

Article

## Robotic Systems in Healthcare with Particular Reference to Innovation in the ‘Fourth Industrial Revolution’ — An Ethical Challenge for Management —

Martin POHL

University of Tsukuba, Faculty of Humanities and Social Sciences, Associate Professor

The use of robotic systems is undergoing an evolution; they will become part of daily life in many fields, including the healthcare sector. Examples of operational robotic systems suggest huge growth potential. The ‘Fourth Industrial Revolution’ based on the Internet of Things (IoT) and ‘Everything-as-a-Service’ (XaaS) will provide the platform for innovations.

Macro-trends in the healthcare sector in Japan, for example, suggest that in many fields of healthcare, new robotic systems may be developed and implemented in the near or mid-term future. For these trends to be accepted by stakeholders, ethical standards have to be developed for robotic systems in the healthcare sector. From the viewpoint of management, acting in accordance with ethical principles will make success of a new product likely and as such prove investment successful.

**Keywords:** Robotic System, Healthcare, Innovation, Fourth Industrial Revolution, Internet of Things, Ethics, Management

### Introduction

Robotic systems play an increasingly crucial role not only in traditional industrial production, but also in service industries such as health. From a medical point of view, current robotic systems make surgeries safer. From a business point of view, the Gartner Consulting Group determined that initial robotic systems such as ‘mobile health monitoring’ are on the edge of profitability, whereas other fields, such as ‘biochips’, based on robot technology are still in an early stage of development.

Robotic systems in healthcare are like any other product and service only successful if they add both financial and social-ethical value. So the core question is whether robotic systems add monetary and/or social value to healthcare. As a hypothesis it is expected that in fact robotic systems can do so. For example, first, robotic systems can reduce labor costs. Second, robotic systems can increase the independence and social participation of vulnerable people. Third, robotic systems can increase the quality of care. Fourth, robotic systems can perform activities that cannot be done by humans.

To prove these statements, the research will be based on three steps. At first the macro-trends in the Japanese health sector will be analyzed. In the second step applications of existing and prototype robotic systems will be collected based on information on the internet and by contacting selected enterprises, to develop an understanding of current robot-technology in the market or close to the market. Based on this, the collection of robotic systems can be categorized to focus management thoughts. As a third step the paper will conclude by

developing the spectrum of a scenario embedded in ethics, and how robots in the mid-term-future may be a blessing for human beings.

The methodology used in this paper is based on three analytical approaches. *First*, to cover the major macro-trends surrounding robotic systems in healthcare a *PESTEL Analysis* will be undertaken. This analysis is an analytical concept to identify the major trends and influencing factors, which affect a market or an industry. Results of the literature research will be included. *Second*, a *Situation Analysis* will analyze the existing market fields for robotic systems. In other words this will determine what kind of robotic systems exist in the market or close to the market. This includes prototypes and robotic systems in operation. For doing so a search of the literature and other documents including medical and management material will be undertaken related to the overall topic of this research. *Third*, with *Ethical Analysis* the results from two approaches will be set in an ethical context. Therefore an early consideration of trends management may react proactively at an early stage.

For common understanding of ideas in this paper, '*Robotic Systems*', '*Fourth Industrial Revolution*', '*Internet of Things*' (IoT), '*Everything-as-a-Service*' (XaaS) must be defined.

What is a 'Robotic System'? "The word 'robot' (Czech translated as "work") was created in 1920 by the Czech artist Josef Čapek for his play: R.U.R: Rossum's Universal Robots. Before the creation of this word these machines were called 'automat' or 'semi-automat'. The word 'robot' itself went through many metamorphoses with the result that a general accepted definition does not exist. It is generally agreed that a robotic system is a machine with a degree of autonomous function."<sup>1</sup>

The 'Japanese Industrial Standard Association' defines a robotic system as "a mechanical system which has flexible [autonomous] motion [and intelligent] functions analogous to ...living organisms, or combines such motion to the human will. In this context, intelligent functions mean the ability to perform at least one of the following: judgment, recognition, adaptation or learning."<sup>2</sup>

What are robotics systems in healthcare? The Butter et. al. definition for the European Commission states "Robotics for medicine and healthcare is considered the domain of systems able to perform coordinated mechatronic actions (force or movement exertions) on the basis of processing of information acquired through sensor technology, with the aim to support the functioning of impaired individuals, rehabilitation of patients and also to support individuals in prevention programs".<sup>3</sup> However, a clear distinction for a robotic system in healthcare is not given. Some robots used in healthcare are categorized as 'service robots', however, some healthcare related robotic systems such as those used in logistics do not fall into that criteria either.

The 'Fourth Industrial Revolution'<sup>4</sup> can be characterized as a new level of organization and control instrument of the entire value-added chain consisting of the life-cycle of products. This cycle is increasingly adapting itself to individual customer oriented wishes and begins from an idea, development and production, delivery to the customer and up to recycling including the services needed.

