Technological prospecting for patents on assistive technology related to mobility aid resources

Prospecção tecnológica de patentes de tecnologias de assistência relacionadas com os recursos de ajuda à mobilidade

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Abstract

The present study carried out a technological prospecting in order to present and discuss the main Assistive Technology patents focused on the mobility aid category. This is an exploratory research, with documental and applied research procedures, with a qualitative-quantitative approach, based on searches carried out in the international database Questel Orbit Intelligence for investigation in patent documents. The results found made it possible to map and analyze the evolution of technological production in the world market for assistive products. From this analysis, the growing interest in the development and protection of resources related to mobility was identified, as well as inventors with greater productivity; the

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main patent applicants, such as the prominent academic institutions; the leading countries in patent protection requests, such as China and the United States; the related and most cited terminologies in patent documents and the selection of technologies related to the scope of the research, in order to discuss the main technological trends in these products

**Keywords:** Assistive Technology Related to Mobility. Technological Prospecting for Patents. Physical Disability.

**Resumo**

O presente estudo realizou uma prospecção tecnológica com o objetivo de apresentar e discutir as principais patentes de Tecnologia Assistiva com foco na categoria relativa a auxílio de mobilidade. Trata-se de uma pesquisa de característica exploratória, com procedimentos de pesquisa documental e de natureza aplicada, com abordagem quali-quantitativa, a partir das buscas realizadas na base de dados internacional *Questel Orbit Intelligence* para investigação nos documentos de patentes. Os resultados encontrados possibilitaram mapear e analisar a evolução da produção tecnológica no mercado mundial de produtos assistivos. A partir desta análise, foi identificado o crescente interesse no desenvolvimento e proteção de recursos relativos à mobilidade, bem como, os inventores com maior produtividade; os principais depositantes de patentes, como o destaque das instituições acadêmicas; os países líderes nos pedidos de proteção patentária, a exemplo da China e Estados Unidos; as terminologias relacionadas e mais citadas nos documentos das patentes e o recorte de tecnologias relacionadas ao escopo da pesquisa, a fim de discutir as principais tendências tecnológicas nesses produtos.

**Palavras-chave:** Tecnologia Assistiva Relativa à Mobilidade. Prospecção Tecnológica de Patentes. Deficiência Física.

**Introduction**

More and more technology has entered the spaces of society bringing innovation and solutions that affect people's lives. This advance encourages research development focused on the benefits brought in the technological field, including those related to social inclusion process, a topic that has shown growth and evidence in recent years, bringing several opportunities to the area of Assistive Technology (AT).
Assistive Technology resources are tools used by People with Disabilities (PwD) or with reduced mobility in the process of motor rehabilitation and social inclusion. These resources promote better performance of functional capacity and greater independence in carrying out daily activities, as well as, study, work and leisure activities. In addition, they also enable access to spaces and environments, whether domestic or public.

Considering this context, the present study carried out a technological prospecting focusing on the theme of technological production of mobility aid resources, one of the most widespread AT categories included in the ISO 9999/2016 international classification. In order to support discussions around trends in the technology field and other relevant aspects to this investigation, a statistical dimension of data included in the technology state of the art and access to information in patent documents of assistive resources were sought focused on mobility aid. The objective is to present and discuss the main existing resources of Assistive Technology aimed at people with motor dysfunction or reduced mobility. In order to guide this research, the following question was raised: What are the main technological resources, whose protection was requested in the form of a patent, for people with motor dysfunction or limited mobility? These two terminologies – motor dysfunction or limited mobility – were mentioned in order to reach all demand forms for AT use for mobility, whether due to pathological causes or not.

Technological prospecting refers to a set of methods and techniques for data collecting and processing, as well as information analysis about technology, in order to support other processes, especially decision-making ones. Patent prospecting is a form of technological prospecting, however, it should be clarified that the latter is broader than a patent data search, as it involves other concepts, such as competitive intelligence and foresight, for example (RIBEIRO, 2018). In a prospecting, the techniques can be used in a complementary way depending on the objectives to be achieved.

In this study, the patent prospecting was carried out in the Questel Orbit Intelligence international database, once patents, in addition to innovation indicators, they are important sources of technical information that allow to guide decision-making process and actions inherent to processes of technological development, technology transfer and even those related to the production chain, being also a strong competitive instrument. Access to technological information makes up the strategic and competitive intelligence actions of companies, given uncertainties related to Research and Development (R&D) activities and the economic perspective that, in general, lead innovative companies in search for assertive
strategies for competitive advantages for their products and market (PARANHOS; RIBEIRO, 2018).

In addition, it is possible to identify trends in technology field through patents, a fact that is addressed by many authors, such as Savchenkov, Bazhin and Volkova (2020), Cao, Cai, Wang, Ding and Yang (2021), Choi and Song (2018) and Krzysztof Klincewicz (2020), which can guide and stimulate the proposition and configuration of effective public policies (HAASE; ARAÚJO; DIAS, 2009), in order to put into practice fundamental rights to citizenship exercise of the final target audience: people with disabilities. Therefore, we sought to analyze patents related to the subject through technological prospecting, and from there, it was possible to find, treat and discuss data that supported and guided relevant approaches on the subject.

