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INBOTS
Inclusive Robotics for a better Society

INBOTS WHITE PAPER

ON

INTERACTIVE ROBOTICS STRATEGIES TO INCREASE PUBLIC AWARENESS AND ACCEPTANCE

This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 780073

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1. Executive Summary

This white paper aims increase the knowledge of acceptance, access and use of interactive robots among the public, being citizens in the European Union and associated countries – Iceland and Switzerland. The conclusions are the result of analysis of statistics and recent validated models of social uptake and acceptance related to interactive robots European-wide and of testing potential design that can promote social uptake and acceptance in some areas where interactive robots are less mature or developed. The content was discussed within the European community at more than sixty occasions and laid the foundation for the analysis and the results reported in white paper.

Interactive robots are defined as any robot that is interacting in close proximity with humans, more precisely a system that has a physical body, so that it can interact in close proximity with humans and with the environment. The report has an interdisciplinary perspective related to Science Technology Studies (STS) from which we can retrieve three scientific facts: that the uptake of interactive robots cannot expect to take place in isolation from the social context; that the practical significance and meaning of the technology is not predictable outside the context in which it is intended to be implemented; and that the potential uptake of interactive robots is not separated from previous technological developments, it is not a revolutionary development but rather an evolutionary development.

2. Key findings

1. Key findings derived from Chapter 3: Europe´s position in social uptake of interactive robots

Insufficient statistics on social uptake and use of interactive robots among the public Europe-wide is a problem that tend to lower the speed and target fulfilment. The inventory of best practices in different parts of Europe shows leading, promising and potential developments with different degrees of maturity in different sectors.

2. Key findings derived from Chapter 4: Lessons from technology development being evolutionary

The fast and comprehensive social uptake of information- and communication technologies in the past two decades is, for different reasons, expected to nurture acceptance and social uptake of interactive robots. These reasons are increased habituation to communicate over distances, transferring certain tasks to machines and getting used to being part of life in modern society and at the heart of social cohesion. Today 83 % of European citizens and 85 % of the households' access Internet every day.

3. Key findings derived from Chapter 5:Social uptake and use of interactive robots in different sectors

Interactive robots have reached different stages of maturity in different sectors. Available statistics and best practices show that industry is at the leading-edge including

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manufacturing, logistics, rescue activities and exoskeletons. A promising area with a number of applications implemented is education. Other promising areas starting to use interactive robots are health care including social care, robotized assistance for surgery and assistance to compensate for physical losses. Interactive robots at public places for example marketplaces is an example of a potentially promising area with a few single examples

4. Key findings derived from Chapter 6: Industry as the leading user of interactive robots

Interactive robots prove to have developed into a useful and safe technology. In manufacturing, it is appreciated because of its ability to perform repetitive tasks. Interactive robots are used as wearables both in manufacturing as exoskeletons to prevent fatigue, injuries, reduce workload and to compensate for disabilities. The main barrier for using wearables in industry is the lack of user-acceptance. In logistics, interactive robots are used to increase efficiency in transportation. The barriers are related to various tasks carried out in this sector, necessarily requires human collaboration. In rescue activities interactive robots are actually requested by search and rescue teams that find this technology having a high readiness and public awareness. The barriers are mainly related to the complexity of emergency response and the need for standards.

5. Key findings derived from Chapter 7: Education as a promising user of interactive robots

Interactive robots are used in education activities from lower levels of education up to higher education. It is proven to improve cognitive skills, social skills and scientific skills. The barriers for further developments are lack of supporting equipment, lack of knowledge among teachers and lack of curriculum that support using this technology.

6. Key findings derived from Chapter :8: Health care as a promising user of interactive robots

Patients with decreased mobility after neurological injuries such as stroke or spinal cord injury are expected to benefit from powered exoskeletons. Motion tasks in daily life, that may be supported are walking, running, sit-to-stand transfers, ascending and descending stairs and lifting heavy loads. The barriers are related to control and adaptability. Implementation is dependent on acceptance and regular use in daily life. Another requirement is that exoskeletons need to be developed in conjunction with other existing or emerging technologies, structures and services.

7. Key findings derived from Chapter :9 How to enhance promising and potential use of interactive robots

The lack of acceptance is crucial for the social uptake of the promising and potential interactive robots described in previous chapters. Acceptance means that interactive robots is dependent on contextual, cultural and individually related actors. Today there

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are well-developed models to understand what makes it possible and what prevents the acceptance of new technology. The opposite also applies, that interactive robots isolated from the context where it is supposed to be implemented or given to people without experience of technical changes and of the advantages this can bring, will have difficulty being accepted and used.

Highlights

With reference to section 2.1 of the DoA, the work carried out in WP6 and its result will increase the knowledge about the distribution of interactive robots in different sectors and what are the barriers and what can be done to improve the situation. The result show that interactive robots today are unevenly distributed. The most important conclusion is that there are good reasons, both economic and social reasons, to consider what creates acceptance and uptake of robots in less robotized sectors. There are promising developments in new and emerging sectors such as in public sectors and in social care but one obstacle is insufficient insights about what creates social uptake which might risk both investments and welfare.

3. Introduction: Europe´s position in social uptake of interactive robots

Europe is well placed to become a leader in the use of interactive robots, but developments are unevenly distributed among different sectors and information about the spread and use is inadequate. The inventory of best practises in different parts of Europe shows different degrees of maturity in different sectors. In some sectors, the development is far advanced, in others there is a promising development or a potential for development. Lack of access to information about social uptake and acceptance Europe-wide is a problem that tend to lower the speed and target fulfilment. Eurostat, being the statistical office of the European Union, provide a clear picture of developments in the industry both in terms of products and services but lack the corresponding indicators for the public uptake and acceptance.[1] Without statistics on the social uptake and use of digital resources, in the beginning of what seem to be a new technological wave of interactive robotics, policy makers are flying blind.[2]

This white paper aims at enhancing social uptake and acceptance of interactive robots among the public, being citizens in the European Union and associated countries: Iceland and Switzerland?, by grasping the societal values, needs and expectations of interactive

[1] Eurostat Outlook 21/01/2019: https://ec.europa.eu/eurostat/en/web/products-eurostat-news/-/DDN-20190121-1

[2] Bodrožić, Zlatko, and Paul S. Adler. "The evolution of management models: A neo-Schumpeterian theory." *Administrative Science Quarterly* 63.1 (2018): 85-129.

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robots and report on what specific robotic applications are needed and identify a set of key findings where interactive robots are socially desirable. It includes a report on available statistics and research on the challenges of implementing interactive robots in different areas. The conclusions are the result of a number of scientific endeavours. First, the scientific work of analysing statistics and recent validated models of social uptake and acceptance related to interactive robots European-wide. Second, they are the result of testing potential design that can promote social uptake and acceptance in some areas where interactive robots are less mature or developed. These focus groups were conducted in Sweden within total 94 participants including line managers, frontline care personnel, older people and students who are training to become frontline care personnel. In 2020 these conclusions will be turned into a proposal for a strategy including how to implement key requirements and assess implementation of interactive robots.

Interactive robots are defined as any robot that is interacting in close proximity with humans, more precisely a system that has a physical body, so that it can interact in close proximity with humans and with the environment. The report has an interdisciplinary perspective related to Science Technology Studies (STS) which is viewing science and technology as socially embedded enterprises interacting with humans and social contexts. Three important scientific facts are derived from this perspective. First, that the uptake of interactive robots cannot be expected to take place in isolation from the social context. Second, the practical significance and meaning of the technology is not predictable outside the context in which it is intended to be implemented. Third, the potential uptake of interactive robots is not separated from previous technological developments, it is not a revolutionary development but rather an evolutionary development, based on already existent systems of technologies and social relations. Hence, although interactive robots are not the same as the 1990s IT development, it is difficult to imagine the use of interactive robots without prior domestication and normalization processes of information and communication technologies and the legislations, standards, infrastructures, political decisions and different actors whose "negotiations" determined the degree to which these systems became accepted and used.[3]

Green biotechnology is one example, how the introduction of a new technology can fail due to public non-acceptance. Green biotechnology is a research tribe of genetic engineering with plants as genuine objects. Especially in agriculture and forestry the application of genetically modified species can contribute to an increasing nutrition and health. But the promises and positive potentials of these technologies are surrounded by public fears and misunderstandings which lead to a strong gap of factual acceptance – although from a scientific point of view green biotechnologies are not evaluated as per se unsaved. One reason is the perspective of users has not been included when introducing these technologies. A technical or economic benefit for producers does not automatically lead to the trust of consumers. Another reason relates to the complexity of biotechnologies. Again, for layman but also many scientists it is difficult to understand the very details of genetic engineering.

[3] Latour 2005

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4. Lessons from technology development being evolutionary?

Socio-economic aspects have generally a strong influence on technological developments. In the case of interactive robotics especially the social impact is pretty high since robots are often not only seen as means to fulfil certain ends. Technology users relate very personal emotional expectations like hope and fear to robotic systems. Robotic appearance plays a crucial role.[4] The more humanoid a robot appears, the more likely are projections of socio-cultural values – robots appear as "quasi-others" and social "mirrors".[5] Service applications are of a high socio-economic significance including similar effects: because of the close interaction between robots and end-users, the robotic systems often become objects of psychological projections which leads to crucial multidisciplinary problems – including ethical issues as well.[6] Two key concepts in the debate are trust and acceptance. With a unique focus on stakeholders and the designers of artificial intelligence – including robotic systems – recently the High-Level Expert Group on Artificial Intelligence of the European Commission released *Ethics Guidelines for Trustworty Artificial Intelligence*[7].