Condition is the availability of all relevant information data, in real time by interlinking all parts of the value-added chain and the ability, to optimize the production process at all times by using the data. By combining humans, objects and systems, dynamic, real-time and self-organizing value-added chain networks are created. They can be optimized towards different criteria such as cost, availability and use of resources.<sup>5</sup>

The Instrument of the 'Fourth Industrial Revolution' is the 'Internet of Things' (IoT). It is the network of

<sup>1</sup> POHL, Martin: A Comparison of Websites by Robot Manufacturers in Germany and Japan: The Ethical Relationship Between 'Robot' and 'Human Body' as a Management Challenge (2015) p.28

<sup>2</sup> SHENKAR, Oded: The Robot Masters: How Japan Has Won the Race to the Robotized Work Place (1991) p.145

<sup>3</sup> BUTTER, Maurits, et al: Robotics for Healthcare (2008) p.12

<sup>4</sup> The 'Fourth Industrial Revolution' is known in Germany as "Industrie 4.0". See POHL, Martin: "Industry 4.0" – An Evolution at the Beginning of the 21<sup>st</sup> Century (2015) Unpublished Slide Presentation

<sup>5</sup> PLATTFORM INDUSTRIE 4.0 (Ed.): Industrie 4.0. White Paper FuE Themen (2015) p.3

physical objects or ‘things’ imbedded with sensors and software. Its connectivity enables objects to exchange data with the operator, other connected devices or the manufacturer.<sup>6</sup> Grounded on the IoT, businesses will establish global networks that incorporate their facilities in the shape of ‘Cyber-Physical Systems’ (CPS), a system of collaborating computational elements controlling physical entities. These facilities are capable of autonomously exchanging information, releasing actions and controlling each other independently.<sup>7</sup> This will enable the production of robotic systems for individual customers, such as health nanobots for an individual patient.

The IoT enables the ‘Everything-as-a-Service’ (XaaS): Products and services systems are no longer separate from each other. Innovation is designing new businesses where products, services and interfaces are seen as interconnected parts. “Each product system is interlinked to a service system, and every system is dependent on products that grant value to customers. (Every product and service has an interface. Its touch points) define the way customers collaborate with services and physical products”.<sup>8</sup>

## 1. PESTEL Analysis: Macro-Trends in Healthcare in Japan

PESTEL Analysis is used as a strategic tool for understanding potential directions for business positions. It includes six fields: *political, economic, social, technical, environmental and legal* factors. In principle, the challenges of industrialized countries related to robots in healthcare are not very different therefore the following PESTEL Analysis will focus on health provision from a Japanese perspective. Conclusions related to robotic systems for healthcare are drawn after the analyses.

### Political Analysis:

As a general guideline government support is a condition for the operation of healthcare systems, regarding financing and regulating quality, cost effectiveness, safety, and patient focus. Governments are also actively responsible for innovation in the healthcare sector as they launch research programs and support medical research institutes. In Japan also, the main political target of the Japanese government is maintaining a cost-effective health system while providing access to healthcare for the entire population. Both cost and revenue are under permanent observation of the Ministry of Health, Labor and Welfare. Examples of reducing expenditure are the limitation of cost for new pharmaceutical products – and after being on the market – the annual decrease of remuneration for these products by the health insurance system, the long and bureaucratic procedure for permitting new health products in the list of products being refunded by health insurance, competition of health insurance funds under strict guidelines of the government such as a strict contribution corridor for insured while offering equal scope in services. In addition, prevention of diseases plays an important role.

On the contribution side, health insurance via contributions of the insured covers about half of the cost. About one-third comprises government health expenditure and the rest out of pocket payments.<sup>9</sup> The outlook of the Japanese health system is characterized by an aging society causing increasing cost and a national debt which is among the highest in the world. As a consequence, tight cost control in the Japanese health system will also be a main target of Japanese politics in the future.<sup>10</sup> Costs may increase or decrease depending on efficiency and effective investment in emerging technologies, including robotic systems at its forefront.

<sup>6</sup> MELZER, Rudolf J.: Mit Industrie 4.0 könnte Europa der Anschluss gelingen (2014) p.27

<sup>7</sup> WAHLSTER, Wolfgang: Neue Fabrikwelten: Industrie 4.0 (2013) p.12

<sup>8</sup> FELL, Mark: Roadmap for the Emerging “Internet of Things” (2014) p.30; CAGAN, Jonathan; VOGEL, Craig M.: Creating Breakthrough Products (2013) pp.258-261

<sup>9</sup> WHO and MHLW (Ed.): Health Service Delivery Profile Japan 2012 (2012) p.3; MOSSIALOS, Elias et. al. (Ed.): International Profiles of Health Care Systems 2014 (2015) p.83

<sup>10</sup> JONES, Randall S.: Health Care Reform in Japan (2009) p.6

### Economic Analysis:

From a macroeconomic point of view, the Japanese economy has stagnated since the burst of the financial bubble in 1990. Japan is an important player in global trade however the outlook for the global economy is uncertain and depends on multiple factors. Japan's public debt –as already mentioned– is the highest among industrialized countries based on GDP. A value added tax increase from 8% to 10% is planned for the near future to cover the expected increase in cost of social insurances including health due to the aging of society, among other factors. The total health expenditure in Japan amounts to about 10.3% of the GDP.<sup>11</sup>

There is a shortage of health related human resources, physicians, but in particular nursing staff.<sup>12</sup> In contrast to other industrial countries foreign health workers barely play a role. The Japanese education system provides enough health workers, however, many of them leave the health sector after some years to move to industries with better working conditions such as higher pay and settled working hours. The competition with the growing nursing sector for the elderly in care houses and the difficulties faced by the public authorities in providing further money will likely deteriorate this situation in coming years. Among other factors, robotic systems may play a role in this context.