As the topic discussed deals with technologies designed for people with mobility limitations, it is pertinent to base the research by presenting a brief study contextualizing physical disability and Assistive Technology.

This article is divided into seven sections: first, this introduction presents the topic discussed, the objectives and its relevance, both to academia and society. In the second section, there is a theoretical framework addressing physical disability, impacts and classification of Assistive Technology in order to support the study on the subject. The third section brings the methodology applied to reach the objectives with procedures’ detailing and search strategies necessary for the research development. In the fourth section, there are the results and discussions addressing current aspects of the technological production of mobility aid resources. Then, in the fifth section, the final considerations are presented; in the sixth, the acknowledgments and, finally, the bibliographic references, in the seventh and last section.

Physical Disability and Assistive Technology

2.1 What is Physical Disability?

In order to understand the universe and function of Assistive Technology (AT), it is necessary to know the context of the audience, and for what demands it is intended. AT's products and services are primarily used by PwD.

Preliminarily, it can be said in general terms, that physical disability is perceived as a change in the body that interferes with a person's movements and locomotion.
The scope of this study covers motor dysfunction and reduced mobility as determining factors for the use of mobility aid technology. However, it is pertinent to clarify that not every context in which there is reduced mobility, it is associated with a physical disability diagnosis. There is a portion of society that due to circumstantial and often non-permanent situations, have reduced mobility, that is, a limitation in movement, such as certain obese, elderly, pregnant women and people who have undergone certain surgical procedures or who are occasionally with immobilized limbs. Unlike people with motor dysfunction, they do not fit the definition of physical disability, but may require the use of Assistive Technology. For this reason, they should be considered in the statistics of related studies.

As it can be seen in some studies (CHIU; WEI; HUNG; WU, 2021; RENAULT; GUEVARA; BAUDON; SERGENT; CHARPILLET; DENOYELLE; THIERY; AMEL; GITIAUX; VAZQUEZ, 2020; CAVARSAN; GORASSINI; QUINLAN, 2019), motor dysfunction can be understood as a motor deficiency that affects motor skills. That is, it represents an alteration in the individual's motor coordination, mobility or speech. It is one of the evident characteristics of physical disability, and, for a better understanding, some of the several existing definitions of the latter have been highlighted, as presented below.

First of all, when dealing only with the terminology “disability”, Article 1 of Decree N° 3,956 (BRASIL, 2001) defines it as "a physical, mental or sensorial restriction of a permanent or transitory nature, which limits the ability to exercise one or more essential activities of daily living, caused or exacerbated by the economic and social environment”.

For the Ministry of Education (MEC), physical disability is determined by differentiated motor conditions, caused by neurological, neuromuscular, orthopedic injuries and by congenital or acquired malformations that can compromise mobility, general motor coordination and speech (BRAZIL, 2006).

Decree No. 3,298, of December 20, 1999, in its Article 4, with the wording changed by Decree No. 5,296, of December 2, 2004, brings in more detail the concept of physical disability, considering as a "person with a disability" that one which falls into the following categories:

[...] complete or partial alteration of one or more human body segment, causing impairment of physical function, appearing in the form of paraplegia, paraparesis, monoplegia, monoparesis, tetraplegia, tetraparesis, triplegia, tripaesia, hemiplegia, hemiparesis, ostomy, amputation or absence of limb, cerebral palsy, dwarfism, limbs with congenital or acquired deformity, except for aesthetic deformities and those that do not hinder the performance of functions (BRASIL, 2004)
Aiming at training teachers involved in school inclusion process, the MEC makes a detailed approach on the types of physical disability, the causes that determine it and the various impairments caused by this type of disability in its document published in 2006: “The school inclusion of students with special educational needs – physical disability” (BRASIL, 2006). They are summarized below.

Regarding the impairments caused by physical disability, the upper or lower limbs may be affected by absence, deformity, paralysis, lack of motor coordination, presence of involuntary movements that interfere with the use of hands, locomotion and sitting position. Even vitality can be impaired, through a marked lack of vigor and agility caused by diseases that affect the body's metabolic system and influence school performance (BRASIL, 2006).

In terms of the nature, physical disability comprises two types that present themselves as orthopedic disorders - those originating in the bones, muscles or joints - and neurological disorders, associated with injuries or deterioration of the nervous system. Moreover, depending on the type, it can be progressive or non-progressive, temporary, definitive, recoverable or compensable, which is the case of amputation, compensated by prosthesis use (BRASIL, 2006).

The MEC (BRASIL, 2006) also points out the causes of a physical disability that can be hereditary (resulting from diseases transmitted by genes); congenital (when they occur at birth or in the intrauterine phase) or acquired (when they occur after birth, because of infections, poisoning, trauma or accidents). There are elements and situations that are normally considered risk factors, such as sports or work accidents; urban violence; drug use and smoking; toxic agents; epidemics or endemics; bad eating habits; lack of sanitation, and even a sedentary lifestyle.

