(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 4 458 341 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
06.11.2024 Bulletin 2024/45

(21) Application number: **24174194.1**

(22) Date of filing: **03.05.2024**

(51) International Patent Classification (IPC):
A61H 3/04 *(2006.01)*

(52) Cooperative Patent Classification (CPC):
A61H 3/04; A61H 3/02; A61H 2003/0205;
A61H 2003/043; A61H 2201/0173;
A61H 2201/1635; A61H 2201/5046;
A61H 2201/5061; A61H 2201/5084;
A61H 2201/5092; A61H 2201/5097; A61H 2230/00

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA
Designated Validation States:
GE KH MA MD TN

(30) Priority: **03.05.2023 PT 2023118631**
02.05.2024 PT 2024119444

(71) Applicants:
- **Universidade do Minho**
  4704-553 Braga (PT)
- **Orthos XXI Unipessoal Lda**
  4809-012 Guimarães (PT)

(72) Inventors:
- **PEIXOTO DOS SANTOS, CRISTINA MANUELA**
  4715-280 BRAGA (PT)
- **FERRETE RIBEIRO, NUNO MIGUEL**
  4770-702 TELHADO - V.N. DE FAMALICÃO (PT)
- **PEREIRA CERQUEIRA, RODOLFO BETTENCOURT**
  4715-267 BRAGA (PT)
- **FERNANDES PEREIRA, JOSÉ LUÍS**
  4715-012 BRAGA (PT)
- **LOPES DURÃES, RUBEN JOSÉ**
  4820-010 ARMIL (PT)
- **ARANTES COSTA, BEATRIZ**
  4706-630 BRAGA (PT)

(74) Representative: **Patentree**
Edificio Net
Rua de Salazares, 842
4149-002 Porto (PT)

(54) **GAIT SUPPORT DEVICE AND RESPECTIVE OPERATING METHOD**

(57) The present disclosure relates to a device with omnidirectional movement for supporting a user's gait and respective operating method, wherein the device comprises a controller; a shaft with a grip for support of the user; and a base which comprises: an upper plate and a lower plate for supporting electronic components including said controller, at least three wheels for supporting the base, and at least three electric actuators for acting on said wheels; wherein the controller is configured for controlling the actuators for acting on said wheels for correcting the user's gait; wherein the actuators are distributed between the upper plate and the lower plate; wherein the grip comprises a plurality of vibrotactile motors for giving feedback to the user; wherein the shaft is connected to the upper plate of the base by a connection element.

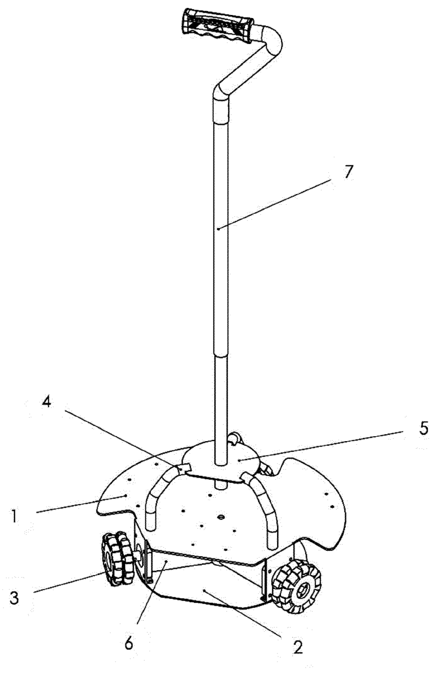

Fig. 3

EP 4 458 341 A1

Description

TECHNICAL FIELD

[0001] The present invention belongs to the field of medical devices, namely devices intended for users with reduced mobility who require a support backing for walking and respective operating method. Concretely, the present invention is related to a gait support device, robotic cane type, also intended for preventing falls in real time.