### Social Analysis:

In Japan, as in other industrial countries, macro level socio-cultural factors include rising expectations about health. These expectations arise out of sociological and cultural processes. Patient empowerment and virtual exchange of communication has become another criterion. Micro-level socio-cultural factors include patient safety and labor conditions in the health sector. Not only the relatively low payment of nursing, staff but the stressful working conditions cause absenteeism and long-term incapacity to work.<sup>13</sup>

Based on this global development, Japan's healthcare system is under pressure. Furthermore, this pressure is caused by a phenomenon called "double aging": an increasing demand due to the growing number of elderly people based on a baby boom after World War II and better medical procedures. At the same time, the younger age groups are decreasing as is the population in Japan as a whole. While the number of people receiving allowances out of the social security systems is increasing, the people contributing to the systems are decreasing. The rural-urban migration is ongoing, and while metropolitan areas are still growing, parts of Japan are graying rapidly making it difficult to keep traditional healthcare delivery at a reasonable level.

Demographic factors in healthcare are related with epidemiological factors. The difference in life expectancy between women and men is decreasing. Chronic diseases will likely increase. In Japan, the top three of causes of death in 2010 were cancer (30%), heart disease (16%), and cerebrovascular disease (10%). Aspiration pneumonia is an emerging health issue due to the aging population.<sup>14</sup> Expectation of people includes having a high quality of life including the absence of disease until old age. Japanese have the longest healthy lives.<sup>15</sup> Also in this context robotic systems may find their place.

### Technological Analysis:

The acceptance of new technologies is an important factor for the successful implementation of a new device and "how society has discussed ethical, social, environmental issues and the way end users have been informed about the new technology and how they got accustomed to the new technology."<sup>16</sup> Beyond that technological developments are the driving forces for social change.

In the context of robotic systems innovations may have many different background sources.<sup>17</sup> What all these

<sup>11</sup> OECD (Ed.): OECD Health Statistics 2014 – How does Japan compare? (2014) p.3

<sup>12</sup> WHO and MHLW (Ed.): Health Service Delivery Profile Japan 2012 (2012) p.4

<sup>13</sup> BUTTER, Maurits, et al: Robotics for Healthcare (2008) p.24

<sup>14</sup> WHO and MHLW (Ed.): Health Service Delivery Profile Japan 2012 (2012) p.1

<sup>15</sup> NHK WORLD NEWS (Ed.) Study: Japanese have the Longest Healthy Lives (2015) online

<sup>16</sup> BUTTER, Maurits, et al: Robotics for Healthcare (2008) p.24

<sup>17</sup> Peter Drucker points out as innovation sources: (i) The unexpected, (ii) The incongruity, (iii) Innovation based on

sources have in common is the product planned for the market goes through several stages starting from the original idea to later mass product. Crucial in the health market, the product has to meet legal criteria to proceed from one stage to another, especially, and including Japan, patient trials,<sup>18</sup> and in certain cases the approval of an ethical review committee. As such, pure science including the academic sector is no longer the ruling model. Valorisation of output and promotion of innovation is part of their official mission.

Beyond that, technological trends and developments including health related robotic systems are drivers for change in society.

#### Legal Analysis:

Not only in regard to health related robotic systems but also here laws and regulations frequently pose a problem to freedom of research and innovation. When overdone, it may also hinder technological and economic progress.

Obviously, robotic systems are different from other devices due to its degree of autonomy. In the case of healthcare, robotic systems operate close to humans who are often in a helpless situation. Obviously stricter guidelines as per non-health related robotic systems are desirable. However, too strict guidelines will question the approval of robotic systems as a whole.

There are more questions to think about.

- The historically developed legal methodology for medicine and medical interventions will likely be cumbersome for robotic systems therefore a new approach should be developed. If not, legal questions may become a major obstacle to innovation in that field in the future.
- Data security, including privacy of data is important – data may be transferred on a global level.
- Access to the still expensive robot systems causes legal questions regarding regulation if it cannot be covered by public health insurance.

Last but not least there is the question of liability – a complex matter.<sup>19</sup> Responsibility for malfunctions of robot systems could be taken by:<sup>20</sup>

- The person being impacted (why get physically in touch with the robotic system?)
- The patient as end user (why believe in a robotic system?)
- The medical doctor (did he/she really understand the system?)
- The government regulatory authority (giving permission for use of the robotic system too early?)
- The testing agency (is the testing of the robotic system adequate?)
- The producer (release of the robotic system without enough experience in the market?)
- The researchers (error in academic thought?)
- The programmers and designers (immature programming or design?)
- The robotic system itself (if running on self-improvement software based on artificial intelligence?)

If the robotic system is set into the ‘internet of things’ further responsibilities may occur:

- The service enabler (error in programming? Wrong understanding of product-lifecycle?)
- The service provider (technical instability or wrong priority of data-flow?)

#### Environmental Analysis:

Environmental factors include ecological and environmental aspects of robots in health such as sustainable development, considerate use of natural resources such as rare earth, and consumption of energy. Recycling is

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process need, (iv) Changes in industry structure or market structure, (v) Demographics, (vi) Changes in perception, mood, and meaning, (vii) New knowledge, both scientific and nonscientific. In: DRUCKER, Peter Ferdinand: Innovation and Entrepreneurship (1985) pp.37-129

<sup>18</sup> BAST, Uwe: Das neue Medizinproduktgesetz (2007) Unpublished Slide Presentation

<sup>19</sup> Neue Züricher Zeitung (Ed.): Innovation im Gesundheitswesen. Roboter nur als Hilfen, nicht als Begleiter erwünscht (2012) online

<sup>20</sup> BUTTER, Maurits, et al: Robotics for Healthcare (2008) p.29

another aspect which should be considered. As background, in industrial countries, in total the healthcare sector is accountable for about one tenth of the flow of materials, waste production and energy usage, all the factors mentioned before should be considered when designing, using and disposing of (health) robotic systems before robots play a larger role in the health industry.