Furthermore, among the diseases, accidents and injuries that can cause a physical disability, the Ministry of Education highlighted:

a) Diseases in the osteoarticular system – they are characterized by causing a deformity, destruction, malformation or even an inflammatory process damaging bones and joints. Their causes are related to traumatic or genetic problems, as well as alterations in embryo development, blood, vascular, infectious or degenerative diseases, tumors, metabolic alterations, poor posture and alterations in other organs, apparatus and tissues (BRASIL, 2006; ZHAO; YANG; CHEN; ZHANG, 2019);

b) Muscle diseases - they are due to alteration in the central or peripheral nervous system, caused by a neurogenic stimuli absence, that makes it loose muscle strength, generating atrophy - the so-called "neurogenic muscle atrophies". There are also the
“myogenic atrophies” originating from muscular fibers alteration, which among these, progressive muscular dystrophies are the most common ones (BRASIL, 2006);
c) Nervous system diseases – they are disorders of the central nervous system, which corresponds to the brain and spinal cord, as well as of the peripheral nervous system, referring to ganglia, roots and nerves. They are associated with several causes, including genetic, tumor, traumatic, vascular, infectious, metabolic, toxic and even unknown causes (BRASIL, 2006);
d) Spinal cord injury - it is characterized by an interruption in nerve stimuli passage through the spinal cord, which can be of traumatic origin, caused mainly by accidents, or of pathological origin, through tumors, hemorrhages, infections, viruses or others (BRAZIL, 2006);
e) Burns – these diseases are those that can disfigure and change the elasticity of tissues, leading to limited movements (BRASIL, 2006);
f) Cerebral palsy – this is a non-progressive lesion of a developing brain, most often caused by a lack of oxygen in the brain cells, with several clinical forms of manifestation, associated or not with epilepsy, sensory disorders and cognitive impairment. (BRASIL, 2006; CAPPELLINI; SYLOS-LABINI; DEWOLF; SOLOPOVA; MORELLI; LACQUANITI; IVANENKO, 2020).

For MEC (BRASIL, 2006), success in learning processes depends a lot on the opportunity given to students with disabilities through provision of Assistive Technology resources appropriate to their educational needs so that the barriers that prevent their learning are removed.

Regarding the concept of disability, it is worth mentioning that the institution of the Brazilian Law for the Inclusion of Persons with Disabilities (BLI), Law No. 13,146, of July 6, 2015 (BRAZIL, 2015), also known as the Statute of Persons with Disabilities, consolidates this definition as follows:

A person with a disability is considered to be one who has a long-term impairment of a physical, mental, intellectual or sensory nature, which, in interaction with one or more barriers, may hinder his or her full and effective participation in society on an equal basis with others. (BRAZIL, 2015).

It is interesting to note that this more recent definition has brought with it a paradigmatic nature difference, in which it relates disability to characteristics of a person and the environment. In other words, depending on the existential conditions of barriers to access for a PwD, the level of their disability will be considered higher or lower.
2.2 Social Impacts of Assistive Technology

The resources and services that Assistive Technology offers have an immense social impact, as they add value related to independence, capacity, achievement, inclusion and quality of life, making skills and activities possible. Thus, these technologies transform a person’s life as they overcome not only physical access barriers, but also paradigms associated with disability, which facilitates social inclusion process, making the individual more participatory and fulfilled.

As it can be seen, there are several benefits generated by AT, as its products are fundamental in promoting functional capacity of PwD and in motor rehabilitation as a continuous process of stimulation through the daily use of technology. AT products favor access minimizing physical, environmental, architectural and urban barriers. Moreover, they represent an indispensable tool for social inclusion process in the education field. All these possibilities generate a better quality of life for the population with disabilities.

According to the World Intellectual Property Organization (WIPO), more than one billion people in the world need help of some technology in their daily lives, and this statistic tends to grow with the natural aging of human being (UN, 2021). Considering the convergence between the consumer electronics and assistive products industry, it is estimated that this number will reach two billion users by 2050 (WIPO, 2021). Furthermore, in the world scenario of technological production, the Executive Summary of Assistive Technology of WIPO (2021) concluded that the patenting activity in the area of conventional Assistive Technology is almost eight times greater than that of emerging Assistive Technology. In the former, products aimed at mobility predominates, as the sum of its annual deposits is greater than the sum of all deposits referring to other categories in the area.

AT national demand is also significant, once there is a demographic profile in which people with a disability composes of approximately 1/4 of the Brazilian people (IBGE EDUCA JOVENS, 2022). Despite being an incipient knowledge area in Brazil, requiring greater funding and investments in research and development, its legal framework has accomplished great achievements in recent decades, especially through implementation of the Brazilian Law of Inclusion, which represents a legal framework and encouragement for implementation of public policies for access to these technologies. However, actions to promote R&D are still very timid, not meeting social demand in terms of quantity or quality, since government programs offers few options of resources, and those technologies offered need to be adapted to the specific needs of each user (SUGAWARA; RAMOS; ALFIERI;
BATTISTELLA, 2018). This demonstrates the need for greater investments in research and production, in addition to proposing effective public policies.

