanson Robotic team lays claim to having introduced the most lifelike intelligent robots, which are enlivened by Hanson breakthrough technologies such as *'Frubber'* skin material and *Character Engine* cognition software. These robots replicate the appearance of human beings and can be custom crafted into portraits of people. This process Hanson refers to as *'Identity Emulation'*, which seems similar in concept to Prof Ishiguro's Geminoids.

[22] Ishiguro, Kanda, Hiano, Eaton, *Interactive Robots as Social Partners and Peer Tutors for Children: A Field Trial,* 2004. Human-Computer Interaction, Vol. 19
[23] Mori, Masahiro, 1970. Bukimi no tani, The Uncanny Valley (K.F. MacDorman & T. Minato Trans). Energy, 7(4), 33-35 (originally in Japanese)
[24] Hanson Robotics, http://hansonrobotics.wordpress.com/press-statement/

Each Hanson robot emerges as a four-dimensional sculpture. The presence of character arises from the interaction of the mechanics, the Frubber, and the intelligent software, to affect any of 2 to the power of 361 possible expressions

Frubber, mechanical engineering, and artistry brings the appearance of life, whereas Character Engine enables robots to think, to feel, to perceive people and understand speech, hold natural conversations, and evolve into smarter beings. The company believes their robots fulfil the psychological need for face-to-face communication, having applications for the family, therapy, research, education and medicine.

As well as the development of android robots for potential human companionship, which seems to focus on the appearance of robots and the effect this has on human beings, we are also seeing research into the social elements of humanoid robots such as Honda's ASIMO[25] which was designed to *'duplicate the complexities of human motion and actually help people'*.[26]

ASIMO is not humanlike in appearance and looks like a mini astronaut walking around on its tiptoes. Honda is studying how to forge long-term constructive bonds between humans and robots recognising that *'if androids are to play an integral role in the future of the human race and justify Honda's substantial investment in the technology), they are going to need social skills to keep the "creepiness" factor at bay'*.[27]

ASIMO was created just over 10 years ago as part of Honda's programme of research and development into robotics and human mobility.

Honda has been working on intelligence technology for ASIMO since 2005. The robot is capable of interpreting the postures and gestures of people and moving independently in response.

[25] Honda, http://world.honda.com/ASIMO/
[26] Honda, 2003. *We're building a dream, one robot at a time* Smithsonion Magazine
[27] *Robot meet and greet: ASIMO works on its social skills this week,* in Scientific American, Sep 2010. http://www.scientificamerican.com/gallery_directory.cfm?photo_id=D2AA87DD-0F13-F40C-C50D2364409B95A1

ASIMO's ability to interact with people has advanced significantly since its birth over ten years ago. It can greet approaching people, follow them, move in the direction they indicate, and even recognize their faces and address them by name. ASIMO is said to be the world's first humanoid robot to exhibit such a broad range of intelligent capabilities.

Like many of the other robots discussed in this paper ASIMO has the potential to perform many different tasks if it was to be used in the home including cooking, cleaning and laundry.

However, it seems the robots emerging as forerunners in the marketplace are much more specialised in function - such as Roomba, the robot vacuum cleaner, which has sold six million units. Other specialised robots include *BirthSIM*, a simulator robot to assist doctors training in the correct use of forceps for delivering newborns, and *PackBot*, a robot for scoping caves for Taliban fighters in Afghanistan.

These robots were all designed to perform a particular task, and although more complex than designing a robot for one task, ageing is a problem that could also benefit from robotic solutions. This has been recognised by Tandy Trower who founded Microsoft's robotics division and *Hoaloha*[28], a company set up to create 'socially assistive', human-centric robot designs to help address the challenges that come with ageing.

He recently highlighted one of the reasons why the home robotic market has been limited to smaller scale, single purpose creatures. *"It is because people aren't prepared to spend upwards of £5,000 for a robot that merely does housework"*[29].

Tandy Trower believes that as the population continues to age and the health-care system stretches to its limit there will be more need for finding other means of support, and there is potential for pricey robots delivering assistance and companionship.

However, the development of robots is also being slowed by the fact there are currently no universal operating systems. This is something Microsoft Corporation recognises and has been tackling for a number of years.

In 2007 Bill Gates discussed Microsoft's view on robotics, in *Scientific American Magazine,* comparing the fragmentation, lack of a common platform or common standards, to the computer industry of the 1970's.