The factors explained before in the PESTEL Analysis may give different stakeholders important directions which will be explained below. Companies involved in production of health robotic systems have to consider all factors to satisfy the cross-relationships of their customers. Major stakeholders are: *Producers of robotic systems, companies producing healthcare services, health professionals, non-professional users, the government, and science.*<sup>21</sup>

Companies Producing Robotic Systems:

- Due to technical and social innovations new business fields will occur.
- Privacy of data is becoming more and more important.
- Both, operational efficiency and effectiveness will be increasingly important for robotic systems related to the health sector.
- The lack of health workers, both caregivers and physicians, will necessitate use of more technical equipment and at its forefront will be robotic health systems.

Companies Producing Healthcare Services:

- Pressure on prices – due to government intervention, national and international competition – result in more competition among care services.
- As a result of demography, the demand for healthcare will continue to increase.
- Though pressure for keeping patients as out-patients is still limited in Japan, the trend of treating outpatients for disease will increase. Robotic systems may support this process.

Health Professionals:

- Pressure on performance transparency will increase.
- The use of robotic systems will demand new skills.

Non-Professional Users:

- An increasing percentage of the population will get in touch with robotic health systems. ‘Digital Natives’ learn to use robotic systems during childhood though the systems should be easy to use.

Government:

- Cost for health will increase resulting in cost-saving measures. Payment systems by health insurance to the health sector could be focused on using robotic systems balancing quality care and costs.
- Providing research money for R&D to develop robotic systems in health will considerably influence which systems will be developed in the near future.
- Regulations for robotic systems are crucial, based on ethical criteria to be developed.

Science:

- The speed of technical development is constantly increasing.
- Cooperation between science and industry is increasingly important.
- Technology and other fields in science will merge with the development of robotic systems.
- Science depends on financial transfers from government and private enterprise.

Based on the PESTEL Analysis stakeholders may set their existing healthcare robotic systems to develop a management strategy for developing their robotic systems in healthcare. As the next step the existing market fields of robots has to be analyzed to determine the existence of the kind of robots in the market or close to the market.

<sup>21</sup> BECKER, Heidrun et. al. (Ed.): Robotik in Betreuung und Gesundheitsversorgung (2013) pp.105-112

## 2. Situation Analysis: Applications of Robots in Healthcare

When thinking about using robotic systems in healthcare an elementary starting thought is: What are people good at and what are robots good at? Only if robotic systems have advantages over human abilities or have a better relationship with work-cost structure<sup>22</sup> can their use be justified.

People have their strengths in sensing, doing complex work, in judgment and in learning ability. Robots of today's technical standard may be physically very strong, good at doing sustained work, they may do repeat work and may work in fields which people do not like to do. Though robotic systems may gradually improve in human strengths, this will take time and cannot be predicted. Humans and robots have speed, precision work and flexibility in common.<sup>23</sup> Obviously, robotic systems are a promising field, though the speed of development and implementation into the market is diverse. It takes time until robots can do work better than humans and the learning curve from field to field is very different.

From a current perspective it is necessary to determine where the advantages of robots in health can be applied. There are different ways of categorizing robotic systems in health. The most common approaches are based either on the *medical treatment chain* or on the *fields of application*.

### (I) Robotic Systems Categorized by Medical Treatment Chain

When applying this to the medical treatment chain, basically five groups of robotic systems can be determined. (i) It is useful to begin with *prevention* by having a target of no treatment. If there is the risk of a disease, the next step is *diagnosis (robotic systems in preventive therapies and diagnosis)*. If the diagnosis results in a disease, two possibilities may occur: (ii) a *surgery (robotic systems for medical interventions)* plus (iii) *professional care (robotic systems for professional care)* in the hospital (iv) and/or *rehabilitation treatment (robotic systems for rehabilitation treatment)* outside the hospital. At the end of the chain are (v) *activities related to daily living (robotic systems for assistance in life)*.<sup>24</sup> These five groups require more detailed reflection.<sup>25</sup>

With the *robots in preventive therapies and diagnosis* as business fields the connection of diagnostic functionalities to robots already used and diagnostic robots can be underlined. Robotized analysis of motion and coordination as well as intelligent fitness systems belongs to the first group. Tele-diagnostic and monitoring robotic systems as well as smart medical capsules belong to the second group.



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Toyota developed the 'Balance Training Assist'. "The robot acts as a two-wheeled balancing game. The machine displays one of three sports games on a monitor and requires the patient to make moves in the game by shifting his/her weight on the robot."<sup>27</sup>

<sup>22</sup> The economic impact of robotic systems on patient health may be calculated in terms of improvements in quality of life. Disability-adjusted life-years (DALY) estimate the burden of disease by accounting for years of life lost as well as patients' decreased quality of life. On the other hand, quality-adjusted life-years (QALY) express the gain of years based on treatment, here with IoT applications. If the DALY for a disease is ten years, a 10-percent reduction would result in the gain of one QALY. The value of QALY in years can be set in context using GDP per capita of an economy. In: MCKINSEY GLOBAL INSTITUTE: The Internet of Things: Mapping the Value Beyond the Hype (2015) p.42

<sup>23</sup> TANAKA, Hirofumi: Strategy of Mediaroid KK (2015) Unpublished Slide Presentation

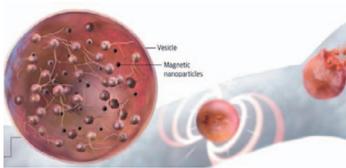
<sup>24</sup> BUTTER, Maurits, et al: Robotics for Healthcare (2008) pp.36-37