BACKGROUND

[0002] Among the most difficult health problems with which the elderly struggle are the falls and unstable balance control. They are a significant cause of immobility and early entry into homes for the elderly, as well as an increase factor in death and morbidity rates. Currently the World Health Organization (WHO) refers to a fall as "an occurrence which results in the fact that a person inadvertently lands on the ground, the pavement or other lower level". Before a fall, there occurs an event which is more frequent and potentially predicts the risk of a fall: the near-fall. A near-fall is considered "a loss of balance which would result in a fall in case enough recovery mechanisms were not activated". The problem with falls in the elderly population is a combination of a high incidence with a high susceptibility to injuries due to a high frequency of clinical disorders (for example, osteoporosis, neurological diseases) and age-related physiological alterations (for example, slower protection reflexes) which cause even a relatively small fall to be particularly dangerous.

[0003] About 28-42% of the elderly (>65 years) fall at least once a year. According to the WHO, the falls are the second main cause of death by unintentional injuries, following the injuries caused by road traffic, representing an average of 684 000 fatal falls and an estimated number of 37,3 million non-fatal falls, requiring medical care, every year. In the United States, almost three quarters of all deaths related to falls occur in the 13% of the population that is over 65 years old, which largely indicates, a geriatric syndrome.

[0004] The General Health Directorate indicates that the physiological falls predicted (78% of the causes), just by fall risk assessment, can be avoided by means of fall risk assessment with validated schedule, planning and specific interventions.

[0005] Approximately 40% of this age group, who live at home, will fall at least once a year and about 1 in every 40 will be hospitalized. Only about half the individuals hospitalized following a fall will be alive a year later. The instability and the recurring non-fatal falls are frequent warning signs for admission in homes for the elderly. According to the European Mortality Database, in 2019 Germany recorded 16.657 deaths, being the member of the European Union with the highest number of deaths by accidental falls. In the same database, the last results for Portugal correspond to 2018, when there were recorded 815 deaths. The non-fatal falls resulting in motor injuries lessen the Quality of Life (Acronym in English Quality of Life - QoL). People who fall develop a fear of falling with consequent depression and autonomy restriction of social and physical activity. This further contributes to the deconditioning, weakness and abnormal gait, and, in the long term, can effectively increase the risk of falls. Additionally, the recovery from injuries caused by falls is frequently delayed in the elderly.

[0006] The expenses associated with the injuries caused by falls are significant from the financial point of view. It is predicted that the social and health costs reach 4% of the European expenses with health care, expected to duplicate in 2050 to 50 billion Euros in the European Union. In the United States of America alone, in 2000 there were spent 19 billion dollars with direct medical costs for injuries related to falls. In 2015, this value increased to over 31 billion dollars in Medicare only, and there are foreseen costs of 43,8 billion dollars in 2020. Several studies have also shown the average cost of the health system by injury caused by a fall. In the Republic of Finland and in Australia, these costs are of 3611 dollars and 1049 respectively. In Portugal, the value can rise to about 3000 Euros if the injury is severe. The pressure over the national health system has intensified with the increase in population aging which, unfortunately, tends to worsen. According to the United Nations, in 2085 the elderly population will be triple the current one.

[0007] The socio-economic impact of the injuries enhances the crucial importance of implementing strategies which mitigate or eliminate the risk of fall. According to data from Canada, a reduction of 20% in the incidence of falls can result in net savings of more than 120 million dollars per year. To alleviate this social and economic burden, the existing systems are mainly centered on fall detection, with little emphasis on fall forecast. Detecting the impact is the basis of the fall detection systems, which notify the user and the health caregiver of the occurrence of a fall to expedite and improve the medical services rendered. Since these systems cannot avoid the falls, the scientific literature also explores the fall prediction systems, which are conceived to warn users before a fall, avoiding the emotional and physical effects of a fall. They must be able to recognize all the situations and potential conditions for a fall and offer a scheme to avoid them. The fall prediction systems or the Falls Risk Assessment Tool (FRA) can also be divided into two different categories: i) prediction of future falls - which can estimate the risk of fall by means of some clinical evaluation tests. These examples frequently use questionnaires or functional evaluations of posture, gait, cognition and other risk variables. These clinical evaluations are subjective and qualitative, there being habitually used threshold assessment scores to categorize between who falls and who does not fall. To evaluate the balance and strength of the lower members, these tests are typically the Timed Up and Go Test (TUG), the Berg Balance Scale (BBS), the sit to stand and the one leg stand; and ii) real-time fall prediction system - recognizes abnormal gait patterns to calculate the probability of occurrence of a fall in real time, continuously evaluating the risk of fall using data from sensors while the user is carrying out his Activities of Daily Living (ADL) (for example, walking, climbing stairs, sitting down, getting up, catching objects). Upon detecting anomalous situations, the user can be notified in good time, or an external aid can be used, such as a walker or a robot, as a fall prevention technique. The robotic walking aid devices provide safety and stability, rendering assistance in many phases of ADLs, according to the mobility level of the user, which results in better QoL and autonomy for the elderly.