Today´s development of interactive robots can, from a social science perspective, be regarded as a continuation of an ongoing automation that goes back several decades and in which citizens gradually learn and accept new ways of communicating and interacting. Here is meant the gradual utilization of communicating over distances in several different ways, transferring certain tasks to machines and getting used to being part of life in modern society and at the heart of social cohesion. Interactive robots can be expected to both increase mediated communication and at the same time introduce new possibilities such as exoskeletons supporting weak muscles.[8]

For this reason, it makes sense to consider the social uptake of digital applications as a prerequisite for adopting and accepting interactive robots. Digital inclusion or exclusion have long been a focus for the EC and there are statistics on the frequency of internet access among European citizens.[9] Today 83 % of European citizens living in cities access Internet every day. The variation ranges from 70 % in Italy and 72 % in Romania to 96

4 Coeckelbergh, Mark. "Robotic appearances and forms of life. A phenomenological-hermeneutical approach to the relation between robotics and culture." *Robotics in Germany and Japan. Philosophical and technical perspectives* (2014): 59

5 Ihde 1990, p. 42, pp. 97-108, 107; Coeckelbergh 2011, p. 61, p. 65: Coeckelbergh, M. 2011: "You, robot: on the linguistic construction of artificial others." In: AI & Soc (2011), 26, pp. 61-69; Ihde, D. 1990: Technology and the Lifeworld. From Garden to Earth, Bllomington.

6 Decker M (2014) Who is taking over? Technology Assessment of Autonomous (Service) Robots. In Funk M / Irrgang B (Hrsg) Robotics in Germany and Japan. Philosophical and Technical Perspectives. Peter Lang, Frankfurt a.M. u.a., pp. 91–110; Funk, Michael (2019) Roboter- und Drohnenethik. Eine methodische Einführung. Wiesbaden, Springer

7 AI HLEG (2019) Ethics Guidelines for Trustworty Artificial Intelligence. High-Level Expert Group on Artificial Intelligence. 8. April 2019. European Commission, Brüssel [https://ec.europa.eu/futurium/en/ai-alliance-consultation (12. April 2019)], p. 7.

8 SOU 2014:13. En digital agenda i människans tjänst – en ljusnande framtid kan bli vår. Delbetänkande av Digitaliseringskommissionen.

9 Eurostat 2016: Digital inclusion – individuals. http://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do#

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% in Denmark and 93 % in Sweden (ibid). Citizens who never use Internet amounts to 14 % in total (ibid). The adoption rate is both high and encompass key areas of society. In 2016, 85 % of the European households had access to Internet, compared to 70% in 2010, while ten years earlier this kind of statistics were hardly developed on an European level.[10] In 2016 we can conclude that 82 % of the European population use Internet, usually with their mobile/smart phone. The highest share of accessing Internet via smart phones are found in Spain (93%), in Cyprus (88%) and in Netherlands (88%). There are differences between age groups. For example, access to a smart phone is in the age group 16-24, 94 %, in the age group 25-34, 91 % and in the age group 65-74, 48%. Internet is mostly used for sending or receiving e-mails, 86%, finding information, 80%, and social networking, 63%. In 2016 almost all European businesses were connected to Internet, 97%. Since 8 out 10 European consumers search for information on goods and services online, 80% of businesses have their own website. The number of websites is highest in Finland, 95%, Denmark, 93% and Germany and Sweden, 91%. Social media is the most widely use of Internet among businesses in Europe, 46%.

To conclude, against the background of the relatively rapid adoption of ICT and the gradually developed habit to communicate in new ways, that have taken place over the past two decades, there are good reasons to believe that interactive robots, under the right conditions, will be socially accepted and used.

5. Social uptake and use of interactive robots in different sectors

Interactive robots have reached different stages of maturity in different sectors. Despite of the lack of European wide statistics in areas where European union have no overarching social policy – especially welfare policies – the review of scientific articles, business reports and the inventory of best practises in individual countries show that interactive robots are established to varying degrees.

Industry is at the leading edge contextualised in the discourse about the new digital economy. This discourse includes issues such as advanced, manufacturing, robotics and factory automation, new sources of data from mobile and ubiquitous Internet connectivity, cloud computing, big data analytics and artificial intelligence, all related to business.[11] Even though new phenomena are pointed out in relation to the new digital economy, for example labour markets, there is still a lack of statistics on the integration of interactive robots in working life, on those outside the labour market and other issues of public nature such as education, housing, healthcare and individuals societal behaviours and social integration (ibid). This lack run the risk to harm individuals but mainly prevent decisionmakers to evaluate if public resources are spent in an effective way. Health care, interactive robots to support decreased mobility and chronic illnesses, assistive needs are sectors that are discussed but lack adequate information on access

10 Eurostat: https://ec.europa.eu/eurostat/web/digital-economy-and-society/data/database
Report: Digital Economy and Society in the EU 2017.

[11] Eurostat 2018: Power from Statistics: data, information and knowledge. Outlook report 2018 https://ec.europa.eu/eurostat/cache/digpub/keyfigures/).

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and use. One explanation why it is not yet included can simply be that this is a relatively new field. Another explanation is that these sectors are considered as national issues related to various welfare systems and national agendas of social policies and as such not part of a transnational discourse.[12] Education is a sector using interactive robots but lack European wide statistics even though it is highly discussed in scientific publications. Interactive robots at public places for example marketplaces is an example of a promising area with a few single examples.

To conclude, interactive robots have reached different stages of maturity in different sectors. Available statistics and best practices show that industry is at the leading-edge including manufacturing, logistics, rescue activities and exoskeletons. A promising area with a number of applications implemented is education. Other promising areas starting to use interactive robots are health care including social care, robotized assistance for surgery and assistance to compensate for physical losses. Interactive robots at public places for example marketplaces is an example of a potentially promising area with a few single examples such as robots giving information at the entrance of shopping malls

6. Industry as the leading user of interactive robots

Eurostat statistics show that 25 % of large enterprises in the EU use robots, 12 % of medium sized enterprises (employing 50-249 persons) and 5 % of small enterprises (employing 10-49 persons).[13] Enterprises more commonly use industrial robots than service robots. Enterprises use service robots mainly for warehouse management systems (44 %) followed by transportation of people and goods (22 %), cleaning or waste disposal tasks, as well as assembly works (21 % each) (ibid). Best practises can be found in manufacturing; in exoskeletons as wearables in working life; and in industrial related areas such as logistics and rescue activities.

1. Interactive robots in manufacturing

Regarding the industrial collaborative robots, the state of art, highlight a good development of application in industrial workplaces especially where the movement are repetitive and the components to be manipulated are quite heavy. The target of the Human Robot Collaboration (HRC) is the strict interaction between the persons (the worker) and the robot. The innovative sensitization used is enabling the robot to be safe also if happen the contact with the human. In this way, some tasks that so far were developed only by the human now can be carried out in collaboration with robot, safely and productively. For the HRC there are already several application field in mechanics and car body assembling in industry. Many applications today are related to the bin picking, pick and place of small components. In these cases, the activity is shared between human and robot leaving to the human the more complex and cognitive tasks and addressing to the robot the heavier and not ergonomics tasks. This collaboration and the related

[12] Horn & Scweppe 2017
[13] Eurostat Outlook 21/01/2019: https://ec.europa.eu/eurostat/en/web/products-eurostat-news/-/DDN-20190121-1

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interaction are nowadays a real innovative working approach because so far today industrial robots were confined in a protected cell with safety fencing. It is still missing the use of humanoid in big factories. Some studies are ongoing, in order to understand the physical, safety and psychological aspects related to the collaboration, that are fundamental to allow the use of these systems. In particular safety and perception are a focal point in order to increase the acceptability by the users.

In the industrial field, in fact one of the emerging social phenomena is the constant increase in population ageing at work. According to Eurostat, in 2017, the population of the EU-28 was estimated at 511.5 million people. Young people (0-14 years old) accounted for 15.6 % of the EU-28 population, while people of working age (15-64 years old) accounted for 64.9 %. The proportion of older people (aged 65 and over) was 19.4 % (an increase of 0.2 percentage points over the previous year and 2.4 percentage points over 10 years earlier).

Furthermore, in Europe, the incidence of Work-related Musculoskeletal Disorders (WMSD) is around 38.1% and the impact on GDP of the related countries (up to 3.3%) increases focus on the phenomenon (EU-OSHA, 2017). Risks are mainly associated with maintaining awkward postures manual activities and for long time, lifting moderate weight frequently. The most affected body districts are the back and the upper limbs (EU-OSHA, 2010; Zurada, 2012). the onset of musculoskeletal disorders has a serious effect on the absenteeism and on reallocation of workers.

The need to prevent musculoskeletal disorders in the long term, in order to ensure an active aging through device able to support elderly people both in daily life, together with the constant ageing of the working population, has led the industrial world to an increasing interest to new technologies, including the exoskeletons (FondazionErgo, 2017).

a. Case Study Industrial robots collaborating at manufacturing places

i. The problem

One of the case studies in automotive industry is: working under the car body with arms at shoulder level. The work activity is about the assembly of components under the car body in the final part of the assembly line. This kind of workstation, due to the prolonged awkward posture, is particularly heavy from the point of view of the ergonomics, analysed through specifics indices (OCRA, OAWS, RULA, Strain Index and HAL/ACGIH TLV) as reported in the standard ISO 11228-3. The modification of the workstation, in order to avoid the posture is very difficult because the car must not be rotated due to the fact that it is has just been filled with the internal fluids. This is a common shared situation with all the automobiles factories.

The general solution is represented from a user-friendly intelligent, cooperative, lightweight, wearable, human-robotic exoskeleton for manual handling work. The proposed solution in general not requires specific task programming.

It is highly flexible and can be used directly in craft or mass production or in auxiliary processes. The specific solution addressed to the case study it’s the use of an exoskeleton

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for the arms supporting in a typical task of the automotive industry. The support given by the exoskeleton is finalized to keep awkward posture all shift long. The exoskeleton configuration can be different in application from one company to another, but the function and the interaction is the same.