Gates described how he saw robotics developing in the same way the computer business did 30 plus years ago. *"… As I look at the trends that are now starting to converge, I can envision a future in which robotic devices will become a nearly ubiquitous part of our day-to-day lives…"* [30]

[28] Hoaloha Robotics, http://www.hoaloharobotics.com/intro
[29] Metro.co.uk, Robots strut their stuff at InnoRobo, 30.3.11
[30] B.Gates, *A Robot in Every Home*, 2007. Scientific American Magazine

Conclusion

It seems undeniable that robots bring benefits to human beings. They have done so in industrial settings for many years and are rapidly expanding into the fields of medicine, pharmaceuticals and warfare.

With regard to older people robots could potentially improve independence and security in the home by providing support in everyday tasks and connecting with the outside world. They could also provide companionship for older people who are less mobile or have fewer opportunities to socialize.

The direction in which robots are heading in terms of caring for older people is unclear. There are many approaches and ways in which robots could assist older people but a hurdle still exists in terms of their acceptance by the people who will be using them. It is unclear if they will be universally accepted and - if they are - whether the majority of people prefer robots to look like robots or to look like fellow human beings.

The work at Hanson Robotics, creating intelligent machines that resemble humans, and research into Geminoid Robots by Prof. Ishiguro in Japan represent a belief that robots need to act and look like human beings in order to be accepted.

However, as highlighted above, much of the research into assistive social robots to date has focussed on pet-like companion robots that do not look like human beings.

Honda's ASIMO is another well-known robot that does not resemble a human being physically but does have some of the intelligent characteristics of a human.

In summarising this report it seems that robots either need to look nothing like human beings or they need to replicate them almost exactly in order to be accepted. In both scenarios, design will be a key factor in establishing robotic solutions that people want to have in their homes.

And, finally, if robots are to achieve a truly ubiquitous presence in our lives, the current trend of stand-alone systems that do not connect one to the other is a commercial barrier. In the same way that the Continua Alliance argues the case for global inter-operability in the field of assisted living technology, it seems clear that that the lack of a common robotic operating system will deter the sustainable development and deployment of solutions for the home.

References

Robot meet and greet: ASIMO works on its social skills this week, Sep 2010, in Scientific American

We're building a dream, one robot at a time, Honda, 2003. Smithsonian Magazine

Solving Japan's Ageing Problem, March 2010. The Guardian

BBC, *Early Origins of Uncanny Valley*, Nov 2009, http://news.bbc.co.uk/1/hi/technology/8344203.stm

Honda Website, http://world.honda.com/ASIMO/

Hoaloha Robotics Website, http://www.hoaloharobotics.com/intro

Hanson Robotics Website, http://www.hoaloharobotics.com/intro

Intelligent Robotics and Communications Laboratories Website, http://www.irc.atr.jp/en/

Mori, Masahiro, 1970. Bukimi no tani, The Uncanny Valley (K.F. MacDorman & T. Minato Trans). Energy, 7(4), 33-35 (originally in Japanese)

Ishiguro, Kanda, Hiano, Eaton, 2004. *Interactive Robots as Social Partners and Peer Tutors for Children: A Field Trial* Human-Computer Interaction, Vol. 19

A.V. Libin, E.V. Libin, 2004, *Person-robot Interactions From the Robopsychologists' Point of View: the Robotic Psychology and Robotherapy Approach*, Proceedings of the IEEE, Vol 92, No 11

K. Richardson, *My Friend The Robot*, The Times Higher Education, published 16.2.07

Nicks, V. History of Robotics in Japan

A.Tapus & MJ Mataric, July 2006. *Towards Socially Assistive Robotics*, International Journal of the Robotics Society of Japan

A.Tapus, M.J. Mataric, B Scassellati, 2006 *The Grand Challenges in Socially Assistive Robotics,* IEEE Robotics and Automation Magazine Special Issue on Grand Challenges in Robotics

J. Broekens, M. Heerink, H. Rosendal, 2009. *Assistive Social Robots in elderly care: a review,* Gerontechnology*;* 8(2): 94-103

Japan Robot Association, 2001. *Summary Report on Technology Strategy for Creating a 'Robot Society' in the 21st century*

Deborah Levine Gera, 2003. *Ancient Greek Ideas on Speech, Language, and Civilization*. Oxford University Press

Leonardo Da Vinci's Robots, www.leonardo3.net. Retrieved 4.2.2011

B.Gates, *A Robot in Every Home*, 2007. Scientific American Magazine

BBC, Robot Carers developed in Bristol Laboratory, 8.11.10

Metro.co.uk, *Robots strut their stuff at InnoRobo*, 30.3.11