[0008] The falls occur occasionally and assume many different forms. On average, those residing in homes for the elderly suffer 2.6 falls per person and per year. The low frequency thereof, combined with the difficulty in instrumenting a subject and the unexpected character thereof, lead to lack of data which can be used in several algorithms for detection and fall forecast systems. On the other hand, there are several types of falls which can occur, as well as a number of reasons which lead to a fall. Thus, forecasting falls is a challenge.

[0009] Thus, the implementation and use of walking aid devices is assumed as an essential tool for providing safety and stability. This area has been highly explored, bearing in mind that these devices try to help in different phases of the ADLs of the patients (for example, getting up, sitting down, providing balance while standing or moving, going up and down stairs), providing a higher QoL and autonomy to the elderly.

[0010] With the technological evolution, there has been a progression to robotic assistance means, so as to provide more safety, improve interaction with the user, allow controlled handling, and even enable incorporating systems which provide fall detection and prevention mechanisms. Among the robotic mobility assistance means there are highlighted the robotic wheelchair, the robotic mobile walker, the robotic exoskeleton and the cane-type robot. The use of support devices is associated to the user's limitations, which means that each walking aid device is designed for the corresponding health levels and mobility conditions of each person.

[0011] Among these devices, there is highlighted the cane-type robot, which is a device that is not commercialized yet, able to detect and prevent falls. The cane-type robots, in comparison with other means of assistance, are highlighted due to: 1- the low cost thereof, which makes them the most accessible product in the market; 2- low weight, facilitating the use and working thereof; 3- reduced dimensions, which allows the use thereof in external and uncontrolled environments. With the purpose of aiding with walking, the cane-type robot offers less body weight support, when compared with the walker, not placing as much support on the upper members. Thus, it promotes greater corporal activity and more extensive and complete muscle use of the lower member. By having this moderate support, the user will have a better recovery, more independence and more practical use while walking.

[0012] Although all the cane-type robots in question share the same purpose of assisting with gait, they present very different solutions and mechanical characteristics from each other. Each cane-type robot presents different weight and dimensions and several types of components. They can also present several handling modes, which allows the device to be controlled by one hand, two hands or even with no contact. In addition, there exist different configurations and models of cane-type robots, which can vary between 1 to 5 degrees of freedom, as well as contain a mobile structure composed of 1 to 4 wheels.

[0013] Among these types of structures for cane-type robots there exist certain solutions, as is the case of patent document CN 110575371 A and US20130041507A1, which have only 1 or 2 points of contact with the ground. Thus, there exists the possibility of these types of devices, due to the inherent characteristics of the designs thereof: 1- providing few degrees of freedom to the system, limiting the user's movement; 2- not being able to stand alone without the assistance of in-wheel motors, which enhances the lack of stability in case of engine failure; 3- not being sufficiently robust to provide the necessary support to support the body weight of the user transferred to the device in case of a fall.

[0014] Another important point in conceiving a cane-type robot arises from the decision to use or not external devices by the user, namely wearable sensors. These external sensors try to collect some behavior data of the user which can be necessary to detect and prevent the occurrence of a fall. In this sense, patent document CN112137847 comprises an accelerometer for detecting falls, sending a signal to the emergency contact of the user, when the latter falls. However, a camera films the fall process and while this happens the airbag which the user has coupled to his waist is activated, avoiding more serious consequences which can result from the fall. Additionally, there also exist devices wherein the wearable sensors appear in watches, as in the case of patent document KR 20160144193 A, and in shoes, as in patent document CN104382307A, having the same purpose of acquiring postural information of the user for fall prevention and detection.