<sup>25</sup> BUTTER, Maurits, et al: Robotics for Healthcare (2008) pp.37-38

<sup>26</sup> McNICKLE, Michelle: 10 Medical Robots That Could Change Healthcare (2012) p.11

*Robots for medical interventions* allow the accomplishment of tasks that physicians themselves cannot achieve due to the precision, endurance and repeatability of robots. Furthermore, robots can work in a very small contained space inside the human body. In the following fields the use of robots is becoming increasingly popular:

- “Robot assisted micro surgery,
- Robot precision surgery,
- Robotic devices for minimal invasive surgery,<sup>28</sup>
- Medical micro- and nanobots,
- Remote surgery,
- Robotized assistance for small medical interventions,
- Robotized surgery assistance.”<sup>29</sup>



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The nanobot ‘Steerable Surgeons’ “is made of flat nickel parts assembled to make a 3-D tool that can be used during retinal surgeries, in drug therapy and for ocular disease. Its power sources are external electromagnetic coils, and it uses magnetic field gradients as a steering mechanism.”<sup>31</sup>

Though *robots supporting professional care* are mainly focused on the aging society they overlap with the health categorization. Products in this field are robotized aid for nurses, robotized patient monitoring systems, robotized physical tasks in care provision<sup>32</sup> and robotized paramedic tasks.<sup>33</sup>



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‘Cody’ is a ‘human-scale’ mobile manipulator. The “healthcare robotics’ nursing assistant uses a direct physical interface (DPI) that lets a nurse have direct control over the movement of the robot. ... Using the DPI, the nurse is able to lead and position Cody by making direct contact with its ‘body’. When the user grabs and moves either of the robot’s end effectors - or the black rubber balls attached to the robot - Cody responds.”<sup>35</sup>

Both in clinics as well as at home *robots for rehabilitation treatment* may support, not replace the therapist. Robotics in physical therapy can be divided into muscle sustaining therapies and motor-coordination therapies. Robot assisted therapies for cognitive and mental diseases are frequently based on role playing concepts.<sup>36</sup>

<sup>27</sup> Ibid. See also: TOYOTA Deutschland (Ed.): Toyota entwickelt Roboter für Pflege- und Gesundheitswesen (2011) online

<sup>28</sup> An early example is the ‘da Vinci Surgical System’. SCUTTI, Susan: Innovation ? Medical Robots are not just the Future of Health Care, but Part of the Present (2015) Slideshow p.2

<sup>29</sup> BUTTER, Maurits, et al: Robotics for Healthcare (2008) p.55

<sup>30</sup> McNICKLE, Michelle: 10 Medical Robots That Could Change Healthcare (2012) p.8

<sup>31</sup> Ibid

<sup>32</sup> PLUTA, Werner: Cody wäscht bettlägerige Patienten (2010) online

<sup>33</sup> STEEVES, Rich: Robots Invade Your Pharmacy (2013) online

<sup>34</sup> McNICKLE, Michelle: 10 Medical Robots That Could Change Healthcare (2012) p.6

<sup>35</sup> Ibid

<sup>36</sup> SCUTTI, Susan: Innovation – Medical Robots are not just the Future of Health Care, but Part of the Present (2015) Slideshow p.4



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A 'HAL' hybrid assistive limb is a "cyborg-type robot, by which a wearer's bodily functions can be improved, supported and enhanced."<sup>38</sup> "Major causes of lower limb disabilities are disorders of the cerebral and nervous muscular system. In those cases, the brain cannot use ordinary neural pathways and cannot order to move the legs. The Hybrid Assistive Limb for medical use the 'Lower Limb Model' – moves the wearer's legs in accordance with the wearer's intention."<sup>39</sup> It can teach the brain how to move the legs.

With the *robotic systems for assistance in life* as commercial fields: first applications may help users with devices for improving their lives by focusing on their daily activities, second on mobility of disabled people, and third intelligent prosthetics may replace parts of the body.<sup>40</sup>



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The electric wheelchair 'Friend' is equipped with a computer, a robot-arm and sensors such as a camera, connected with the robot-arm. With a joystick operated by the chin a disabled person may use the robotic system. Reading of books including turning of pages is possible.<sup>42</sup>

## (2) Robotic Systems Categorized on Fields of Application

As mentioned before, another way to categorize robotic systems is by fields of application. One group may include robotic systems such as *training devices and aids for mobility and independence*. A second group may be *telepresence* and *assistant robotic systems*. And a third group may be social-interactive robotic systems.<sup>43</sup>

### Robotic systems such as training devices and aids for mobility and independence

These robotic systems help with (re-)learning human needs such as moving a wheel-chair, moving a hand or foot. Three sub-groups of robotic systems may be characterized: passive guidance, supporting of an active movement and bimanual guidance, where the movement of one healthy part of the body is transferred to another, sick part. The devices allow long-term intensive therapies and permit accuracy when exercising. They may give motivation when therapists are not available, though they do not have the sensitivity and experience of therapists. These robotic systems can be fixed directly with the body (orthosis) or fixed with the body (exoskeleton). Other aids may be robotic 'smart' wheelchairs.<sup>44</sup> Some products are already on the market, though they are still expensive. Research on the efficiency of these systems is still limited. A breakthrough will be dependent on financing such as by the public assurance system.

