# Emerging Technologies and the Field of Assistive Technology; Possibilities and Challenges

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**Based on joint work with Sarah Abdi, Mark Hawley and Irene Kitsara**

**Abstract**. Assistive technology has been around for at least 5000 years and can play a huge role in supporting people with functional limitations or disabilities in their daily lives. The past few decades have witnessed a very rapid growth in the number and types of assistive devices, and it is expected that this growth will continue at an even higher speed. This chapter presents a brief history of the development of assistive technology and an overview of emerging technologies that are likely to impact the field of assistive technology. This impact is expected to be impressive; new technological developments enable the development of completely new assistive devices, creating the feeling that almost everything will become possible. A huge challenge, however, will be how to steer these developments in such directions that they do not increase existing inequities but reach those people who need them the most. The chapter presents some examples of what can be expected in the next few years, building on the potential that emerging technologies offer.

## Neue Technologien und Assistive Technologien; Möglichkeiten und Herausforderungen

**Zusammenfassung.** Assistive Technologien gibt es seit mindestens 5000 Jahren, und sie können eine große Rolle bei der Unterstützung von Menschen mit Funktionseinschränkungen oder Behinderungen in ihrem täglichen Leben spielen. In den letzten Jahrzehnten hat die Zahl und Art der Assistiven Technologien sehr schnell zugenommen, und es ist zu erwarten, dass sich dieses Wachstum noch beschleunigen wird. Dieses Kapitel enthält einen kurzen geschichtlichen Überblick über die Entwicklung von Assistiven Technologien und einen Überblick über neu entstehende Technologien, die sich wahrscheinlich auf den Bereich der Assistiven Technologien auswirken werden. Es wird erwartet, dass diese Auswirkungen beeindruckend sein werden; neue technologische Entwicklungen ermöglichen die Entwicklung völlig neuer Assistiven Technologien, wodurch das Gefühl entsteht, dass fast alles möglich sein wird. Eine große Herausforderung wird jedoch darin bestehen, diese Entwicklungen so zu steuern, dass sie die bestehenden Ungleichheiten nicht verstärken, sondern diejenigen Menschen erreichen, die sie am dringendsten benötigen. In diesem Kapitel werden einige Beispiele dafür vorgestellt, was in den nächsten Jahren zu erwarten ist.

# 1 Introduction

The earliest 'proof' of assistive technology (AT) being used by humans stems from about 3000 years before Christ. On a drawing in an Egyptian pyramid, a person using an under-arm crutch can be seen (Vlaskamp, Soede, and Gelderblom 2011). And everybody knows pictures of pirate captains with wooden prosthetic limbs later in history. Prosthetic legs were also already known by the Romans 300 years before Christ, as can be seen in the Science Museum (Science Museum Group n. d.). A most beautiful example of early-stage AT is the iron prosthetic hand found in a castle in Slovenia, which was used by an unknown person in the 17th century (Marinček 1992). Such examples demonstrate that AT is not new; it has been around for as long as humans had the possibility to create tools and devices to enhance their functional capacities. Along with the development of technology and the increasing skills of people to create new things, the number and ingenuity of such assistive devices has increased and still is increasing. Today, a staggering number of more than 15.000 assistive devices exist, as described in the EASTIN database of assistive devices (Eastin Association n. d.). And it is likely that this number will increase in the future. AT has become a real discipline and specialty.
This chapter presents a 'sneak preview' of what developments can be expected in the near future in the field of AT based on a literature review about trends in technology (Abdi, Witte, and Hawley 2020) and a large study of patents published by the World Intellectual Property Organization (2021). It will be just a 'sneak preview' because developments are currently going so fast that it is impossible to predict what will happen. However, it is possible to describe some major trends and examples, which will be done in sections 3 and 4, respectively. In doing so, it is possible to see some major challenges related to these trends. These will be discussed in section 5 of this chapter. But before looking at the future, a brief history of AT is presented.