The need is to combine the repetitive performance of robots with the individual skills and ability of people. People have an excellent capability for solving imprecise exercises; robots exhibit precision, power and endurance. The objective of collaborative robotics is an innovative manufacturing process that achieve significant economic and ergonomic benefit through robotic assistance in manual processes. Interactivity between human and robot and their productive collaboration is the challenge in this field of innovation.

In particular, the case study used for reference is a typical task of the mechanical industry. It consists of assembling of both small and heavy components in the manufacturing of the gearbox of cars.

ii. The solution

For increasing ergonomics and efficiency of the workstation, the work task is shared between a robot able to manipulate the heavy gear and the worker that is able to assemble correctly the small components. The aim is to allow efficient and productive interaction between a worker and a robotic assistant, such as the case shown in Picture IRSIPAA 1 (a)Picture IRSIPAA 2 (b). The robot is working very close to the worker without fences or safety barriers. This is possible because the robot is properly developed for this purpose and the several sensors on board give to the robot a high level of sensitivity and safety even in the eventual touching with the worker or collision with him. This kind of interactive robotics is able to supports high level of interaction between robot and human workers. There is a similar application in Fiat Chrysler Automobiles (FCA) workshop. In this case, mechanical components are assembled in strict cooperation between human and robot as in Picture IRSIPAA 3 (c).

iii. The impact

The main impact is the simplification of the work cell preparation; there is also a reduction of operator's manual operations and an operation time reduction. More in general it is possible to say that the main positive impacts are

- Product quality improvement
- Productivity improvement
- Ergonomic workload reduction
- Investment costs reduction respects conventional robot application

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Picture IRSIPAA 1 (a) There are important examples in workshops of BMW, Ford and in FCA

Picture IRSIPAA 2 (b) There are important examples in workshops of BMW, Ford and in FCA

Picture IRSIPAA 3 (c) There are important examples in workshops of BMW, Ford and in FCA

2. Interactive robots as wearables in working life

a. Motivators

Nowadays the state of art regarding exoskeleton applications can be largely divided into two main categories (excluding the military application because is not addressed to societal use): industrial exoskeletons on one side and exoskeletons with a more medical or rehabilitative purpose on the other side. Their motivators are very different as industrial exoskeletons in general aim to reduce the fatigue as well as loads on muscles or the skeleton and avoid long-term effects of bad posture during work-related tasks, while the other category aims to improve the quality of life after injuries or for people with disabilities.

In industrial domain, many different exoskeletons are currently being investigated in research, both passive and active (motor-powered), and some are available as a product, mostly passive devices.

In FCA, for instance, the use of exoskeletons is intended to support the workers in those workstations that are difficult to automate due to high flexibility of the process and the need of the humans' experience. Most of these workstations refer to the assembly line: two examples could be the assembly of components under the car body in the final

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assembly line, where the workers need to work above shoulder height for a longer time., and the assembly of components inside the car body, while standing outside of it, that allows for a forward bending trunk posture. In both the situations, the exoskeletons could be useful for supporting the working postures.

b. Enablers

The development of industrial exoskeletons is facilitated by the ambition to reduce work-related diseases and decrease workload in jobs that are fatiguing and strenuous. This has the possibility to reduce absenteeism and allow people to work longer in a sustainable fashion. In rehabilitative and medical exoskeletons, the technology is pushed by the desire to keep people active and independent in the society. This is important to be able to organize the care of elderly even when the population is ageing and the share of active workers in the society is shrinking.

c. Barriers

One of the obstacles in the uptake of the technology is related to user-acceptance. It includes not only the acceptance of the design of the exoskeletons, but also its compatibility with the workstations and with the colleagues. Furthermore, users seem willing to use the assisting or supporting technology when they already experience problems, but as a preventive measure, wearable exoskeletons are more difficult to establish. This is due to the added encumbrance and weight, while the benefit is not visible on the short term. There is also a lack of understanding of their long-term impact on other parts of the body when using them for long periods of time. The difficulty of using active devices in general is linked to the incomplete standards related to these devices.

3. Interactive robots in logistics

a. Motivators

Robotics applied to logistics tries to increase the efficiency of transport by carrying out more processes in a shorter time, which normally have been carried out exclusively by people. The use of more sophisticated robots in aspects such as fine handling and understanding of the environment that surrounds them is already a reality that thousands of workers in this sector are starting to experiment in their jobs. Large parcel companies are at the forefront in making investments in robots to improve the internal management of their products. These companies are pulling and promoting the robotic industry and will continue to do so in the next few years.

b. Enablers

Traditionally in Logistics, factories and warehouses have worked with the following types of robots:

- Robots for storage. They tend to be present in large logistic centers and allow storing full pallets in height using shelves with Cartesian robots of tens to hundreds of meters.
- Robots for internal and internal-external transport of goods or elements through autonomous mobile platforms or wired ones.

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- Robots for packaging: packaging of products in boxes and selection of products for the realization of a specific palletizing by customer with its traceability.

Their robustness, reliability and effectiveness in tasks have meant a positive feedback in businesses, becoming an enabler of robotics applied to logistics.

In the near future, on the one hand, the creation of a new paradigm of human-machine collaboration is expected to overcome complex problems of logistics in warehouse, such as manipulation of thousands of different objects, on the other hand, autonomous vehicles and aerial robots will advance the field of automated parcel delivery. The transport of last mile delivery has a great responsibility to ensure that products arrive on time and in the conditions in which it is expected. Pilots are being carried out in which autonomous vehicles (equipped with GPS sensors and video cameras) of different dimensions (Mercedes-Benz Vision Van[14] or Metro Group[15]) are used to carry small packages or even food inside a neighborhood.

The use of drones for delivering small merchandise (up to 2.5 kg) is increasingly close to being carried out avoiding delays due to traffic jams and allowing access to remote places that would otherwise be inaccessible (transport of medicines to isolated places or transport of small pieces to working sites of difficult access).

c. Barriers

The main barrier for the adoption of robots in the field of logistics is related to the fact that the difficulty involved in various tasks carried out in this sector, necessarily requires human collaboration. This implies that in the short-medium term, the tendency will be to work collaboratively between humans and robots to increase the productivity of these tasks in the most efficient way. In the long term, both the public sector (European Union) and the private sector (robot manufacturing companies and distributors) are making significant investments in robotics research to reduce the unit cost of robots, orienting them to have a greater specificity and flexibility in logistic tasks.

d. Case study: Wheeled robots in logistics (to carry parcels)

i. The problem

ACCIONA Construction S.A has a machinery park with two well-differentiated areas: 1.- An interior one, consisting of two large warehouses that have metal racks 6 meters high and several tens of meters in length in which metal pieces of large construction machines are stored (Picture IRSIPAA 4), and 2.- A large outdoor area in which heavy vehicles and large metal structures are parked, connected by dirt roads (Picture IRSIPAA 5), which have potholes and whose path may change eventually because one of the roads is blocked by another vehicle, or due to other incidents. In this context, it was thought as a very useful solution for improving efficiency in warehouses to focus workers in specific and high value tasks while the robot transports load and pieces from one point to another one autonomously. This use case was developed thanks to a research project and was

[14] https://www.mercedes-benz.com/en/mercedes-benz/vehicles/passenger-cars/mercedes-benz-concept-cars/ultimate-in-luxury-vision-mercedes-maybach-6/
[15] https://postandparcel.info/73527/news/metro-group-testing-starship-delivery-robots-in-dusseldorf/

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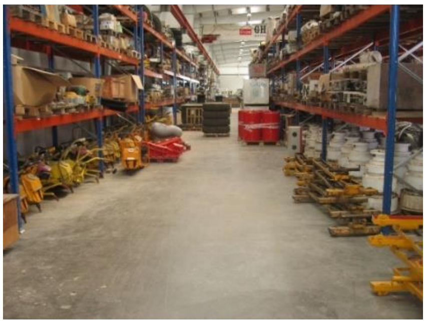
very interesting because it provided economic savings by dedicating the driver to complex tasks in the workshop.

International companies such as Volvo16, Komatsu17 or Caterpillar18 and other public-private stakeholders are introducing since 2012, semi-autonomous heavy machinery for earthworks and transport of raw materials and equipment, improving internal logistic in the construction sector.



PICTURE IRSIPAA 4 ACCIONA CONSTRUCTION SA INTERIOR AREA

PICTURE IRSIPAA 5 ACCIONA CONSTRUCTION SA EXTERIOR AREA

ii. The solution

Within the framework of a research project with national funding, the TITAM platform has been developed. It has 4 drive wheels (bidirectional all-wheel drive), 1 Tn load capacity, location and autonomous navigation (SLAM) indoors and outdoors making routes between one and another environment continuously through intelligent sensory fusion and autonomous decision making. The platform generates new automatic routes if it encounters obstacles that block its current path, reaching its goal in another way. The user only has to load the platform at the source and select the destination point. The rest is done automatically. If it is necessary to change the target, the user can do it remotely or in site easily, driving it manually or blocking virtually or physically some paths. Interactivity achieved is high. This robot reduces the workload and improve efficiency. It has security systems to avoid collisions with objects and collisions with people.

[16] https://www.volvoce.com/global/en/this-is-volvo-ce/what-we-believe-in/innovation
[17] https://www.komatsu.com.au/innovation/autonomous-haulage-system
[18] https://www.cat.com/es_US/support/operations/technology/cat-minestar.html

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PICTURE IRSIPAA 6 TITAM PLATFORM INSIDE (LEFT) AND OUTSIDE (RIGHT)

iii. The impact

This system allows optimizing the management of logistics tasks in warehouses and outdoors. Workers in origin and destination spend their time optimizing different components that will be transported, but avoiding the transport work, so they earn more time to organize the workshop and inventory correctly (workers themselves are more productive). On the other hand, in the field of Occupational Health and Safety, accidents and risks of people in transport and working outdoors in cold and hot weather are eliminated.