2.3 Classification of Assistive Technology According to International Standard

At an international level, there are several systems for classifying Assistive Technology, such as the HEART Classification and the MPT (Matching Persons and Technology), oriented towards differentiated purposes (GALVÃO FILHO, 2009), among them, the most used is the international standard ISO 9999. The incentive to use this classification is due to its inclusion, since 2003, as a member of the Family of International Classifications of the World Health Organization (WHO-FIC), which comprises high quality classifications for sectors of the health system.

ISO 9999, as an international standard, establishes a classification and terminology of assistance products, specially produced or available, for people with disabilities, based on the terminologies of the International Classification of Functioning (ICF), one of the most important of the World Health Organization family (WHO). In the ICF, health-related domains are classified based on body functions and structures, domains of activity and participation, and environmental factors, since they are part of the context of an individual's functionality and disability. Therefore, in the ISO 9999 Classification, assistance products used by a person with a disability, but which require another person’s help for its operation, are included; and excluded those used for assistive products’ installation; solutions derived from combinations of assistive products individually classified in the international standard; medicines; assistance products used exclusively by healthcare professionals; non-technical solutions such as personal assistance, guide dogs or lip reading; implanted devices and financial support (ISO 9999, 2016).

The classification of the International Standard ISO 9999/20166 focuses on Assistive Technology resources, and it classifies them into three levels systematized by sequential numerical codes, organizing assistive products into 12 classes, each into subclasses, and these into sections (EASTIN ASSOCIATION, 2021).

In this Standard, terms and definitions are presented, in which the concept of assistive product is aligned with the terminology of the International Classification of Functioning, Disability and Health (ICF), being defined as:

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6 Items included in ISO 9999/2016 classes and subclasses are found attached as supplementary material.
[...] any product (including devices, equipment, instruments and software), specially produced or generally available, used by or for persons with disabilities to participate, protect, support, train, measure or substitute for bodily functions, structures and activities, or to prevent impairments, activity limitations or participation restrictions (ISO 9999, 2016, p.1).

Although its concept was still under discussion at the Global Cooperation on Assistive Health Technology (GATE), a more specific definition was adopted by the Technical Aid Committee (TAC) of the Special Secretariat for Human Rights of the Presidency of the Republic since 2007 in Brazil. This definition recognizes Assistive Technology as an interdisciplinary knowledge area, including other elements such as "services", for example, unlike the expressions "Technical Help" and "Support Technology", used by other international classifications, differentiating themselves because they are more generic expressions, and also cover different contexts of realities and concepts (CAT, 2007 apud GALVÃO FILHO, 2009, p. 20).

Therefore, after discussions and in-depth conceptual study, during the VII TAC Meeting, on December 14, 2007, the terminology "Assistive Technology" was made official in the country, as the most adequate and correct terms’ conceptualization, adopting the following definition:

Assistive Technology is an area of knowledge, with an interdisciplinary characteristic, which encompasses products, resources, methodologies, strategies, practices and services that objective to promote functionality, related to the activity and participation of people with disabilities, incapacities or reduced mobility, aiming at their autonomy, independence, quality of life and social inclusion (BRASIL, 2007, p. 3).

Considering the recommendation of possible referrals for nomenclature revision in legal instruments in Brazil, as well as the expression use of its terminology always in the singular because it is an area of knowledge (GALVÃO FILHO, 2009), its consolidation has been contributing to guide relevant actions for the area advancement and recognition, as well as the development of Assistive Technology policies in the country.

In addition, tangent to the subject of AT categories, it is relevant to consider and highlight the existence of "Web Accessibility" as a segment belonging to the area of Assistive Technology, as provided for in the World Wide Web Consortium (W3C), an international standard that develops standards for the Web, such as HTML, CSS, among others. Such standards are called the W3C Recommendations and are used for accessibility support and reviewed by the Accessible Platform Architectures (APA) Working Group (HENRY, 2022a).

Along with the popularization of the World Wide Web, from 1991 onwards, the mass use of the World Wide Web, better known as the Web, became a reality, establishing the mark
of a new era. In this context, the Web Accessibility arose eliminating accessibility barriers, through websites and virtual tools that are designed and coded properly for people with disabilities. Contemplating physical, visual, auditory, speech, cognitive and neurological disabilities, the accessible Web can provide, to the disabled user, an effective perception, understanding, navigation and interaction in the internet environment, in addition to allowing the contribution and creation of Network contents (HENRY, 2022b).

Web accessibility has brought many benefits, not only to the specific audience of People with Disabilities, the elderly or people with temporary restrictions, but also to organizations and to all people without any type of limitation that use it, providing equal opportunities in different areas, such as education, commerce, governments, business and recreation (HENRY, 2022b).

**Methodology**

Concerning methodological procedures, this is an exploratory research, with documentary research procedures, of an applied nature, and developed using a quantitative approach, analyzing existing assistive resources in the technology state of the art through a patent technological prospecting.