# 2 A brief history of assistive technology

In 2011, Vlaskamp, Soede, and Gelderblom published a very nice booklet in which they gave an overview of milestone developments in the field of AT. This booklet gives a fascinating overview of how AT has existed for ages. One of the striking things that occurs when reading through the list of inventions over the ages is that many really innovative AT inventions are much older than most people think. This indicates that it takes many years for a new invention to develop into a widely available and used solution. A few examples of this are: the first bifocal eyeglasses stem from 1764; the first electrical hearing aid was invented in 1902; the text telephone in 1964; an environmental control system with voice recognition in 1986; the MANUS robot manipulator in 1988; the MyTobii eye-gaze controlled communication device in 2006; and the PARO social robot, that is still seen as innovative in many care settings, already in 2003. These are just a very brief selection of examples of how long the process from development to large-scale use of AT can take.
An important characteristic of the AT field is that many innovations are stimulated by wars; large numbers of disabled soldiers returning from the battlefields needed assistive devices like prosthetic arms and legs. Many other assistive devices are inspired by individual experiences, an engineer who had a family member or friend with a disability and decided to develop a solution for that person. And some devices were

invented as a solution for personal functional problems. This explains the fragmented character of the AT field. Most consumer market products are developed with a large group of potential users in mind, carefully identified in market analyses. However, in the AT field, the process is often the other way around, starting with an individual solution that (not always) finds its way to larger user groups. That process takes a long time, often fails, and very similar solutions can enter the 'market' independently. Only in the past few decades has there been a trend that general-purpose technologies enter the AT field. Smartphones, tablet computers and other wireless wearable devices developed for the general public appear to be very powerful assistive devices for persons with disabilities. This has fundamentally changed the AT field. Many more solutions have become available for persons with disabilities or functional limitations, and this trend will very likely continue as demonstrated in the next sections.

# 3 Emerging technologies that will change the field of AT

Abdi, Witte, and Hawley (2020) performed a broad review of the grey literature about technology trends, explicitly looking for technologies that foster the development of new products and services with the potential to assist independence and active participation. The scope was broad enough to gain an overview of emerging enabling technologies yet narrow enough to identify those holding the greatest potential for AT applications. This review resulted in five emerging enabling technologies that could be relevant to the AT field: 1) artificial intelligence; 2) robots; 3) computer/machine interfaces; 4) advanced sensors; 5) Internet of Things (IoT) and connectivity. With a very different mixed methodology, the WIPO study mentioned in the introduction also tried to identify the most important emerging technology fields that may be relevant to the field of AT (World Intellectual Property Organization 2021). The WIPO analysis confirmed the five key emerging technologies mentioned above but identified four additional fields: 6) additive manufacturing; 7) new materials; 8) autonomous vehicles; 9) virtual reality (VR) / augmented reality (AR). The resulting nine technologies are briefly described below.

## 3.1 Artificial Intelligence

Artificial intelligence (AI) is undoubtedly the most rapidly developing emerging technology. It is generally seen as having huge potential for the AT field. AI allows computers to perform human-like complex tasks such as speech and speech recognition, image and object recognition, translation, interpretation of complex situations or data, detection of emotions, and much more. These AI capabilities can, certainly in combination with other emerging technologies like robotics, be used in assistive products for blind persons, persons with speech problems, persons with cognitive problems, and many more. The WIPO study identified a large number of patents directed towards such applications (World Intellectual Property Organization 2021).

## 3.2 Robots

Robots have already had a huge impact on many fields of our economy and have first been introduced into the AT field about 35 years ago. The MANUS robot manipulator mentioned before and the PARO seal robot are nice examples of early-stage robotic applications for persons with disabilities (Driessen, Evers, and van Woerden 2001;

Shibata 2012). One could argue that this is no longer an emerging technology. That is true in the logistics industry and manufacturing. However, robots that closely interact with people in their natural environment, and certainly people with physical or other vulnerabilities, are not yet mainstream technology. They are, however, rapidly developing. Advances in AI and sensor technology enable the development of more autonomous robots that can interact, adapt and respond to their environment, also when that environment is unpredictable and changing. This will enhance the collaboration between people and robots, which is essential for assistive robots. Current developments can be seen in companion robots, exoskeletons, autonomous devices, and soft robotics. The WIPO study identified many patents in these directions, but it will likely take some more years before these become available as assistive devices.

## 3.3 Computer/machine interfaces

As a result of development in different technological fields like computer vision, VR and AI, completely new ways of interacting with digital technology have become possible. They use human voice, vision, brain activity, emotions, gestures or other movements as means to interact with technology. For persons with disabilities, these new interfaces offer fascinating new possibilities to sense and control their environment, operate assistive devices, direct robots, etcetera. Probably one of the most interesting possibilities is offered by direct brain-computer interaction, but this field is still in an early stage.

## 3.4 Advanced sensors

Sensor technology is not new, but the cost and size of sensors, their energy consumption, their capabilities to send data wirelessly, and the range of parameters that sensors can measure has increased dramatically in the past few years. Such advances have increased and improved wearable technologies, IoT applications, the performance of robots, 3-D sensing, real-time analysis and monitoring of the performance of assistive devices, smart alarm systems, etc. The possibilities are seamlessly endless. In the WIPO report, many examples of applications can be found.