4. Interactive robots for emergency response (rescue)

a. Motivators:

The recent demand of robotic system for emergency response, Search and Rescue (SAR) operations is due to a combination of three new motivations: Technology readiness, general public awareness toward the use of robots and direct request from SAR teams to benefit from advanced equipment [19].

The technology readiness level of cluster of robots or of robot/human in direct interactions have reached in the recent years a maturity that will allows it to be extended and implemented outside laboratories [20,21]. The start of implementation of robotics devices inside factories have proven the capabilities of such system. It is combined with the recent boom in consumer imbedded technology (toy drones, smartphones) created a generalisation of the awareness of the general public toward advanced robotic systems.

The demand of use technology for rapid access to remote location for data gathering and safer access to dangerous or remote areas by the SAR have also pushed the development for robotics tooling [22]. It is corresponding to the same global demand of system and technology awareness.

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[19] Cubber, Geert De, et al. "Search and rescue robotics-from theory to practice." (2017).
[20] European Commission FP7 Research and Innovation, https://ec.europa.eu/research/fp7/index_en.cfm
[21] De Cubber, Gert, et al. "Search and rescue robots developed by the european icarus project." 7th Int. Workshop on Robotics for Risky Environments. 2013.
[22] White paper, ICARUS: Providing Unmanned Search and Rescue Tools, September 2012, Conference: 6th IARP Workshop on Risky Interventions and Environmental Surveillance, Geert De Cubber.

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The rise of utilisation and development of robotics tools created a need for defining rules and standard for coordinated activities with robotics tool or direct human-robot interactions.

b. Enablers:

The development of robotic systems for field utilisation is supported by Agencies and national programmes for technology transfer (e.g. EC FP7, Horizon 2020)[23]. The main objectives of these programmes are to create a contact between the technology and knowledge owners (mainly research laboratories) and the end-users (e.g. SAR teams). These transfers are directly supported by the industries in order to develop more product oriented robotic systems [24].

c. Barriers:

The implementation of robotic solutions during SAR operations faces some barriers before full integrations in the emergency responses.

These difficulties are mainly created by the complex technology transfers from very research-oriented organisations (e.g. universities and R&D laboratories) to a product with system critical application toward human end-users (e.g. SAR operations).

It is important to highlight that at the opposite of the industrial applications; no standard or norms are previously existing for human robot interaction on the emergency field or no standard or norms are existing for multi-robot and human coordination during SAR operations. It is observed to be mainly due to the low past experience of robotics applications on field for SAR situations

Even if the interest from the SAR teams and general public is high, we noticed a self-protection behaviour of the same public toward experimental system. System validation on field ("battle-tested") are therefore needed before full acceptance by the SAR team and general public.

d. Case Study: Robots for Emergency Response, Search and Rescue (SAR) Operations

i. The Problem:

During the hours following the 2011 Fukushima Daiichi nuclear disaster and after the August 2016 Central Italy Earthquake, the Search and Rescue (S&R) teams deployed onsite faced urgent and dangerous operations. They were requested to access hazardous areas where human victims could be trapped under unstable ruins. Accessing these restricted areas could endanger the life of the rescue personnel above what was considered an acceptable risk by the men and women deployed on the S&R operations.

[23] Davids, Angela. "Urban search and rescue robots: from tragedy to technology." IEEE Intelligent systems 17.2 (2002): 81-83.
[24] Jennings, James S. et al., "Cooperative search and rescue with a team of mobile robots." 1997 8th International Conference on Advanced Robotics. Proceedings. ICAR'97. IEEE, 1997.

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An Urban Search-And-Rescue (USAR) deployment is a multi-hazard discipline introducing a large variety of threats to both the rescuers and the potential victims[25].

Independently of the work of the S&R teams, many research laboratories around the world are working on remote operated robots able to achieve highly dexterous teleoperation over large distances. Unfortunately, no norms or standardization works exist between the high-tech laboratories and the direct operational procedures of the USAR teams, leading to improper use of the existing robotic tools or even rejection of potentially more effective equipment because of incorrect implementation.

ii. The Solution:

The ICARUS project was founded by the European commission Horizon 2020 framework to provide capabilities and definitions for cooperative robotics during S&R operations including large data analyses and direct human/robot interactions. It directly connected the Belgian First Aid and Support Team (B-FAST) and several research institutions in Europe.

PICTURE IRSIPAA 7 OPERATOR WEARING THE ROBOTIC ICARUS EXOSKELETON FOR REMOTE CONTROLLING A LARGE EXCAVATOR ARM IN A USAR TRAINING (PICTURES CREDIT: ICARUS PROJECT)

The ICARUS EC project was evaluated in August 2015 in the training grounds of the Belgian Search and Rescue team in Marche-en-famenne, Belgium. The developed S&R robotic systems were deployed in the Urban Search and Rescue training area in order to validate their ability to find and interact with injured victims during a large disaster, and also to test advanced robot control by remote operators wearing robotic exoskeletons.

iii. The Impact:

The project has shown the crucial need of standardisation of the communications between all the robots deployed to the disaster area. The direct implication of the human rescue team added irreplaceable value for sensible victim manipulation or key strategic decisions. The direct synergy between the humans and the robots proved to be an extremely efficient answer to the inherent risks of USAR operations but proved also the crucial need of strict norming and standards during robot/machine interactions.

[25] Davids, Angela. "Urban search and rescue robots: from tragedy to technology." IEEE Intelligent systems 17.2 (2002): 81-83.

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The ICARUS SAR example was combining interaction human/robot in various environments and various operational modes (wearable, swam robotic, coordination human/machine). It offered an interesting opening toward advanced technologies (laboratories and technology research groups) while in the same time being tested with the end-product costumers (firefighters, SAR teams).

The EC understanding of the capabilities of robotics interactions for SAR teams lead to many other research projects aimed at creating various of advanced robotics system [26][27].

To conclude, interactive robots proves to have developed into a useful and safe technology. In manufacturing it is especially appreciated because of its ability to perform repetitive tasks. Interactive robots are used as wearables both in manufacturing as exoskeletons to prevent fatigue, injuries, reduce workload and to compensate for disabilities. The main barrier for using wearables in industry is the lack of user-acceptance. In logistics interactive robots are used to increase efficiency in transportation. The barriers are related to various tasks carried out in this sector, necessarily requires human collaboration. In rescue activities interactive robots are actually requested by search and rescue teams that find this technology having a high readiness and public awareness. The barriers are mainly related to the complexity of emergency response and the need for standards.

7. Education as a promising user of interactive robots

According to *Global Educational Robot Market Analysis* by *Verified market research* several kinds of robots (such as mobile robots, articulated robots, autonomous vehicles, and others) are used from lower levels of education up to higher education. Global Educational Robot Market was valued at USD 609 Million in 2017 and is estimated to reach USD 1.9 Billion by 2025, growing at a rate of 13.8% from 2018 to 2025[28]. The growth rate of educational robot's market depends highly on the social acceptance of robots in education. **Educational Robotics** has already been incorporated in formal and informal education with the ambition to contribute to the preparation of the future robotics society.

The integration of educational robotics into the school can provide an effective tool for improving students' scientific and technological knowledge about robots. Additionally, it reinforces the development of skills, namely, (i) social skills, (ii) science skills, and (iii)

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[26] Walkman anthropomorphic robot platforms unstructured environments and work spaces as a result of natural and man-made disasters. https://www.walk-man.eu/

[27] Robust Mobility and Dexterous Manipulation in Disaster Response. https://www.centauro-project.eu/

[28] https://www.verifiedmarketresearch.com/product/global-educational-robot-market-size-and-forecast-to-2025/#table-of-content

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cognitive skills, that can be used in different subject areas as well as for personal development [29,30]:

Social skills: During robotics activities, students a) develop teamwork skills, b) improve their communication skills by working in a "peer-supported learning environment", and c) learn how to be operative in the social world using 'negotiation' and 'social interaction' [31].

Science skills: Robotics incorporates STEM in hands-on practices and can increase students' engagement and understanding of subject areas, such as engineering and computing[32]. Students design robots by connecting the electrical components and using mathematical calculations and predications through a problem-solving process[659].

Cognitive skills: Robotics projects challenge students a) to come up with different possible solutions, b) to develop and express their solutions, c) to articulate their understanding and reasoning, and d) to become active researchers and lifelong learners[33].

The aforementioned results are also corroborated by teachers' perception on educational robots, as reported in [34], indicating that robotics activities offer learning experiences that are hard to gain through traditional classes.