<sup>37</sup> CYBERDYNE Inc. (Ed.): HAL for Medical Use (2015) online

<sup>38</sup> CYBERDYNE Inc. (Ed.): What's HAL. The World's First Cyborg Robot HAL (2015) online

<sup>39</sup> CYBERDYNE Inc. (Ed.): HAL for Medical Use (2015) online

<sup>40</sup> SILVERSTEIN, Ed: Low-Cost Robohand Provides Miracle for Five-Year-Old Boy, Others Can Benefit from Device (2013) online

<sup>41</sup> DPA (Ed.): Roboter hilft Behinderten beim Arbeiten (2012) online

<sup>42</sup> Ibid

<sup>43</sup> BECKER, Heidrun; RÜEGSEGGER, Adrian: Robotik in Betreuung und Gesundheitsversorgung (2013) p.62-63

<sup>44</sup> STEEVES, Rich: Robotic Wheelchair Can Smoothly Traverse Even the Bumpiest Terrain (2012) online



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'Bestic' "is a small robotic arm with a spoon on the end. The arm can be easily maneuvered, and a user can independently control the spoon's movement on a plate by choosing what and when to eat."<sup>46</sup>

### Telepresence and assistant robotic systems

*Telepresence robotic systems* are remote-controlled, mobile robots. They can replace the physical presence of a care person. These robots can be used for example in rural areas.



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The 'RP-VITA' is an independent telemedicine assistant system that allows physicians to care for patients remotely. "The system features mapping and obstacle detection, as well as avoidance technology and an iPad user interface for control and interaction. The robot can also interface with diagnostic devices and electronic medical records (EMR) systems."<sup>48</sup>



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'AnyBots' "provides a type of immersive telepresence, meaning instead of focusing merely on audio and video communications, the 'AnyBots' robot allows for movement controlled by a remote. ... 'AnyBots' can turn on sensors at the control of not the person in the room, but the person who wants to do the communication."<sup>50</sup>

*Assistant robotic systems* support humans in their everyday work such as routine work or physical and psychologically demanding work. These robots can be divided into the subgroups of robots supporting care staff, for example cleaning of the floor or distribution of food.<sup>51</sup> The other group of robotic systems is designed to help sick people at home. They allow people to live in their homes and may support relatives in providing assistance. They may remind people about taking medicine, communicate with nursing staff and collect data regarding diseases.<sup>52</sup> Depending on their function, the robots have different designs, such as the shape of animals, humans or a fanciful shape.

<sup>45</sup> McNICKLE, Michelle: 10 Medical Robots That Could Change Healthcare (2012) p.5

<sup>46</sup> Ibid

<sup>47</sup> McNICKLE, Michelle: 10 Medical Robots That Could Change Healthcare (2012) p.4

<sup>48</sup> Ibid

<sup>49</sup> McNICKLE, Michelle: 10 Medical Robots That Could Change Healthcare (2012) p.9

<sup>50</sup> Ibid

<sup>51</sup> MALSEKI, Debra Ann: Health Care Robotics (2014) online

<sup>52</sup> SCUTTI, Susan: Innovation – Medical Robots are not just the Future of Health Care, but Part of the Present (2015) Slideshow p.3



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The ‘Swisslog RoboCourier’ “is an autonomous mobile robot. The tool dispatches and delivers specimens, medications and supplies throughout the hospital. Once the robot is carrying what needs to be delivered, a person identifies the destination and the robot selects the most efficient route to deliver the materials. ... The robot uses laser detection to ensure precise and safe navigation, while voice-activated messages alert staff of the robot’s presence. The robot also stops and waits until traffic is clear, and it can signal doors to automatically open so it can move through.”<sup>54</sup>

There is little research on the analysis of acceptance of telepresence and assistant robotic systems such as the relations between the robot and patients and care staff. One risk could be a feeling of safety that is not justified.<sup>55</sup>

### Social-interactive robotic systems

*Social robots* are virtual social actors produced to form an illusion of a ‘real’ social interaction. In contrast to artificial or mediated items social robots are physically tangible and real since they are embodied.<sup>56</sup>

Social robotic systems evoke social behavior based on human behavior in forming emotional bonds. They can distinguish between objects and social agents in their environment with whom they are in touch. They show social intelligence. Most of the social robotic systems are designed as toys. Humanoid robots which can walk on two legs can be characterized into:

- *Utilitarian humanoid robots*: They interact as embodied ‘beings’ providing guidance in shops, serving food in hospital etc.
- *Affective humanoid robots*: They are created to interact with human on an emotional level – either on the internet or in mostly private homes. Humans can enter into an individual relationship.



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‘CosmoBot’ is used “to enhance the therapy of developmentally disabled children between 5 and 12 years old. The robot can make therapy more interesting for children and allows for better success when achieving long-term therapy goals: ... the robot collects data on a child’s performance. This allows therapists to evaluate how successful the therapy is.”<sup>58</sup>

Though, it must be questioned if a relationship between human and robotic system is really a social interaction. Context and action are interrelated however robots cannot set communication into a context. Artificial intelligence is based on planning models, in other words, the mind is fixed before action takes place. This may contradict with the interpretations of humans, which may cause communication problems.<sup>59</sup> Crucially, the control of communication is within the competence of the individual human being.