## 3.5 IoT and connectivity

Advances in connectivity and computing have had a huge impact on the connectivity of assistive devices and the digital experiences of end-users. The speed of data transfer has increased rapidly over the past few years, and developments like edge computing allow much faster real-time responses through local data processing. These advances have boosted the IoT, in which everything is connected, and devices can communicate and share data, enabling smart passive monitoring and alarm systems. These same developments have also boosted the possibilities of VR and AR by eliminating data processing delays, thus creating interesting new possibilities for assistive devices. An important future development is quantum computing, which is expected to enable even faster connections between even smaller and ‘smarter' sensors and other devices. It is hard to predict what impact this will have on the AT field, but there are quite a few patents related to these technologies.

## 3.6 Additive manufacturing

Additive manufacturing is a technology that enables the automated creation of 3D objects from a computer model. It is mostly referred to as 3D printing. It has huge value for the field AT because it allows for more individualized customized products and components of products that meet personal needs. And, maybe even more importantly, it can relatively rapidly be done at the ´point of care´, bypassing long processes of ordering, transport etc.. In combination with the development of new materials that can be used for printing, this technology allows new approaches in prosthetics, orthotics, devices for activities of daily living (ADL) support and many other areas. There are still some serious issues regarding safety and certification, but the potential of making things for individual needs ´on the spot´ is very compelling (Jong et al. 2023). This also opens up possibilities for developing countries and other low-resource settings.

## 3.7 New materials

For most people working in the AT field, material science is not the first thing they have in mind. There are, however, many new materials that have great potential for the production of assistive devices. Composite materials like glass- or carbon fibers, sometimes combined with other materials like polymers, for example, enable the development of very strong and durable prosthetics and orthotics, parts of wheelchairs and other mobility devices, but also biocompatible implants, textiles containing soft sensors, and many other applications.

## 3.8 Autonomous vehicles

Autonomous cars can already be seen on public roads, although there still is some ambiguity regarding their safety and trustworthiness. These same technologies can also be applied to mobility devices for people with disabilities, with smart rollators and smart electrical wheelchairs as examples. This field overlaps with that of robotics. Autonomous vehicles can even be seen as robots, but their use is very different. That is why they are mentioned separately here. Thinking about mobility, the functional domain where the highest percentage of people experience limitations, one could imagine autonomous transport systems and smart devices that help people navigate as future assistive devices.

## 3.9 Virtual reality / Augmented reality

VR and AR have a huge potential for people to experience new things. It can be used in education, training, rehabilitation, leisure activities like gaming, and many more. Augmented reality can help people to understand their environment or support them in performing complex activities, with interesting examples in work (e.g. engineers, surgeons, pilots). VR ‘worlds’ are becoming more and more realistic, opening up all kinds of new applications, also in the field of AT.

# 4 What new Assistive technology applications can be expected?

With a bit of fantasy, it is easy to think of many possible applications of the technologies described. Interestingly, they enforce and enable each other. The enormous development in AI, for example, has only been possible because of huge developments in connectivity and computing, as well as human-computer interfaces. Robots will rapidly become smarter due to the fast developments in AI. All these technology domains seem to enforce each other and together create all kinds of new possible applications. The WIPO study showed that only a small portion (3 %) of all patents in these domains refer to AT as an application area, but still, they identified more than 11.000 patent families explicitly mentioning AT applications. In the table below, a few examples of such new applications are described, with each of the enabling emerging technologies that enable them. These examples stem from actual patents filed. They clearly show how these different technologies together form the basis of new assistive devices/solutions.

Table 1 Some examples of emerging Assistive technology applications and the enabling technologies making them possible