As a secondary source, the Questel Orbit Intelligence patent database was chosen because it is considered a broad and versatile tool for international patent search and it comprises a great number of resources according to Pires, Ribeiro and Quintella (2020). Many patent prospecting works, using this database, were carried out in several areas, such as in Sustainable Mobility concentration area described in the research by Tiago Sinigaglia et al. (2019), and in Biotechnology area, identified in the work of Eduardo Bastos et al. (2021) who investigated, through the Questel Orbit Intelligence platform, patents’ panorama of medicinal plants with pharmacological activities in Brazil. Even in the health area, many prospects can be observed, such as the study of production and innovation in vaccines against infectious diseases, at a global and national level, observing the reflexes on access to vaccination in Brazil and the sustainability of the Unified Health System, developed by Carlos Augusto Gadelha et al. (2020); as well as in the research related to the analysis of scientific and technological development on the Internet of Things (IoT) applied to health environment from an innovation perspective, in which both, scientific articles and patent documents from the aforementioned database were explored (ROSA; SOUZA; SILVA, 2021).
In order to identify the keywords, as well as the international classification codes of patents that were adhering to the research scope, a semantic search was initially carried out in this same database with the terms MOBILITY AID and ASSISTIVE TECHNOLOGY, which correspond to the following keywords in Portuguese: “auxílio de mobilidade” and “Tecnologia Assisitiva”. This was done as a strategy to define appropriate fields and prospecting terms, not being relevant the number of documents retrieved, but rather patent classification codes, and main terminologies used in patent documents. The analysis of the results obtained from this semantic search indicated that the keywords used in the preliminary search were adequate, as they referred to documents that cover this area of technological domain. The analysis also showed that the most cited International Patent Classification (IPC) subclass codes in the patents retrieved in this preliminary search were: A61G and A61H. Subclass A61G refers to transport, personal vehicle or specially adapted accommodation (devices to assist patients or people with physical disabilities to walk); surgical tables or chairs; dentist chairs; burial devices (embalming dead bodies); while subclass A61H refers to physical therapy devices (devices to locate or stimulate reflex points on the body); artificial respiration; massage; bath devices for special therapeutic or hygienic uses or specific parts of the body (electrotherapy, magnetotherapy, radiation therapy, ultrasound therapy) (INPI, 2021).

Based on this preliminary search and aiming to reach an adequate amount for analysis and treatment of data from patent documents, the following data search syntax was defined on the Questel Orbit Intelligence platform: ((MOBILITY 1D AID) OR (ASSISTIVE 1D TECHNOLOG+))/TI/AB/CLMS AND ((A61G)/IPC OR (A61H)/IPC). Therefore, the search strategy used keywords searched in the title, abstract and claims of patent documents; as well as International Patent Classification subclass codes. The search resulted in a recovery of 396 patent families related to Assistive Technology resources included in the mobility aid category. Therefore, this result represents the totality of the technologies analyzed and treated in this study. The searches were carried out on October 14, 2021.

Results and Discussion

Using the strategy described in the Methodology section, documents relating to 396 patent families were retrieved. It was observed, as shown in Graph 1, that most of the classification subclass codes of the 396 technologies surveyed are found in Section A of the IPC (84.2%). They are related to human needs, which is understandable, since the object of
the Research – mobility aid and Assistive Technology – concerns processes and products directly associated to human needs.

**Graph 1 - Codes of the most cited IPC subclasses**

Source: Elaborated by the author based on the Questel Orbit Intelligence platform (2021).

Most of these 396 patent families are concentrated in IPC A61H and A61G classifications, with 314 and 135 families respectively, as shown in Graph 1. The predominance of these subclasses may be related to the search syntax used in this prospecting. Subsequently, subclass A61F also stood out, which corresponds to filters implantable in blood vessels; prostheses; devices that clear or prevent collapse of tubular structures in the body (stents); orthopedic, nursing or contraceptive devices; fomentation; eye or ear treatment or protection; bandages, dressings or absorbent pads; first-aid kits. Next in the results comes subclass A45B, in which canes are allocated (walking accessories for blind people are grouped in A61H 3/06); umbrella; ladies' fans or similar (cane holders or umbrella holders can be found on the A47G 25/12); followed by subclass A61B, which refers to diagnosis, surgery and identification (INPI, 2021). Access to information about international patent classification codes can be accessed at the INPI website (2021), available in the references.

As for the legal status of these 396 patent families, on the study date in 2021, it was found that 41.2% patent families are active, which may mean that they are in force or under analysis, and 58.8% are dead, implying that they are in the public domain. From this data, it can be inferred that more than half of the target technologies of this study are in the public domain and many of them may be granted patents whose validity has already expired. This data raises the recommendation, in a future research, to verify which of these technologies have effectively reached the market and, whether it is worth to analyze the production feasibility of these technologies, once their patent has expired.
The technological domains in which these patent families were framed are represented in Graph 2.