<sup>53</sup> McNICKLE, Michelle: 10 Medical Robots That Could Change Healthcare (2012) p.10

<sup>54</sup> Ibid

<sup>55</sup> A list of existing research studies can be found in BECKER, Heidrun et. al. (Ed.): Robotik in Betreuung und Gesundheitsversorgung (2013) p.48 and p.51

<sup>56</sup> LILL, Felix: Unheimliche Helfer. Eine neue Generation von Robotern soll den Alltag verändern. Eindrücke von der Mensch-Roboter-Konferenz in Tokio (2013) online

<sup>57</sup> McNICKLE, Michelle: 10 Medical Robots That Could Change Healthcare (2012) p.7

<sup>58</sup> Ibid

<sup>59</sup> BECKER, Heidrun et. al. (Ed.): Robotik in Betreuung und Gesundheitsversorgung (2013) p.60

### (3) Robotic Systems in the Context of the “Internet of Things”

Health robotic systems within context of the Internet of Things (IoT) are in a very early stage of production, so it is too early to talk of a specific category. Furthermore, the robotic systems in this context being developed in future may be included in the previous two groups of categorization. The existing systems focus mainly on improving health and wellness. Internet-connected devices used in medical facilities may have a health-related relationship; however, they may be closer to factory settings. In principle three groups of devices may be determined:

- *Wearables*: The devices available presently designed to carry or wear are mainly focused on diabetes, chronic heart failure, and chronic obstructive pulmonary disease. Most of them represent an early stage of a robotic system: they have sensors and transmit information; however, most of them are not able to fulfill coordinated mechatronic actions.
- *Intelligent implantables, injectables and ingestibles*: The devices available today are mainly prototypes, such as nanobots that recognize early stage cancer or can clear arteries.
- *Non-wearable measurement devices*: These “devices gather and transmit health data from the human body periodically but are not attached continuously.”<sup>60</sup> Not all of them are robots.

For all three groups it can be stated, that “using IoT technology for more continuous and consistent monitoring of patients with chronic diseases can help patients to avoid medical crises, hospitalizations and complications.”<sup>61</sup>

In brief there are a lot of robotic systems: starting from training devices and assisting preventive therapies up to robots which can do surgeries or who appear as humanoid robots. Many of the robotic systems are still prototypes and as such knowledge about their helpfulness is limited. The difference in technical complexity among the robotic systems is large.

### 3. Ethical Analysis: The Bottleneck for Robotic Systems in the Market

Ethical issues in the arena of public discussion usually arise only when stakeholder groups have differing opinions about what is appropriate and what is inappropriate within the context of new developments. Robotic systems for major healthcare issues have not been discussed, though there are severe emerging issues. The ethical thoughts in this paper concentrate on three topics: first *communication between human and robotic systems* in general, second the *operational level of robotic systems in healthcare* and on third *the IoT as crucial part of the health related robotic systems* of the future.

Communication between human and robotic systems: Only humans understand the meaning of communication and only in robotic system fields is programmed communication possible. Furthermore, only humans can understand meanings out of context. Humans use energy to establish and maintain human relations with other humans and animals and receive in return emotional support such as friendship. This is part of human existence. Also for communication with robots humans have to use energy. But what is the return? Can the mechanical smile of a robot be appreciated in a similar way as the smile of a human? Can it be argued that this depends on the context, such as a lonely person in a hospital, or a culture, such as the open-minded Japanese culture. Or, at its core: is it ethically appropriate to develop and sell robotic systems for humans who have no other opportunity to develop emotional bonds?<sup>62</sup> In that sense the interaction between human and robotic systems may convert society with the result that both human beings and the individual may

<sup>60</sup> MCKINSEY GLOBAL INSTITUTE (Ed.): The Internet of Things: Mapping the Value Beyond the Hype (2015) p.38

<sup>61</sup> MCKINSEY GLOBAL INSTITUTE (Ed.): The Internet of Things: Mapping the Value Beyond the Hype (2015) p.39

<sup>62</sup> BECKER, Heidrun et. al.(Ed.): Robotik in Betreuung und Gesundheitsversorgung (2013) p.62

have to be re-defined.

On an operational level of robotic systems in healthcare two questions appear: Do health related robotic systems violate ethical values? And if such robotic systems act by themselves: do they do that in an ethical way?

Related to the first question, basic values in the health sector are first: no damage, second: autonomy, third: care, fourth: righteousness. From the point of view of ethics, this discipline has to think about the new developments and evaluate, if there is a violation against these ethical principles. From the viewpoint of management, a violation of these principles will make a success of a new product very unlikely and as such the investment a management failure. What could be the ethical demands?<sup>63</sup>

- *Dehumanising*: The care of sick people by robots may be called inhuman, especially, if the care has been undertaken by human before. On the other hand, robotic systems may be companions for sick people.
- *Social Poverty*: The care by robots of sick people may be considered an exclusion by society in an increasingly health orientated society. There is a positive correlation between social poverty and mortality.
- *Experimenting with Sick People*: The use of robotic systems may give the impression, that sick people may be used as test subjects. Though, people having no chance to survive based on present know-how may benefit from experiments.
- *Exploitation of Human Emotions*: Robots with communication abilities may use human emotions for doubtful purposes.
- *Redefinition of Human*: If applying robotic systems in healthcare, humans might be presented with the situation where they are surrounded by robotic systems that simulate human behavior, while themselves being dependent on robotic systems.
- *Risk of Developing a Dual-Use Technology*: Technologies developed for the health sector may be used for military purposes.
- *Human Enhancement Technologies*: Technologies developed for health diseases may be used to increase abilities of healthy people. This may cause questions about the definition of future humans. Touching the ethical dividing line between healing and enhancement may impact the definitions of illness and health.
- *Affordability*: Robotic systems will be only successful if they can be used by a large percentage of the population. This does not only apply if only wealthy people have access, but an ethical boundary may be crossed when the gap is widened between what can be done and what is actually done.