[0015] The inconvenience of devices such as these which use wearable sensors is that there exists something additional which the user has to use for working to occur in the desired manner. This extra accessory can lead to a lower adoption and greater resistance to using the device, thus resulting in abandonment of same.

[0016] As regards the fall detection methods, some are based on wearable sensors, as previously mentioned, and others depend on sensors embedded in the device which can be complemented with wearable sensors, with the same purpose of acquiring data which allows assessing the walking status of the user and consequently distinguishing between a normal walking state and an abnormal walking state on the part of the user and thus detect a possible fall.

[0017] After detecting the fall, there immediately enters the fall prevention which activates actuation mechanisms so as to enable the user to recover balance, granting a type of support which in its turn would not be possible by means of traditional mobility assistance devices. Patent document JP 2015217155 A, CN 107015564 A and CN107693314A, are devices which have similar fall detection and prevention systems. The devices include a Laser Range Finder (LRF) for detecting the position of the legs of the user, which jointly with a 6-axis force-torque sensor, enables activating a pre-fall state in case the mass center of the user is outside the area of the support polygon, indicating that the user is about to fall. The fall prevention mechanism acts so the robotic device moves in the same direction as the fall, placing itself in front of the user so as to provide greater support and thus support a higher body weight percentage of the user. Although the components incorporated within these devices that are responsible for the fall detection method, namely the LRF and the 6-axis force-torque sensor, allow offering important information about the gait, the posture and the stability of the user, they present elevated costs (higher than 1000€) which can be a barrier in the production of a cane-type robot which is accessible to most users.

[0018] These facts are described to illustrate the technical problem solved by the embodiments of the present document.

GENERAL DESCRIPTION

[0019] The present disclosure is related to a walking aid device, also known as robotic pyramid, capable for applying movement control and real-time fall detection algorithms. The purpose of this apparatus is assisting elderly users in walking, allowing a quantitative and continuous assessment of the gait and the risk of fall of the user and promoting greater support in abnormal gait conditions through the movement thereof in space to a position believed to be more advantageous for the recovery of balance of the subject. The result expected from this support is the real time fall prevention after detection of abnormalities in the gait, thus promoting greater independence and better quality of life to the target population. These contributions are possible by means of monitoring the spatiotemporal parameters of the device and the user. In addition to the strategy for fall prevention, the system will be able to provide clues/sensory data by means of a real time biofeedback system, directly connected to the sensor unit, with the purpose of using these stimuli to increase the awareness of the users relative to their motor function. In orderfor the fall prevention to work as expected, the system must be able to adjust to the specific gait patterns of the user, detecting abnormalities.

[0020] At this time, the systems proposed in literature require the use of wearable sensors by the subject, so as to gather vital information for the correct working of the methods currently suggested. However, it is important to emphasize that it is desired that the device be comfortable, discrete and easy to use, something which is compromised by the use of wearable sensors. Bearing this in mind, there exists as objective for this solution the exclusion of wearable sensors, so as to ensure greater adoption on the part of the target population.

[0021] Additionally, the device comprises a navigating strategy so as to allow detection of possible obstacles to the movement thereof and, consequently, that of the user, signaling and stopping the movement to avoid a collision. In this way, and allied to the fall prevention system, as the device autonomously detects relevant events and activates a corresponding response, there is not such a high cognitive load for the user, that is, an extremely attentive attitude is not required when walking. In short, this device can be easily included in the user's daily life, not constituting a cognitive burden or requiring the use of additional equipment for the correct working thereof, ensuring greater support to the user in fall situations which could result in negative consequences.

[0022] Currently, the market lacks a robotic solution for daily assessment, fall risk forecast and fall prevention, in home and/or institutional context. At the same time, the current fall assistance solutions require the use of wearable devices to complement the prevention action and usually lack artificial intelligence.

[0023] The device, or robotic pyramid, is distinguished by the continuous monitoring ability and mobility assessment (number of steps, speed, distance covered) in a customized manner (to the user and motor activity). This continuous customized assessment contributes to a more effective and timely clinical and/or ergonomic diagnosis, in detriment of the subjective assessment currently employed, and for predicting a more realist fall risk indicator in face of the daily activity of the users.