![Graph 2 - Technological fields of greater concentration of technologies related to mobility](image)

**Source:** Elaborated by the author based on the Questel Orbit Intelligence platform (2021).

Most of these 396 patent families were concentrated in the Medical Technology field (396), with some approaches also associated with other domains, such as Transport (49), Furniture, Games (29), Other Consumer Goods (27) and Control Mechanisms (19). It indicates that the medical area, composed by areas of hospital, physical therapy, and other ramifications, can be the great demander of mobility resources. Furthermore, it shows that there may be a great market potential in this area, especially due to the process of motor rehabilitation, as it is presented in Jacob, Maia and Miter (2018), and Varela and Oliver (2013).

In addition to the data already discussed, patent prospecting also allow the observation of the global development scenario of assistive technology mobility resources, its main inventors, depositors, preferred countries for protection of their technologies, and analysis of some of these innovations. Therefore, more data were presented, analyzed and interpreted, as shown below.
Graph 3 shows the number of patent families according to priority year. Between 2001 and 2012, there was a gradual growth in the number of mobility resource patent families, reaching a maximum in 2016, with 45 families. After this period, there was a small decrease in the number of orders, but it does not necessarily represent a decline, since the number of deposits remained higher than in the initial years, which probably means that this is a technology in development. Although until October 2021 no patent family was found on the subject under study that year, there is a trend of growth or maintenance of interest in these technologies and this may be due to the fact that society is becoming increasingly inclusive. This movement occurs in several countries, which requires development and use of assistive technologies. Therefore, the interest in development and protection of this type of technology shall remain high.

Graph 4 presents the main depositors that appear in up to 4 patent families. It was observed that among these eight main depositors, four are companies; three are universities; and one is a research institute.
The New Zealand company Rex Bionics, creator of a robotic device for use in rehabilitation of people with mobility disabilities, including the most severe ones (REX BIONICS, 2017), stood out by participating in 7 patent families, in parallel with the company Bock Otto Mobility Solution, also with 7 families. Known in the market for over a hundred years, the company Ottobock, a global market leader in prosthetics, invested in 2019, 9% of sales revenue in research and development of innovative AT products, such as orthotics, prostheses, wheelchairs and exoskeletons, besides providing medical technology-related services in nearly 60 countries. (OTTOBOCK, 2022)

Nan Kai University of Technology, located in Caotun County, Nantou, Taiwan (WIKIPEDIA, 2021), as well as National Chin-Yi University, in Taiping District, Taichung, Taiwan (WIKIPEDIA, 2021), rank second place as one of the main depositors, each presenting 6 patent families. Subsequently, Shu Te University, a university located in Yanchao district, Kaohsiung, Taiwan (WIKIPEDIA, 2021), with 5 patent families granted, demonstrating that, among the 5 main applicants, 3 are Taiwanese universities. Finally, with 4 patent families granted are the Oriental Institute of Technology (Taiwan) and the companies Care & Care Health Products (Taiwan), Everlasting Healthcare (United States), Rebotec Rehabilitationsmittel (Germany) and Xiamen World Gear Sports Goods (China).

As it can be seen in Graph 4, the first place is occupied by two companies, representing the production sector of goods or services supply; however, the following three organizations are universities, which do not have the purpose of producing goods or services. Therefore, technologies generated by universities will only reach the market if there is a technology transfer process. The participation of academic sectors creating and developing technologies is important, but this importance only takes effect if, in addition to being created and
developed, the technologies are transferred to organizations that, in fact, can produce and make inventions available to society. Also noteworthy is the number of organizations based in Taiwan among the main applicants, which is in agreement with a study published on the subject by Lee et al. (2009).

In order to analyse the researchers who participated in the inventions of mobility resources of these 396 patent families, Graph 5 presents the innovative scientists who are the main inventors in these patent families, highlighting the 9 main creators of these innovative technologies.

Graph 5 – Top inventors of mobility-related assistive products and number of patent families in which they participated.
Source: Elaborated by the author based on the Questel Orbit Intelligence platform (2021).

It is observed that, among the data presented in Graph 5, Dmitrij Hildebrand appears as inventor in 9 patent families, which highlights him as the researcher with the highest number of patents related to assistive technology mobility resources among the patents studied. Dmitrij Hildebrand is Head of Technical Development at Bischoff & Bischoff, a German company that is one of the leading manufacturers in the Medical Technology field, which has been operating internationally since 1997 with production units and sales offices in Europe, aiming to improve the mobility of people with this need (LINKEDIN, c2021). Du Wenquan, from Taiwan, was shown as the second leading inventor, participating in 5 patent families, three of them from the company Everlasting Healthcare (USA), and two as an independent inventor.

The other 7 inventors participate in only 4 patent families each. They are: Jihong Cai (from Care & Care Health Products, Taiwan), Florian Doring (from Bock Otto Mobility...
Solutions, Germany), Yuqun Fang (inventor in four patent families with different applicants, all from Taiwan: Hui Zhou Andon Industries; Pingguo Chaoneng Electronic Medical Instrument Technology; Ping Guo Super Electronics Medical Instrument Technology; Andon International; Jan Mao Industries), Shun-Nan Huang (is inventor in three patent families of Sanction Industry, Taiwan, and in one patent family is an independent inventor), Richard Little (from Rex Bionics, New Zealand), Bruno Michael Carmen (from Xiamen World Gear Sports Goods, Taiwan), Jia-Bao Zhang (from National Chin Yi University of Technology, China).