1. Barriers

Despite the fact that the results of the relevant projects[35] show mostly a learning gain with the use of robotics, the successful integration of robotics in schools has often to encounter a number of challenges and barriers. First, there is **inadequate access to supporting equipment and materials** (e.g. expensive educational robotics kits, inadequate software/hardware, materials, guides, etc.), which necessitates the use of free or low-cost equipment as well as provision of technical and instructional support [36]. Moreover, most of the applications utilize the robot either as a passive end tool in the learning activity *or as a product with pre-defined detailed instructions, addressing learners as passive consumers rather than creative learners[37,38]. Additionally,*

[29] The Role of Education for the Social and Economic Uptake of Robotics: the Case of the eCraft2Learn Project, Dimitris Alimisis, DimitriosLoukatos, EmmanouilZoulias, Rene Alimisi, INBOTS
[30] Benitti, Fabiane Barreto Vavassori. "Exploring the educational potential of robotics in schools: A systematic review." Computers & Education 58.3 (2012): 978-988.
[31] Robotics Intrigue Middle School Students and Build STEM Skills, Grubbs, M. (2013), Technology and Engineering Teacher 72 (6): 12–16. http://eric.ed.gov/?id = EJ1006898
[32] Grubbs, Michael. "Robotics intrigue middle school students and build STEM skills." Technology and engineering Teacher 72.6 (2013): 12.
[33] Chalmers, Christina, et al. "Preservice teachers teaching technology with robotics." (2012).
[34] Grubbs, Michael. "Robotics intrigue middle school students and build STEM skills." Technology and engineering Teacher 72.6 (2013): 12.
[35] Mubin, Omar, et al. "A review of the applicability of robots in education." Journal of Technology in Education and Learning 1.209-0015 (2013): 13
[36] Educational Robotics: Open questions and new challenges. Alimisis, D., (2013), Themes in Science and Technology Education, 6(1), 63-71.
[37] The Role of Education for the Social and Economic Uptake of Robotics: the Case of the eCraft2Learn Project, Dimitris Alimisis, DimitriosLoukatos, EmmanouilZoulias, Rene Alimisi, INBOTS

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teachers' lack of knowledge and confidence in their technology skills, combined with their workload, indicates the need for efficient pre-service and in-service training.

Another important barrier is **the lack of well-defined curriculum**, since in most cases robotics is considered as an extra-curricular activity[663]. This is related to the misconception that *robotic technologies are a job-related skill, relevant* only for *those who intend to follow robotics/engineering careers.* Moreover, educational robotics has mainly focused on supporting only the teaching of robotics-relevant subjects [39]. These misconceptions, together with gender-biased opinions that robotics is a "male" topic, leads to discouragement or even exclusion of students[40] . *The wide-ranging skills that can be developed with the support of educational robots necessitate a shift from these misconceptions to the acknowledgement that robotics education offers a valuable learning gain for every student.*

2. Case study (Robotics in Education) The eCraft2Learn project

a. The problem

The equipment usually used in school education is not always suitable: most robots are pre-fabricated, or they final form is predefined, and they can be assembled following step-by-step instructions. This approach results in a guided instruction that addresses learners as passive consumers rather than creative makers. Passive methods in education, robotics included, result usually in trivial knowledge instead of skills development and finally don't foster curiosity and positive attitudes to robotics for youth. Moreover, commercial products are widely used, which do not give the opportunity to students to learn how to construct a robot and to be engaged to basic electronics and programming skills.

b. The solution:

The **eCraft2Learn project** provides a learning methodology for educators and students including ideation, planning, creation, programming and sharing to enable them to **make their own robots**, using open source innovative technologies, low cost materials, digital fabrication and the DIY philosophy. Open Educational Resources for project- and craft-based learning and for establishing a digital maker space for teachers and students are available. Educational scenarios (use cases) for the realization of specific projects have been developed and realized throughout pilots in Greece and Finland (For more information, see https://project.ecraft2learn.eu/)

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[38] Rusk, Natalie, et al. "New pathways into robotics: Strategies for broadening participation." Journal of Science Education and Technology 17.1 (2008): 59-69.
[39] Benitti, Fabiane Barreto Vavassori. "Exploring the educational potential of robotics in schools: A systematic review." Computers & Education 58.3 (2012): 978-988.
[40] The Role of Education for the Social and Economic Uptake of Robotics: the Case of the eCraft2Learn Project, Dimitris Alimisis, DimitriosLoukatos, EmmanouilZoulias, Rene Alimisi, INBOTS

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c. The impact

The validation study has highlighted that the most salient impact of the eCraft2Learn ecosystem on the students has to do with the development of creativity, problem-solving, critical thinking and team working skills. The robotics projects that were developed by the students were interdisciplinary in nature and in line with the philosophy of the "*maker movement*". The projects have helped students demystify robots and offered unique opportunities to explore a rich set of robotics tools and technologies, to tinker their robots, to be creative, and to be involved in problem solving. Students have highly valued their involvement in the hands-on activities and shown strong sense of ownership of their robotic projects. Moreover, the projects offered unique opportunities for students to communicate and share their projects with classmates, but also with people from a wide range of ages and knowledge, thanks to their participation in the Athens Science Festival, the Joensuu Science Festival and other public events.

Finally, the eCraft2Learn labs and events have promoted the social acceptance of robotics not only for the students involved in the labs but also for their schoolmates, parents and the general public. Well designed and organized educational actions in robotics that incorporate the making culture ("make your own robots") can promote understanding and demystification of robots for the young generations and contribute to the development of a future robotics society.

To conclude, interactive robots are used in education activities from lower levels of education up to higher education. It is proven to improve cognitive skills, social skills and scientific skills. The barriers for further developments are lack of supporting equipment, lack of knowledge among teachers and lack of curriculum that support using this technology.

8. Health care as a promising user of interactive robots

1. Rehabilitation and powered exoskeletons

a. Motivators

The number of patients with decreased mobility after neurological injuries such as stroke or spinal cord injury, is rapidly increasing. The quality of life of people who are suffering from these disorders can be improved by the use of assistive devices [Chen 2016].

b. Enablers

One example of assistive devices are powered exoskeletons. Powered lower limb exoskeletons allow patients suffering from a neurological disorder to walk in real-world settings enabling intensive training and leading to health benefits [Miller 2016]. In the next years powered lower limb exoskeletons may be transferred into daily life applications. Neurological patients with walking disabilities who desire a level of autonomy can be assisted during different motion tasks. Motion tasks in daily life, that may be supported by exoskeletons, are walking, running, sit-to-stand transfers, ascending and descending stairs, lifting heavy loads etc. [Yan 2015]. The use of assistive devices in

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motion tasks is often tested in individual walking tasks only. To be applicable in daily life the use in different motion tasks and the switching between these different tasks have to be validated. Vocal commands and simple haptic control devices are used to switch between the different states controlling the support for a specific motion task.

c. Barriers

The control and adaptability of the assistive device remains a major challenge in the exoskeleton development. User interfaces are required that transfer the intention of the patient to the device in an intuitive manner [Young 2017]. Furthermore, exoskeleton devices should also be used in conjuction with other existing or emerging technologies that can further address major limitations. [Gorgey 2018]. The conjunction of these technologies and the assisting devices may establish their integration into daily life activities.

d. Case study - Cybathlon

i. The problem

Assistive robotic technology will only fulfill its potential if devices are accepted and regularly used by people with physical disabilities in their everyday life.

ii. The solution

The Cybathlon is a unique championship in which people with physical disabilities compete against each other to complete everyday tasks using latest robotic technology.

The competition herewith offers a platform to drive forward research and challenge the usability of assistive robots. Furthermore, it helps to promote inclusion by informing about chances and limitations of assistive technology, by stimulating a dialogue and by generating awareness for people with disabilities.

iii. The impact

The first Cybathlon competition organized by the ETH Zurich was successfully launched in 2016. Sixty-six pilots from 25 nations competed in a sold-out stadium (4600 spectators).

Six disciplines were part of the competition comprising races with brain-computer interfaces (BCI), functional electrical stimulation driven bikes (FES), powered arm prostheses, powered leg prostheses, powered exoskeletons and powered wheelchairs. The event had an international outreach and promoted new developmental and research work of the participating and even non-participating teams on all continents. As such, the Cybathlon may serve as benchmark for other fields targeting inclusive robotics for a better society [Baur 2018].

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PICTURE IRSIPAA 8 PICTURE WAS TAKEN AT THE CYBATHLON REHEARSAL IN JULY 2015 BY ALESSANDRO DELLA BELLA, ETH ZURICH

e. Case study: human hand augmentation through wearable robots.

i. The problem

Stroke is a brain attack affecting 17 million people worldwide each year, it is the second most common cause of death and a leading cause of adult physical disability[41]. Between 2015 and 2035, there will be a 34% increase in total number of stroke events in the EU from 613,148 in 2015 to 819,771 in 2035. The number of stroke survivors in the EU will rise from 3,718,785 in 2015 to 4,631,050 in 2035 (about the 25%). Stroke survivors can experience a wide range of outcomes that are long-lasting, e.g. problems with mobility, vision, speech and memory; personality changes; fatigue; and depression. Impairment of the hand grasping function is one of the common deficits after a stroke: approximately 60% of stroke survivors suffer from some form of sensorimotor impairment associated with their hand.

ii. The solution

Wearable robots are expected to work closely, to interact and collaborate with people in an intelligent environment. By definition, a wearable robot is a *mechatronic system designed around the shape and function of the human body, with segments and joints corresponding to those of the person it is externally coupled with*.[42] Such definition perfectly fits for exoskeletons, whose main purposes are enhancing human body force and precision capabilities or helping in rehabilitation processes. The progress in miniaturization and efficiency of the mechanical and sensing components has extended the field of wearable robotics to new devices which can be represented as *extra limbs*. This very promising and challenging research direction consists in adding robotic supernumerary limbs to humans, rather than substituting or enhancing the human ones. Focusing on human hand, adding wearable extra-fingers increases the overall workspace of the healthy hand, the capability of grasping and manipulating large objects.