[0024] Additionally, the device or robotic pyramid is distinguished by assisting the user, by means of tactile vibration, only when necessary, in detriment of continuously warning the user whenever the fixed balance thresholds are exceeded. In this way, it reduces cognitive effort, favoring the extended daily use thereof and ensuring the preventive potential thereof over the current solutions. Real time assistance also innovates by means of the quick repositioning of the cane (the cane shaft with the grip) which, when strategically activated, guide the user in the best configuration for correcting the balance. The combination of these assessment and assistance functionalities in a robot is distinctive on its own. Additionally, the device or robotic pyramid innovates by introducing a digital counselor which: a) provides a daily report on motor performance and postural evolution, for subsequent analysis by clinicians or caregivers; b) suggests motor learning exercises adapted to the evaluation and evolution of every individual.

[0025] Thus, they allow new daily assistance activities for the users, constituting competitive advantages of the device or robotic pyramid.

[0026] In an embodiment, the manufacturer will follow a sustainable perspective, complying with the European ecology norms (Ecolabel). The eco-friendly cane will have a modern and lasting design, with good quality materials, guaranteeing comfort and safety to the user.

[0027] The device is adjustable, adapting to the needs of different users.

[0028] The use of the device or robotic pyramid will have a social impact for the different users. The device or robotic pyramid will provide older adults with a 50% reduction in fall episodes, fall prevention and increase of physical activity in 20%, with consequent cardiovascular benefits and physical and mental well-being. These aspects can equally impact the elderly population, promoting active and healthy aging. The indirect results of a more active elderly population include reduction of dependence on third parties and social isolation.

[0029] Daily assistance will increase the physical ability of the users (individuals with high risk of falling and/or fear of falling) in 20%, reducing the social isolation and stimulating proactivity. Indirectly, the device or robotic pyramid will promote reduction of absenteeism and early retirement and increase physical activity by 10%.

[0030] Some of the advantages of the device are:

free of the need for using wearable sensors by the user;
with three points of contact with the ground for greater mobility and stability of the system;
intuitive and easy to use;
able to bridge the users' needs;
accessible cost;
able to detect and prevent falls.

[0031] Briefly, the present invention allows:

Following a non-pharmacological approach, which has shown to be in the forefront in helping with treatment of motor symptoms in question;
Does not require cognitive effort on the part of the users, which can compromise their multitasking, nor their freedom of movement. Designed to be light and ergonomic, the robotic pyramid aims at being used daily for long periods;
Being adaptable to each person's gait: inclusion of a gait monitoring system and respective processing units for analysis of the adaptable gait;
Being universal and adjustable to the different users: achieved by means of the handle height adjustment; universal supply of vibrotactile stimulation at one of the sensitive anatomic areas, the hands;
Having a development centered on the user by means of continuous validation with the final user and validated by clinicians;
Being a reliable system; continuous validation;
Being compact: inclusion of the electronic components both for monitoring and analysis of the gait, as for tactile stimulation in the same device, which does not become unpleasant for the users;
Allowing segmentation and analysis of the gait carried out by means of a laser and force sensors;
Allowing a complete analysis over the movement and contextual activity of the user, enabling an actuation strategy more adapted to them;
Being a system based on the concept of intelligent aid: upon using gait information of the user, the device is able to discern the desired direction for rendering the necessary balance support. This intelligent approach allows the device to automatically adjust and provide customized, efficient and adaptive assistance, accompanying the user's movement in a precise manner;
Including the implementation of graphic applications interconnected to the database and systems for keeping data gathered by the device, allowing the clinicians and investigators to monitor, accompany and study the use of the robotic pyramid by the users;
Including the implementation of graphic interfaces which allow the investigators, clinicians and users to access the device via wireless.

[0032] With these characteristics it is intended to help patients in hospitals, physiotherapy clinics, and even domestic users to overcome the adversities associated with the mobility limitations on the part of the lower members.

[0033] A first functionality refers to the quantitative and continuous assessment of the gait, in home and/or institutional context, so as to allow an effective forecast of the risk of fall by means of sensors and artificial intelligence algorithms. The monitoring of the spatiotemporal parameters of the device and of the user, as well as the characteristics that are common in scientific literature for studying the falls, will be essential.