The present study also analyzed the countries that received the most requests for assistive technology protection related to mobility aid category. Thus, with regard to territorial protection, Graph 6 shows the countries that received the most requests for mobility aid patents. That is, countries that stand out in requesting patent applications, in which 53 was the maximum number of applications per country.

In the monochromatic and gradual scale, it is observed that all countries included in blue color received, at least, 1 deposit, and, at most, China was in the lead with 53 requests. The United States was the second leading nation with 47 patent applications. Germany and
Great Britain stands in third and fourth place respectively, the former with 28 application, and the latter with 22. Although Brazil is not highlighted among the main countries, it received 3 requests for protection related to mobility aid resources.

Notably, the geographic scenario of this prospecting favors China, then, consecutively, the United States, Germany and Great Britain as the most attractive countries in sales and commercialization of these technologies, where the demand for patent protection is more concentrated. They represent a great potential market for assistive technology resources aimed at mobility.

The comparison among countries that receive the highest number of requests for protection of technologies through patents and countries that appear with the highest number of families with priority reveals that Taiwan stands out with 138 priorities in patent families, followed by China (71), United States (71), PCT (56) and Germany (40), according to data resulting from the search for patent families in the Orbit Intelligence database (QUESTEL, 2021). This data indicates that, although Taiwan does not stand out as one of the main markets for the technology, as it is not among the first countries that receive the highest number of requests for protection, it is the country that has the greatest domain of production of the technology. The protagonism of Taiwan in patents generation is related to the fact that some institutions in this country stand out as depositors, such as Nan Kai University of Technology, Shu Te University, the Oriental Institute of Technology (Taiwan) and the company Care & Care Health Products (Taiwan).

According to WIPO patent studies (2021), considering other classes of assistive products, the geographic profile of the largest actors in this area is changing, patent protection for Assistive Technology, in general, is being requested predominantly in five markets: China, USA, Europe, Japan and Republic of Korea. The increase in patent deposits in China and the Republic of Korea has caused a downfall of former US and Japanese dominance in recent years, meaning traditional European, Japanese and US actors are currently facing an increasing competition of Chinese and Korean actors.

However, this innovation geographic trend in Assistive Technology is not homogeneously characterized, it may vary according to its categorization according to WIPO (2021), and even adding that search for patent protection is greater in the area of Assistive Technology for mobility, whose market is being addressed in the present research. The WIPO (2021) confirms the leadership of China, followed by the United States in the second position, in the search for protection of this modality. Protection for other functional categories is
heavily concentrated in the five main target markets mentioned above (China, USA, Europe, Japan and Republic of Korea).

In order to verify the main terminologies related to the mobility aid of these 396 patent families, an investigation was carried out in conceptual data tools provided by this patent base, finding 100 main concepts identified through a Word Cloud. The main concepts were: Mobility aid, present in 136 patent families, Walking aid in 77; Walker in 69; Mobility in 60; Wheelchairs in 59, and Crutch in 43 patent families.

The Graph 7 shows the concepts presented in the Word Cloud brought together by functional similarity in another visual configuration.

Aiming at a more detailed approach, among the 100 concepts presented in Graph 7, the five most common terminologies used in daily life of people with disabilities or reduced mobility were selected and analyzed, considering the international classification ISO 9999 of Assistive Technology. Table 1 shows the result of this survey with the types of resources and their patent quantity.

<table>
<thead>
<tr>
<th>Item</th>
<th>Recurso</th>
<th>Quantidade de famílias de patentes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Walker</td>
<td>77</td>
</tr>
<tr>
<td>2.</td>
<td>Wheelchairs</td>
<td>59</td>
</tr>
<tr>
<td>3.</td>
<td>Crutches</td>
<td>43</td>
</tr>
<tr>
<td>4.</td>
<td>Walking sticks</td>
<td>14</td>
</tr>
<tr>
<td>5.</td>
<td>Scooters</td>
<td>13</td>
</tr>
</tbody>
</table>

Table 1 - Mobility Aids Selected from Orbit’s Word Cloud
Source: Elaborated by the author based on the Questel Orbit Intelligence platform (2021).
When investigating the patents relating to these five selected resources, some cases were highlighted for a more detailed analysis. Thus, observing among 77 families of patents dealing with walkers, the existence of resources that ranged from simple technologies to cutting-edge robotic equipment was noticed. “Mobility Aid”, a technology whose patent was requested by Rex Bionics, leader among main depositors, and its inventor, Richard Little (QUESTEL, 2021), also highlighted among the main ones, as shown in graphs 7 and 8 is an example. It is a product that helps people with paraplegia or limited mobility in an assisted motor rehabilitation process, providing the user with standing, sitting, walking and physical exercises through a control system. Besides performing functions considered impossible to be achieved by an individual with spinal cord injury, it keeps the user hands free, allowing the performance of other functional tasks.