The device consists in a wearable robotic finger with a modular and compliant structure, that can be worn as a bracelet and can be actuated with wearable interfaces. The

41 http://strokeeurope.eu/

42 Pons, José L. *Wearable robots: biomechatronic exoskeletons*. John Wiley & Sons, 2008.

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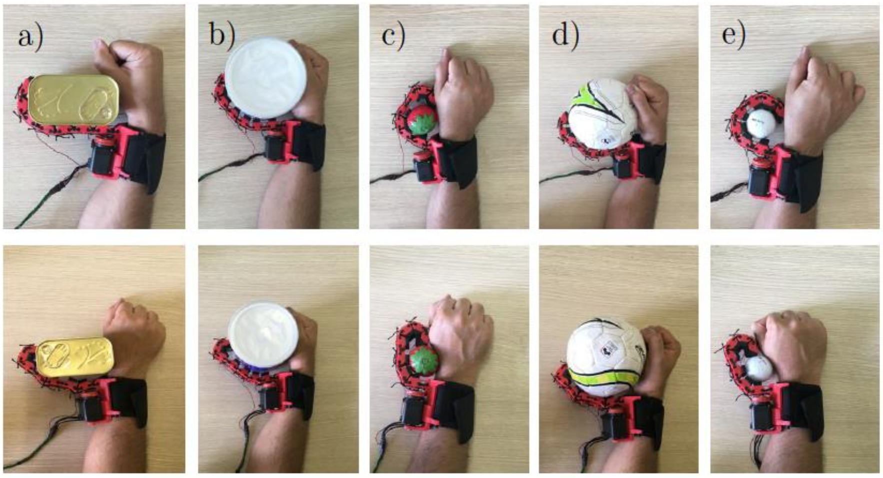
structure of the finger is simple and robust, its compliance allows to adapt to different object shapes and dimensions (Picture IRSIPAA 9).[43]



PICTURE IRSIPAA 9 THE ROBOTIC EXTRA-FINGER USED AS A SUPPORT FOR GRASPING DIFFERENT OBJECT. THE COMPLIANT STRUCTURE OF THE FINGER ALLOWS TO ADAPT TO DIFFERENT OBJECTS' SHAPES AND DIMENSION.

Researchers at the University of Siena started the study of robotic extra fingers to exploit the emerging field of human augmentation by means of robotic extra limbs, representing *per-se* an interesting research topic, that involves much more than engineering. However, the most impact application of the device is currently represented by rehabilitation and assistive of patients with hand or arm impairments, for example after a stroke.

Experiments with five chronic stroke patients (four male, one female, age 40 - 62) were made to prove the effectiveness of the devices in grasp compensation, the subjects had residual mobility of the arm. The goal of the tests was to evaluate how quickly the patients could learn to use the device in Activities of Daily Living (ADL), as for instance preparing breakfast or lunch, using tools, etc.

43 Hussain, Irfan, et al. "Design guidelines for a wearable robotic extra-finger." *2015 IEEE 1st International Forum on Research and Technologies for Society and Industry Leveraging a better tomorrow (RTSI)*. IEEE, 2015

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PICTURE IRSIPAA 10 THE ROBOTIC SIXTH FINGER USED BY A PATIENT IN SOME ACTIVITIES OF DAILY LIVING

iii. The impact

Experiments showed that the robotic extra finger can effectively compensate subjects' grasping functions in activities of daily living, showing great potential even in rehabilitation, as a tool to invent conceptually new rehab exercises. Both patients and clinical staff were enthusiastic about this tool.

It was noticed that compensation process by using a robotic extra-finger motivates the patient to use her or his muscles to coordinate with the device for the completion of the task. Thus, the device represents an active and motivational assistance tool, that encourages the patients to use their potential and residual abilities effectively instead of being fully dependent on the motion of robotic device like passive assistive devices[44].

Currently there are not statistics in EU referring to the uptake or use of the robotic extra fingers for stroke patients. The wearable robotic solutions that we presented are still quite novel and only a limited number of patients has tested them. The preliminary feedbacks are positive and encouraging, but the number of applications is still too limited to get insightful statistics. Contacts between robotics research laboratories, hospitals and rehabilitation centres are currently in progress, they are working on common projects to increase the number of patients that use the wearable extra finger in their rehabilitation process and as an assistive device.

The use of wearable extra fingers as an assistive and rehabilitation tool for patients is still in a preliminary stage: although results were positive, the number of available applications is still too limited. Furthermore, the evaluation of applications for people that have not specific pathologies limiting hand grasping and manipulation ability, in a

[44] Hussain, Irfan, et al. "Toward wearable supernumerary robotic fingers to compensate missing grasping abilities in hemiparetic upper limb." *The International Journal of Robotics Research* 36.13-14 (2017): 1414-1436.

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framework of human augmentation through wearable robots, are also the goal of ongoing research activities.

2. Interactive robots in social care

There is an increase in the ageing of the world population. An aging population is predicted to require long term care, therapeutic and companionship needs. Seniors, mostly those residing in a nursing home, often report feelings of helplessness, boredom and isolation, increasing their risk of depression[45],[46], [47]. As a response to this problem, along to a general lack of medical personnel in health services, elderly population among, also, to autistic children are using robots to serve as companionship[48]. There are several robots that have potential in social care for example Giraff (a teleprecense robot that homecare and healthcare staff, as well as relatives can use to virtually visit individuals in need of care and social stimuli), Bestic (a feeding robot), etc.

PICTURE IRSIPAA 11 GIRAFF – A TELEPRECENSE ROBOT

PICTURE IRSIPAA 12 BESTIC A FEEDING ROBOT

a. Enablers

Our living environment is now using robots. Handicap assistance robots have taken off to the anticipated degree in the past few years. In 2017, a total of 6,423 robots were sold, up from 5,313 in 2016 – an increase of 21%. Numerous national research projects in many countries concentrate on this huge future market for service robots.

The Human-Robot interaction is being used to psychological enrichment; that is, the robots provide a service by stimulating the human mind. Such robots are thought to

[45] Djernes, J. K. (2006). Prevalence and predictors of depression in populations of elderly: A review. *Acta Psychiatrica Scandinavica*, *113*(5), 372–387.

[46] Jongenelis, K., Pot, A. M., Eisses, A. M. H., Beekman, A. T. F., Kluiter, H., & Ribbe, M. W. (2004). Prevalence and risk indicators of depression in elderly nursing home patients: The AGED study. *Journal of Affective Disorders*, *83*(2–3), 135–142. https://doi.org/10.1016/j.jad.2004.06.001

[47] Teresi, J., Abrams, R., Holmes, D., Ramirez, M., & Eimicke, J. (2001). Prevalence of depression and depression recognition in nursing homes. *Social Psychiatry and Psychiatric Epidemiology*, *36*(12), 613–620. https://doi.org/10.1007/s127-001-8202-7

[48] de Swarte, T., Boufous, O., & Escalle, P. (2019). Artificial intelligence, ethics and human values: the cases of military drones and companion robots. *Artificial Life and Robotics*, *0*(0), 0. https://doi.org/10.1007/s10015-019-00525-1

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render assistance, guidance, to provide therapy, to educate and to enable communication [49]. The introduction of companion robots in the elderly population, for instance, mostly in the ones in nursing homes aims to promote similar effects resulting from animal care. The insertion of robots in the elderly's life seeks to promote a better quality of life by increasing social interactions, to decrease loneliness, to help create a sense of purpose [50].

b. Barriers

Presently, the legal system is not adapted to the exponential growth of the Artificial Intelligence and technology, mainly when used in daily applications.

Also, the majority of companion robots are connected to the Internet; that is, the data collected by the robot from the user is recorded and stored in the cloud. Robots have security flows, which can lead to a leak of the user's personal information and, furthermore, robots could be potentially hijacked, having their source code changed to undesired purposes [51].

c. Case study – Use of the Paro robot in a nursing home

i. The problem

Elderly people in nursing homes often report feelings of helplessness, boredom, and isolation, increasing their risk of depression and loneliness and in general they report a lower quality of life than those residing in the community [52].

ii. The solution

In a therapy using companion robots, the robots connect with humans in the physical world using verbal and nonverbal communication aiming a most personal human-robot interaction.

Robot therapy using for example the Paro robot (Picture IRSIPAA 13), a robot with a seal shape, are conducted at hospitals and nursing homes in several countries that like Japan, Denmark, the USA etc.

The Paro robot was used to assist elderly at a day service centre. To investigate the effects the seal robot can create in seniors, their mood was evaluated using face scales

[49] Shibata, T., & Wada, K. (2011). Robot therapy: A new approach for mental healthcare of the elderly - A mini-review. *Gerontology*, *57*(4), 378–386. https://doi.org/10.1159/000319015

[50] Robinson, H., MacDonald, B., Kerse, N., & Broadbent, E. (2013). The Psychosocial Effects of a Companion Robot: A Randomized Controlled Trial. *Journal of the American Medical Directors Association*, *14*(9), 661–667. https://doi.org/10.1016/j.jamda.2013.02.007

[51] de Swarte, T., Boufous, O., & Escalle, P. (2019). Artificial intelligence, ethics and human values: the cases of military drones and companion robots. *Artificial Life and Robotics*, *0*(0), 0. https://doi.org/10.1007/s10015-019-00525-1

[52] Robinson, H., MacDonald, B., Kerse, N., & Broadbent, E. (2013). The Psychosocial Effects of a Companion Robot: A Randomized Controlled Trial. *Journal of the American Medical Directors Association*, *14*(9), 661–667. https://doi.org/10.1016/j.jamda.2013.02.007

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and questionnaires. Changes in their reaction to stress were also measured using the 17-ketosteroid sulfate (17-KS-S) and 17-hydroxycorticosteroids (17-OHCS) hormones in the urine. The nursing staff also performed questionnaires to evaluate their level of stress [53] [54].

Picture IRSIPAA 13 The Paro robot

iii. The impact

After five weeks with the seal robots, the feelings of the seniors improved by the interaction with the robots and there were also evidences of improvement in stress levels. Moreover, the stress levels of the nursing staff also decreased once the older adults required less supervision during interaction with the robots [55].

The societal acceptance or rejection of these robots is the main challenge for this rising technology. Sales of robots for elderly and handicap assistance are estimated to be about 34,400 units in the period of 2019-2021. This market is expected to increase substantially within the next 20 years.