[0034] Another functionality is the ability of the device to prevent falls in real time and detect falls of the user, thus contributing to an objective and reliable evaluation of the physical activity and quality of life of the user. The device supplies real time assistance to prevent falls, moving in space so as to provide a more effective support and maintain the protection of the mass center within the support base established by the user's legs and the device.

[0035] Another functionality of the device or robotic pyramid consists of providing real time vibratory sensory, visual and auditive clues, according to the information obtained with the sensory unit installed in the device. These clues increase user awareness relative to their motor function (*biofeedback*), thus contributing to a more customized assistance.

[0036] The device or robotic pyramid responds to the need for daily assistance solutions which can reduce the prevalence of falls by 10%. The device or robotic pyramid acts as a key element in early detection and daily prevention of falls. It allows obtaining a more precise fall risk forecast (precision>85%) than the current traditional forecast scales.

[0037] In an embodiment, making the motor activity report available, by means of mobile application, will make the individual self-aware of their motor condition, motivating the alteration of motor behaviors. Additionally, these reports can act as support for a diagnosis and more effective and immediate follow up (precision>85%, updated every 5 minutes) and, consequently, allow the interested parties (caregivers and clinicians) to timely outline prevention solutions.

[0038] In a preventive perspective, the use of vibrating mechanisms for warning the person as to the postural correction will lessen by 50% the time in risk conditions. Daily awareness will allow the user to develop a muscle memory and alter, in an autonomous and healthy way, the manner in which he carries out his daily activities. As a complement to the prevention of falls, the digital caregiver will suggest training and/or muscle reinforcement exercises directed to each user, promoting a 20% increase in physical activity.

[0039] Preferably, the users of the device can be older adults with mobility level 3 on the *Holden* scale (functional ambulation classification), that is, people who need support during mobility. However, any user can use said device.

[0040] The present disclosure is related to a device with omnidirectional movement to support a user's gait, comprising:

a controller;
a shaft with a grip for support by the user; and
a base which comprises:

an upper plate and a lower plate for supporting electronic components including said controller,
at least three wheels to support the base, and
at least three electric actuators for acting on said wheels;
wherein the controller is configured for controlling the actuators for acting on said wheels for correction of the user's gait;
wherein the actuators are distributed between the upper plate and the lower plate;
wherein the grip comprises a plurality of vibrotactile motors for providing feedback to the user;
wherein the shaft is connected to the upper plate of the base by a connection element.

[0041] In an embodiment, the connection element comprises a plate and at least three fixing elements.

[0042] In an embodiment, the device comprises a plurality of movement sensors arranged on the base for detecting movement of the device, preferably of the omnidirectional wheels. Preferably, the force sensors will detect the user's intention, as the laser can also detect. Based on the force sensors and the laser, it is possible to monitor the user's gait. That is, the device with the IMU has a reference of their movement in space, being able to monitor the user's gait.

[0043] In an embodiment, the movement sensors comprise an inertial measurement unit positioned on the base.

[0044] In an embodiment, the connection element comprises a plate and at least three fixing elements.

[0045] In an embodiment, the device comprises a plurality of force sensors arranged on the grip to detect forces exerted on the grip. Optionally, the grip can comprise physiological monitoring sensors such as, for example for detecting heartbeat, temperature and galvanic skin response.

[0046] In an embodiment the device comprises one or more, in particular three or more, force sensors arranged on the grip to detect forces exerted on the grip.

[0047] In an embodiment, the force sensor or sensors are arranged on the shaft for detecting directional forces exerted on the shaft by the user in a direction perpendicular to the shaft, for detecting the direction in which the user intends to move.

[0048] In an embodiment, the device comprises one or more, in particular four or more, force sensors arranged on the shaft to detect forces exerted on the shaft.

[0049] In an embodiment, the force sensor or sensors are a plurality of force sensitive resistors.

[0050] In an embodiment, the force sensors (FSRs) on the shaft are 4 and detect in 2 axes x, y (or anteroposterior and mediolateral) which measure lateral forces on the 2 axes. In an embodiment, the third force axis is measured on the grip by 3 FSR force sensors and measure the force only vertically and from top to bottom.