| **Functional domain** | **Examples** | **Enabling technologies involved** |
|---|---|---|
| Mobility | • Smart walkers that remember the route taken and can guide the user back<br>• Smart prosthetics recognize the user's gait to adjust walking and to create a feeling of natural touch | • Smart sensors, robots, IoT and connectivity<br>• AI, smart sensors, additive manufacturing, new materials |
| Environment | • Companion robots for health and emotion monitoring, nursing, wandering and emergency monitoring<br>• Smart houses allowing independent living: navigating, monitoring, cooking, toileting, nursing, etc. | • AI, computer/machine interfaces, smart sensors, robots, IoT and connectivity<br>• AI, computer/machine interfaces, smart sensors, robots, IoT and connectivity |
| Hearing | • Gloves with sensors to measure and detect hand posture, position and gesture, and translate hand motions into speech and/or text<br>• Mind-controlled hearing aids with the ability to monitor health and emotional aspects | • Smart sensors, AI, IoT and connectivity<br>• Computer/machine interfaces, AI, smart sensors |
| Vision | • Gloves that sense the environment and convert information about the environment (color, keys of a keyboard, etc.) to braille output or audio<br>• VR/AR devices to help users observe the surroundings and identify objects, compensating for visual impairments | • AI, computer/machine interfaces, smart sensors, IoT and connectivity<br>• AI, computer/machine interfaces, smart sensors, IoT and connectivity |
| Communication | • Personal communication devices with brain interface technology | • AI, computer/machine interfaces, smart sensors, IoT and connectivity |

| Functional domain | Examples | Enabling technologies involved |
|---|---|---|
| | • Smart assistants as avatars to enhance accessibility in the virtual universe | • AI, computer/machine interfaces, smart sensors |
| Self-care | • Smart incontinence materials that do health monitoring through automated analysis of body fluids and notify caregivers<br>• Feeding assistant robots | • AI, computer/machine interfaces, smart sensors, new materials<br>• AI, computer/machine interfaces, smart sensors, robots, IoT and connectivity |

The number of new innovations is impressive. In established 'conventional' domains of AT, the WIPO study identified 117,209 patent filings over a 20-year period, and in the emerging technology domains, another 15,592. Filings in emerging technology are growing three times faster than conventional, with a 17 % average annual growth rate (AAGR) compared to 6 %. Most patent filings in conventional AT relate to mobility, followed by the built environment, hearing and vision. Yearly filings in mobility are more than those of all six other domains combined. In the emerging AT space, the most active domain over the period is hearing, followed by mobility, vision and communication. However, since 2014, mobility has taken the lead among emerging technology filings, too. Indeed, the fastest growing areas for patent filings relate to mobility and environment both in conventional (9 % and 7 % AAGR, respectively in 2013-2017) and emerging AT (24 % and 42 % AAGR, respectively).

Looking from a distance at the patents identified in the WIPO study, a few general trends are visible.

- As already mentioned, many identified emerging assistive products use one or a combination of several enabling technologies, such as AI, the IoT, computer/machine interfaces and smart sensors. These allow for smarter and connected assistive products which learn from the user's behavior and environment, optimize and customize their functions and support independent living and navigation, telemedicine, smart nursing and more.
- AT has traditionally been considered external to the human body and non-invasive. Several emerging assistive products, however, include implants and other products that would qualify as medical devices, with many of those moving beyond assistance towards augmentation or recovery of missing human functions. The field of AT seems to be converging with medical technologies.
- More technologies with potential for persons with disabilities or functional limitations are becoming mainstream rather than specialized. Convergence between disciplines and technologies increases the breadth of functionality of products for different user groups and will boost the pace of innovation in this field.

## 5 Challenges related to innovation in assistive technology

Looking at the technological developments described, driven by enabling technologies, the future for AT looks brilliant. These developments give rise to excitement and optimism regarding the challenge of bridging the current wide gap between the need for and availability of AT. However, these developments also cause serious concerns. Will all these smart goods and services be accessible, affordable and acceptable to persons with disabilities, including those in developing countries and other low-resource settings? To what extent does new AT meet the real needs of the majority of those with disabilities, most of which are related to rather basic mobility functions, communication, self-care, or relatively simple impairments of vision and hearing? Will these smart and connected assistive products also work in settings with limited Internet access or unreliable power supply? How will aspects like training, maintenance and repair, and recycling and disposal be organized and guaranteed? From a business perspective, focusing on regions and markets where such difficult questions are less pressing is more attractive. And herein lies an important concern: will 'the market' really solve the problem for persons with disabilities?

The key question for the future of AT is how we can best harness the potential of technology to reach as many persons with disabilities as possible and satisfy their most urgent needs. The answer to this requires clear direction as well as the will to make it happen. If we let the market do its work, we will see a world in which the divide between the haves and the have-nots is exacerbated, between people who can afford the most fantastic AT and those who have no option but to live without even the most basic aids and so must carry on struggling as they do today. However, if we are able to steer the development of the AT field and encourage responsible research and innovation, it is well within our grasp to bring about a world in which everyone can access the AT they need to participate in society and lead meaningful lives. Herein lies a huge challenge, as well as a wonderful opportunity, for the United Nations and its various agencies and programs, national governments, and leaders in academia, industry, non-profits, logistics and service provision.

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