In relation to the second question: ‘Are robotic systems able to act ethically themselves?’ The answer seems to be from today’s point of understanding evident. It is questionable that robots may be taught ethical behavior as such. Since robots are developed for a specific purpose, considering ethical questions must be within the context of the purpose.

Since more and more robotic systems will be related to the ‘Fourth Industrial Revolution’ thinking of ethics is crucial in this context. At this early stage it is particularly important to focus on the governance of the IoT. Various stakeholders in the value chain may obtain power: Power over first *network standards*, second *products and their distribution*, and third *network traffic*.<sup>64</sup>

#### Power Over Network Standards

Both, how and what a robotic system can communicate, may be part of closed standards and may create the chance of controlling IoT networks. Closed standards struggle with two main problems. First, they re-create “problems that the internet has already solved: how to assign network names to devices, how to route messages between networks, how to manage the flow of traffic, and how to secure communication.”<sup>65</sup> Second, it is not in

<sup>63</sup> Ibid p.84-85

<sup>64</sup> FELL, Mark: Roadmap for the Emerging “Internet of Things” (2014) pp.52-56

<sup>65</sup> FELL, Mark: Roadmap for the Emerging “Internet of Things” (2014) p.52

the interest of the customer, such as a hospital, that wants to buy products from different makers which speak the same technical language. Though, in contradiction to the customers' desire, it can be expected that in the near future many companies will try to develop closed standards.

#### Power Over Products

Manufacturers traditionally use “the power of distribution systems and intellectual property rights to control the supply of their products. ... (This causes new interdependencies, such as) an IoT-based product may need to employ a third party product. ... (However,) even if both products are present in a market, one of them may refuse to cooperate.”<sup>66</sup>

#### Power over Network Traffic

Network operators “can block or slow down traffic on their broadband networks based on individual users or the type of traffic those users are accessing or by the type of service that is sending the content. ... (Beyond network neutrality) consumers need to be able to afford to pay for their IoT data use. Many devices, also in robotic systems related health sector, will be mobile and as such prone to roaming fees. New business models for data usage have to be developed,”<sup>67</sup> going as far as treating the IoT network as a public utility - health may be a good starting field for development in this direction.

The thoughts on ethics show that there are many open questions applicable for the arena of public discussion. Finding ethical agreements – is a condition for the success of robotic systems in the healthcare sectors – at least within societies where the robotic systems are supposed to be implemented. In the following outlook an approach for a result-orientated outcome will be introduced.

## **4. Summary and Outlook**

This paper states that robotic systems in healthcare will be like any other product and service, that is be successful only if they add both financial and social-ethical value. The core question is, can robotic systems add monetary and/or social value to healthcare? A positive answer is sine *qua non* for the development of any robotic system – and due to that also the thoughts of this text.

Following the research question and the hypothesis of this paper, the ideas are proof that not only the macro-trends are favorable, but on the operational level robotic systems can add value to healthcare. This has already been achieved for robotic systems currently in the market. Due to the large number of different kinds of robotic systems, each system fulfills a different task. Overlapping between tasks is frequent, and so are the monetary and non-monetary values these robotic systems produce. A robotic system may reduce labor-cost and perform activities that cannot be done by humans. But a robotic system may also increase the cost for human resources or capital commitment while increasing the quality of care. A challenge in this context is that monetary transfers can be measured whereas intangible factors such as quality of life are difficult to evaluate and transfer into monetary units. Finding solutions for this has to be the subject of future research.

Whereas technical and management challenges towards new robotic systems are on track – though in different stages – the discussion about ethics is in a very early stage, though the potential for conflict within the context of robotic systems is significant. Whereas many ethical demands towards robotic systems in healthcare are identified as such, public discussions remain fragmented. Since in the very near future more and more health related robotic systems will be part of the 'Internet of Things' (IoT), finding a consensus based on a public discussion is time sensitive for successful ongoing development. Beyond the general ethical discussion on the IoT the health sector has its own ethical context since it is embedded into the context of monetary needs, reflecting modern management, but at the same time in the Hippocratic oath. From an international perspective,

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<sup>66</sup> FELL, Mark: Roadmap for the Emerging “Internet of Things” (2014) pp.52-53

<sup>67</sup> FELL, Mark: Roadmap for the Emerging “Internet of Things” (2014) pp.55-56

comparisons in terms of ethics, business practices including managed innovation, healthcare practices and reflection among different countries being selected, are multidimensional and discrete topics of research. Future work may shed light on them.

The thoughts on ethics indicate: How can these conflicts be socially and economically better and effectively solved based on ethic values? Stakeholders in robotic systems may seek to: First reconcile their underlying interests, second to find who is right, third to state who is more powerful.<sup>68</sup> But what does 'better' and 'effective' suggest, when following this structure? To minimize the cost of disputes is equivalent with reducing transaction cost. Another way of evaluating different approaches is by the parties' mutual satisfaction with the results. Satisfaction does not only depend on the perceived fairness of the resolution, but also on the perceived fairness of the dispute resolution procedure. A third criterion is the long-term effect on the parties' relationship. It may affect the abilities of parties to work together on a day-to-day basis. The fourth criterion is whether a particular approach produces durable resolutions.<sup>69</sup>

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<sup>68</sup> URY, William L.: Getting Disputes Resolved (1993) pp.4-10

<sup>69</sup> URY, William L.: Getting Disputes Resolved (1993) pp.11-12, FELL, Mark: Roadmap for the Emerging "Internet of Things" (2014) pp.62-70

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