3. Robotized assistance to surgery

There is a steadily increase in the uptake of robot-assisted surgery innovations at hospitals around the word [56]. Robotic surgical devices allow surgeon at a console to operate remote-controlled robotic arms.

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[53] Shibata, T., Wada, K., Ikeda, Y., & Sabanovic, S. (2008). Tabulation and analysis of questionnaire results of subjective evaluation of seal robot in seven countries. *Proceedings of the 17th IEEE International Symposium on Robot and Human Interactive Communication, RO-MAN*, 689–694.

[54] Wada, K., Shibata, T., Saito, T., Sakamoto, K., & Tanie, K. (2005). Psychological and Social Effects of One Year Robot Assisted Activity on Elderly People at a Health Service Facility for the Aged, (April), 2796–2801.

[55] Shibata, T., & Wada, K. (2011). Robot therapy: A new approach for mental healthcare of the elderly - A mini-review. *Gerontology*, *57*(4), 378–386. https://doi.org/10.1159/000319015

[56] Moglia, Andrea, et al. "A systematic review of virtual reality simulators for robot-assisted surgery." *European urology* 69.6 (2016): 1065-1080.

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a. Motivators

Laparoscopic surgery has certain limitations, such as two-dimensional imaging, restricted range of motion of the instruments, and poor ergonomic positioning of the surgeon. Initially, robotic surgery systems have been introduced as a potential solution to minimize the shortcomings of laparoscopy and then revolutionized many surgical subspecialties, mainly where procedures have to be performed in confined and poor visibility spaces.

Since their introduction in cardiosurgery, robots have entered all surgical subspecialties. Hundreds of robotic systems are commercially available, and the most widely known are the da Vinci System (Intuitive Surgical, Sunnyvale, CA, USA), Zeus and Aesop (Computer Motion, Goleta, CA, USA), RoboDoc (Integrated Surgical Systems, Sacramento, CA, USA), and Naviot (Hitachi Ltd., Tokyo, Japan). Advanced robots now assist surgeons in procedures, which were unthinkable just a few years ago, ranging from minimally invasive surgery in laparoscopy to complex reconstruction surgery.

b. Enablers

With robot-assisted surgery the surgeon can perform laparoscopic procedures instead of open surgery. This inturn, increases the chances of shorter hospital stays, less pain and scarring for the patient, as well as lower risk of infection and need for blood transfusion (ibid). Other advantages that has been mentioned in regard to robot-assisted surgery are better ergonomics for the surgeon; elimination of physical hand tremor; improved fine motor skills; better vision; and the elimination of fulcrum effect [57].

In 2017 sales of robot assisted surgery or therapy in the world increased by 22% compared to 2016, with 1502 units sold. The total value of sales of medical robots increased to US$ 1.911m, accounting for 29% of the total sales value of the professional service robots. The extraordinary growth rate in the use of robot-assisted surgery is linked to its advantages over conventional surgical techniques.

Robotic surgery offers many benefits to patients compared to open surgery, including:

- Shorter hospitalization
- Reduced pain and discomfort
- Faster recovery time and return to normal activities
- Smaller incisions, resulting in reduced risk of infection
- Reduced blood loss and transfusions
- Minimal scarring

Major advantages for surgeons using robotic surgery include:

- Greater visualization
- Enhanced dexterity
- Greater precision

[57] Schreuder, H. W. R., and R. H. M. Verheijen. "Robotic surgery." *BJOG: An International Journal of Obstetrics & Gynaecology* 116.2 (2009): 198-213.

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Robotic surgery in its more widely adopted form is an advanced form of minimally invasive or laparoscopic (small incision) surgery where surgeons use a computer-controlled robot to assist them in certain surgical procedures. The robot's "hands" have a high degree of dexterity, allowing surgeons the ability to operate in very tight spaces in the body that would otherwise only be accessible through open surgery.

Compared to open surgery (traditional surgery with incisions), robotic and minimally invasive surgery results in smaller incisions resulting in less pain and scarring.

Robotic surgery allows surgeons to perform complex surgical tasks through tiny incisions using robotic technology. Surgical robots are self-powered, computer-controlled devices that can be programmed to aid in the positioning and manipulation of surgical instruments. This provides surgeons with better accuracy, flexibility and control.

Filtration of hand tremor can reduce or eliminate the intrinsic human defect. Scaling of movement provides unprecedented precision otherwise impossible to achieve with unassisted manual techniques. Dexterity in confined anatomic spaces can be increased, as can manoeuvrability without direct visualization. Robots can also protect surgeons against hazardous exposure; telecontrol (telemedicine) of robotic systems can provide patients and surgeons expert in robotics with access to specialized procedures without the need to travel.

PICTURE IRSIPAA 14 SHOWS THE DA VINCI ROBOT, THE CURRENTLY MOST WIDELY USED SURGICAL PLATFORM

When performing robotic surgery using the da Vinci Surgical System:

- The surgeon works from a computer console in the operating room, controlling miniaturized instruments mounted on three robotic arms to make tiny incisions in the patient.
- The surgeon looks through a 3-D camera attached to a fourth robotic arm, which magnifies the surgical site.
- The surgeon's hand, wrist and finger movements are transmitted through the computer console to the instruments attached to the robot's arms. The mimicked movements have the same range of motion as the surgeon allowing maximum control.
- The surgical team supervises the robot at the patient's bedside.

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c. Barriers

The disadvantages mentioned in regard to robot-assisted surgery are high costs (both for the procurement of the system and the maintenance); the bulky size of the robotic system; the lack of tactile feedback (for surgeons); the fear of breakdown of the system; and the lack of different options of robotic systems (da Vinci almost has monopoly of the market).

Despite the enormous potential and superiority of robotics reported in the literature, their use in the operating room is still limited by a number of drawbacks and open technical issues.

d. Case study: use of new robotic technology to surgically place the hardware for spinal intervention.

i. The problem

A 65-year-old woman felt down the steps and crack her back. It further injured her degenerative spine. She was feeling pain and she had lost a lot of balance. She had no sensation on her left leg, feeling that it was constantly asleep. She had severe sciatica because of nerve compression and also mechanical backpain. She wanted to feel better and be able to do things again.

She was informed that she had significant degenerative changes making even routine placement of screws difficult. For that reason, a traditional surgery was not possible.

ii. The solution

The surgeon informed her that there was a new advance: the robotic technology. Two actions were necessary: to decompress the nerves and to stabilize the spine.

They put screws and rods in to hold the spine together, that's the surgeons call a spinal fusion. By means a CAT scan they were able to plan exactly where they wanted those screws to go. Then, the robot took them precisely for each and every one of those screws to the exact entry point allowing them to place the hardware with really submillimeter accuracy.

iii. The impact

After the surgery, the pain was gone, and she could feel things in her left leg again. She felt better again.

Medical robots have a considerable growth potential. A continued increase of medical robots is expected. Roughly 22,100 units are estimated to be sold in the period between 2019 and 2021. Approximately 877,000 surgical procedures were performed with the da Vinci Surgical System in 2017. The surgery robots are used in many different applications. However diverse usage of these robots is still being tested. Advantages and risks need to be considered. In addition to the risks involved with any open or laparoscopic surgery, robotic-assisted surgery also includes the risk of mechanical failure or human error. In conclusion, this is a promising technology that still presents technical and scientific challenges to be approached and adopted by healthcare systems.

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The first is their high cost, for example, a da Vinci System costs over US$1 million, to which annual maintenance and services costs of over US $100,000 should be added. Operating room setup time may take longer and disrupt the surgical schedule; there are documented cases of da Vinci robot-assisted surgery requiring 20–30 minutes longer operating time. Ambulatory surgical procedures, which are common in ophthalmology and are becoming ever shorter, may not be amenable to robotic surgery, especially because operating time is an important outcome factor and because eye surgeons may doubt the advantage of adopting a robotic system in place of conventional procedures with low complications rates. Finally, besides the steep learning curve for new surgical applications, the complexity of surgical robots often poses a considerable challenge for clinicians and the surgical team in the operating room.

To conclude, there is a tremendous interest in interactive robots in health care and social care. The reason for this is an aging population in relation to fewer healthcare workers., patients with ddecreased mobility after neurological injuries such as stroke or spinal cord injury are expected to benefit from powered exoskeletons. Motion tasks in daily life, that may be supported are walking, running, sit-to-stand transfers, ascending and descending stairs and lifting heavy loads. People of age are expected to benefit from social and cognitive stimuli, as well as assistance from interactive social care robots. The barriers are related to the feeling of being in control of the robotics solution and the adaptability of the interactive robot. Implementation is dependent on acceptance and regular use in daily life. Another requirement is that exoskeletons need to be developed in conjunction with other existing or emerging technologies

9. How to enhance promising and potential use of interactive robots?

Robots are like other technologies culturally embedded. Therefore, social acceptance plays a major role in human-robot-interaction. Social trust is one keyword. People tend to trust new technologies if they pragmatically approve to constantly fulfil a certain need. The pragmatic probation depends on moral and religious values, but also on bodily skills, education, expectations and fear. Especially hope and fear linked to new technologies are mediated by different factors like science fiction, political ideologies or worldviews. For instance, in robotics the figure of Frankenstein serves as archetype of dystopian science fiction where man-made artificial life turns into a danger for mankind. Especially early science fiction in the first half of the twentieth century shared this somehow dystopian attitude – including Fritz Langs movie *Metropolis* or the famous play *R.U.R.* by Capek (where the modern terminology of robot was invented in 1920). A more recent example where an IT-network and connected robots start a nuclear war against mankind are the Terminator movies. As science fiction illustrates, the socio-cultural perception of modern robotic technologies is traversed by worldviews and motives typical for romanticism.[58]

[58] Coeckelbergh, Mark. *New romantic cyborgs: Romanticism, information technology, and the end of the machine*. MIT Press, 2017.