This highly innovative technology comprises an exoskeleton that provides support for the body and motion manipulation by the disabled, as well as an energy source that powers both the exoskeleton and the associated control system. This technology is protected in China, and it is still under analysis in the United States, Canada, Hong Kong and European Union countries. Moreover, its domain is framed in Medical Technology.

Among 59 families of patents aimed at wheelchairs, the technology entitled “Adjustable Personal Mobility Aid” was observed. It is a type of wheelchair whose innovation seems to be in the system created in several adjustable levels, initially comprising first and second structural elements and a fastener to connect the elements to each other. It also involves the use of specific washers, aiming at user’s ergonomic adaptation. This is a type of product that aims to reach percentile variations of wheelchair user population in the most appropriate way. This patent was filed by the Invacare company, and its inventors were Robert Cerreto Matthew, Edward Roth and James Molnar (QUESTEL, 2021). As for the technological domain, this invention fell under Medical Technology and Transport, and is protected in the United States and Canada.

In the case of crutches, a mobility aid device for practical use that reunites the stability of a rigid structure of a walker to the characteristics of body support typical of crutches was observed, entitled "Crutch stroller". It increases physical resistance, as it relieves tensions and reduces independence limitations, in addition to providing a safer mobility. Built in aluminum material, it has a triangular shape in its top view, with a set of three wheels at its base, whose elevation provides unobstructed movements of the feet during mobilization. It has handbrake and selective steering controls. This type of technology is appropriate for people with physical limitations resulting from generalized weakness caused by pathologies, disabilities,
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deformities and post-surgical procedures. Its country of protection is the United States, and its inventor and depositor is Gee Sr Larry Ellis. (QUESTEL, 2021)

Another technological resource identified is the “Stairway descending assistance device”, a cane with a device that attaches to the handrail in order to help the user descend stairs. The portable product can be retracted when not in use and offers reliability and safety to the user. It is a simple and very utilitarian technology for people with reduced mobility, created and deposited by Chang Nathan Kazumi in the United States (QUESTEL, 2021). Its technological domain is framed in Medical Technology and Other Consumer Goods.

Among the scooters found in this prospecting, the technology entitled “Vehicle with 3 wheels as mobility aid and sports equipment” was observed. It is a device which has three wheels for displacement, and allows a person with reduced mobility, a light sportive physical activity, since it was also designed to perform a physical activity while sitting on a bench, with an electrical assistance option. As it has a multifunctional feature, the product offers the following possibilities to its user: driving while seated by means of pedal or motor traction, to walk while sitting only using running wheels, and to walk while standing. Its versatility also allows it to be used as a shopping cart, including the function of climbing stairs. The technological domain of this technology encompasses the fields of Medical Technology and Transport. Its inventor is Edgar Klitsch, who filed his patent in Spain (QUESTEL, 2021).

All these elements were brought from the prospecting result, which allowed an overview of the global scenario of Assistive Technology, specifically regarding the mobility aid category. This study should be continued through an investigation of the optimization of these technologies in the product market. That is, to verify effectiveness factors in technological transfer and logistics processes for access to final consumer, as well as to assess in which way they reach society. Furthermore, a future research should evaluate the potential, limitations or obstacles for a possible partnership works among leading companies in this field, as well as identify the assertive strategies and the motivation of actors involved.

Final Considerations

In order to discuss the main Assistive Technology products aimed at mobility, it was necessary to know the demands of its target audience through a preliminary survey of physical disability types and causes and, mainly, its consequent limitations, in order to know users’ reality and understand the context in which they are inserted.
It is concluded that people can reach a stage of life that for circumstantial reasons or the natural aging process may require the use of AT. In addition to this demand, there is also the standard profile of physical disability, generally understood as a change in the body or a disadvantage due to impairment or disability in the locomotor system to the point of hindering and even preventing mobility or motor performance of the disabled. Furthermore, such a limitation can prevent people from participating independently in activities of daily living (ADL), as well as in functional activities, often requiring technological aids in order to promote their social inclusion and improve their quality of life.

For this reason, investment in research, development and activities related to the production of Assistive Technology resources and services, in addition to being fundamental for this process, it represents an opportunity for policies elaboration that guarantee human rights practice and effectiveness. Therefore, it is important to consider and understand the relevance of technological prospecting for R&D activities, including processes that involve decision-making, strategic actions and competitiveness in the market for these technologies.

In this context, relevant aspects for innovation in Assistive Technology were observed and discussed through a patent study. It was identified that main trends in the world market of assistive products indicated a growing interest in the development and protection of Assistive Technology related to mobility from an evolution mapping of technological production, in which China and the United States remained in the lead as countries of greatest interest to companies or inventors seeking patent protection. The technological domains in which the studied patent families fell were the medical and hospital areas. In terms of applicant profile, academic institutions were among the main ones, which requires technology transfer processes in order to organizations and industry can develop and commercialize products that could reach society. It is hoped that future researches pursue elements that support actions and processes in innovation management, as well as seek for problem solutions in people's everyday life.

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