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It has already been pointed out that information in the form of adequate statistics and continuous research and evaluation are prerequisites for being able to increase social uptake and acceptance of interactive robots.

Today there are well-developed models to understand what makes it possible and what prevents the acceptance of new technology. The most influential models explaining acceptance of technology stress that social factors as well as cognitive factors influence user acceptance. The Technology Acceptance Model (TAM) initiated in the end of 1980s determined a person's intention to use a system by perceived usefulness and perceived ease of use.[59] This model that originates from information system research mainly proves that the persons beliefs in what consequences a behavior will have affect the attitude and in turn the actual behavior. It has been widely applied and as a consequence of being criticized for overlooking social and cultural factors the model was expanded in 2003 into a unified theory (UTAUT) merging eight previously published acceptance models.[60] The model explains the relations between a number of factors influencing acceptance but has no direct input to design.[61]

Rogers theory on the diffusion of innovations helps to explain what makes users safe enough to accept new technologies. He present five factors: *Relative advantage* defined as the "degree to which an innovation is perceived as being better than the idea it supersedes"; *Compatibility* defined as the "degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters"; *Complexity* defined as the "degree to which an innovation is perceived as relatively difficult to understand and use" ; *Trialability* defined as the "degree to which the innovation may be tried and modified", and *Observability* defined as the "degree to which the results of the innovation are visible to others".[62]

Questions have been raised about the correlation between technology acceptance and technology adoption. Perceived usefulness is difficult to evaluate for users who do not have any familiarity to the technology in question or similar technologies. It might be more hypothetical than an actual prediction of acceptability. The same argument can be used for perceived ease of use. The technology acceptance models are also criticized for not considering technology adoption and technology adaption, their effectiveness of explaining ongoing technology engagement is doubted and the lack of seeing technology as part of a socio-technical system and everyday practice. It is argued that there is a limited theoretical understanding on uptake, continued engagement, adoption and use of technologies. It is debated which theoretical tools and approaches that can be used to

[59]Venkatesh, Viswanath, and Fred D. Davis. "A theoretical extension of the technology acceptance model: Four longitudinal field studies." *Management science* 46.2 (2000): 186.; doi:10.1287/mnsc.46.2.186.11926

[60]Venkatesh, Viswanath, et al. "User acceptance of information technology: Toward a unified view." *MIS quarterly* (2003): 425

[61] Jachinski, C. (2018) Independent Aging with the Help of Smart technology. Diss. The Netherlands: University of Twente:

[62] Rogers, E. M. *Diffusion of innovations*. New York, NY: The Free Press, 1995
Frennert, S. A. et al., "Elderly people's perceptions of a telehealthcare system: Relative advantage, compatibility, complexity and observability." *Journal of technology in human services* 31.3 (2013): 218

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understand the "uptake of technology" phenomena. The "positivist approach" assumes that there is one reality which researchers can access and objectively measure by the right study design, methods, or instruments while the "interpretive approach" assumes that social reality is not singular or objective but multiple perspectives that can be generalized by relating observations and interpretations to a coherent and plausible theory.

In "The Good Robot Report"[63] 75% of the respondents, were positive towards having robots in the future. Most of the participants wanted a robot that could do tedious work at home such as cooking and cleaning. The reasons for wanting a robot was to free up time to socialize with other humans and to free up time for sporting or developing new skills. Although the majority of the participants could imagine having a robot in the future, they also voiced fears concerning robots being hacked or turning against humans, as well as taking over all jobs.

A survey conducted by the Nomura Research Institute in Japan, the United States and Germany shows cultural differences in the acceptance of robots [64]. According to their survey, Americans had utilized home and retail robots the most, and they were also the ones who had the highest optimism towards future robots. Germans on the other hand, were highly optimistic towards industrial robots but more pessimistic and showed resistance towards household robots. According to the survey, Japanese people had a positive attitude towards robots, but at the same time only 6% wanted to purchase a robot within 12 months, while 61% of the Japanese respondents did not want to purchase a robot in the future or did not know what they wanted. Among the Japanese's respondents 70% thought that their job would be replaced or partly replaced by robots, while less than 35% of the German's and the US respondents thought that their job might be replaced or partly replaced by robots.

During autumn 2018 a series of focus groups workshops, organized by INBOTS, took place in Stockholm, Sweden, with frontline care staff, line managers, students who train to become frontline care staff and older people[65]. The results show that the majority of the participants viewed interactive robots in health- and elderly care as an asset but they also voiced concerns regarding reliability, practical handling, costs and fear of mechanical care. During the focus groups with the students who train to become frontline staff, it was noticed that they were significantly more concerned about care robots taking over their future jobs, and that the utilization of robots would result in unemployment. Even though the "Good Robot Report" does not concern care robots, the result show similar results - that younger people are significantly more worried about robots taking their jobs, and that they will be unemployed in the future due to robots.

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[63] Coplin, D,. The Good Robot report :The robot revolution is coming, *https://www.anki.com/on/demandware.static/-/.../the-good-robot-report.pdf*
[64] Nitto, Hiroyuki, Disuke Taniyama, and Hitomi Inagaki. "Social acceptance and impact of robots and artificial intelligence: Findings of survey in Japan, the US and Germany." NRI Papers (Japan) 213.1 (2017).

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Commission released *Ethics Guidelines for Trustworty Artificial Intelligence*[66]. In this report a definition of trustworthy AI is given:

"Trustworthy AI has three components, which should be met throughout the system´s entire life cycle: 1. it should be lawful, complying with all applicable laws and regulations; 2. it should be ethical, ensuring adherence to ethical principles and values; and it should be robust, both from a technical and social perspective, since, even with good intentions, AI systems cause unintentional harm."[67]

Trust relates to acceptance. Conceptually it is important to differentiate between acceptance and acceptability. Acceptance includes the voluntariness to accept, agree or allow e.g. an action, a statement, a person or an object. It is expressed actively by consensual value judgements that often remain on a subjective level. Acceptability in contrast describes a more objective and rational evaluation, under which conditions e.g. an action, a statement, a person or an object should or should not be accepted. The ethics-guidelines of the High-level Expert Group on Artificial Intelligence discuss trust as a form of acceptability, including a concrete checklist of how to increase trust practically.

It is methodically very important to differentiate between evaluative/normative and descriptive/empirical acceptability. Normative acceptability describes the result of an ethical assessment and the question whether a robotic application is rationally acceptable related to certain human values – e.g. of privacy, safety, autonomy, justice, sustainability or (long term)- responsibility. Obtaining and gaining normative acceptance is an ambivalent process. Strategies of manipulation might increase approval for a short period of time. But real trust in technical products, processes and knowledge depends on pragmatic approving on a long-term scale. Obviously untrue promises or misleading statements might ruin the public reputation and therefore the factual acceptance of certain technologies.[68] Descriptive/empirical acceptability relates to functionality of technical systems, procedures or tools, but also to other fields of human actions – e.g. the pragmatic acceptability of a linguistic formulation, a diplomatic consent or a concrete management decision observed from a certain point of view – like the interests of certain stakeholders. In the case of robotics, the public perception plays an important role. Since robots are complex high-technological systems for layman it is sometimes hard to evaluate their acceptability. On the other hand, especially for innovative developments empirical data and practical experiences related to their applications are missing. Insofar also ethical, legal or technical experts are methodologically challenged. The overarching evaluation of very recent robotic applications remains difficult since many cultural and social factors play a role beside the pure functionality.

[66] AI HLEG (2019) Ethics Guidelines for Trustworty Artificial Intelligence. High-Level Expert Group on Artificial Intelligence. 8. April 2019. European Commission, Brüssel [https://ec.europa.eu/futurium/en/ai-alliance-consultation (12. April 2019)], p. 7.
[67] AI HLEG (2019) Ethics Guidelines for Trustworty Artificial Intelligence. High-Level Expert Group on Artificial Intelligence. 8. April 2019. European Commission, Brüssel [https://ec.europa.eu/futurium/en/ai-alliance-consultation (12. April 2019)], p. 7.
[68] Kornwachs 2013, S. 100-101; Ropohl 2016, S. 29-32, S. 285-288: Kornwachs K (2013) Philosophie der Technik. Eine Einführung. C.H. Beck, München; Ropohl G (2016) Ethik und Technikbewertung. 2. Auflage. Suhrkamp, Frankfurt a.M.

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Pre-conceptions of robots can lead to rejection and resentment towards interactive robots. The above presented results show that beliefs about- and attitudes towards interactive robots often are grounded in conceptional misinterpretations, as robots that once was a thing of science fiction, now seem probable. Hands-on experience of interactive robots, and evidence-based discussions about interactive robots, may help people to gain relevant knowledge, confidence and beliefs to empower them to integrate interactive robots into their everyday life and work environments. Hence to truly change understandings and pre-conceptions towards interactive robots among the general public, researchers need to take an objective stance when presenting evidence and research on interactive robots, and not fall into marketing rhetoric and discourse. The latter is, citing Herbrechter, the matter of "science faction"? at work, i.e. a deliberate blurring of science fiction and fact used by scientists to legitimate, popularize and promote their research to a lay audience with a view to influence "policy"[69].

To sum up, the acceptance and social uptake of interactive robots is dependent on contextual, cultural and individually related actors. Today there are well-developed models to understand what makes it possible and what prevents the acceptance of new technology. The opposite also applies, that interactive robots isolated from the context where it is supposed to be implemented or given to people without experience of technical changes and of the advantages this can bring, will have difficulty being accepted and used.

[69] Herbrechter, S,.(2018) Unsociable Robots – Empathy in Robot & Frank, stefanherbrechter.com/wp-content/uploads/2018/11/Unsociable-Robots.pdf

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