[0051] In an embodiment, the device comprises a laser distance measurer arranged on a surface of the upper plate, for measuring the distance between the device between the user's legs and an obstacle or obstacles. One of the advantages of the device comprising the laser distance measurer is that it is also able to detect the distance between the legs, between the legs and the device and also between the legs and one or more obstacles. The device can also measure the distance to the obstacles within a radius less than 360 degrees.

[0052] In an embodiment, the device comprises a light source, preferably a photodiode.

[0053] In an embodiment, the device comprises at least one photoresistor for brightness detection and activation of the photodiode when the value of the signal obtained is less than a pre-defined value.

[0054] In an embodiment, the photoresistor is arranged on the shaft. Preferably, it is arranged on a lower part of the shaft, more distant from the grip and closer to the base.

[0055] In an embodiment, each of the wheels is an omnidirectional wheel.

[0056] In an embodiment, the actuators are electric actuators, preferably motors.

[0057] The present disclosure is further related to an operating method for a device with omnidirectional movement for support to a user's gait, wherein the device comprises:

- a controller;
- a shaft with a grip for support of the user, wherein the shaft is connected to the upper plate of the base by a connection element and wherein the grip comprises a plurality of vibrotactile motors for providing feedback to the user;
- a base which comprises:
  - an upper plate and a lower plate for supporting electronic components,
  - at least three wheels to support the base, and
  - at least three electric actuators for acting on said wheels;

wherein the method comprises the controller executing the following steps:

- acquiring, from each sensor of the plurality of sensors, a signal received from the grip and the shaft;
- determining from the acquired signals the user's movement;
- controlling the actuators for acting on the wheels for correcting the user's gait.

[0058] In an embodiment, the controller is configured for detecting a vertical force, in particular a force exerted by the user on the grip in a direction parallel to the shaft, by means of one or more, particularly three or more, force sensors arranged on the grip for detecting forces exerted on the grip.

[0059] In an embodiment, the controller is configured for detecting directional forces exerted on the shaft by the user in a direction perpendicular to the shaft, by means of one or more, in particular four or more, force sensors, for detecting the forces exerted on the shaft.

[0060] In an embodiment, the device comprises 5 units responsible for ensuring the necessary functions for the correct working of the system and due processing of data. These units are the following: sensory unit, control unit, memory unit, actuation unit and power unit.

[0061] In an embodiment, so as to apply the algorithms and strategies outlined for the system, it is first necessary to gather the data to be used. Obtaining these data is guaranteed by the sensory unit of the device. The implemented sensors focus on detecting the movement of the device and the surrounding environment, so as to allow the best possible knowledge about the factors external to the device for correctly controlling the same.

[0062] In an embodiment, for detecting the orientation, tilt and acceleration of the apparatus, which can next be extrapolated to obtain the speed thereof, the sensory unit presents an inertial component, constituted by an Inertial Measurement Unit (IMU). Contrary to the other analysis systems, the IMU allows obtaining a complete analysis of the desired structure without requiring a long post-processing of the data, allowing an effective analysis and in real time. In the case in question, the IMU used, combining the degrees of freedom of the accelerometer, gyroscope and magnetometer, allows a detection capacity of 9 degrees of freedom. This last sensor is calibrated already considering the material which constitutes the gait support device for their measurements not to be affected. The information obtained by this component serves as support for a more objective clinical diagnosis based on evidence, allowing to provide clinicians with a quantitative evaluation of the motor symptoms and continuously monitor the evolution of the assistance process. The determination of the orientation and speed of the system are essential for allowing determining situations wherein the robotic pyramid is not in the expected position, such as in cases wherein it has fallen.

[0063] Additionally, the sensor unit presents the implementation of a force unit, by means of the use of Force Sensitive Resistors (FSRs), able to perform measurements of force applied on the device. This force unit presents two systems: an axial detection system and one of vertical detection. In the case of the axial one, this presents, in an embodiment, 4 FSRs arranged in an equidistant manner around the shaft of the device, which allow gauging in which direction the user wishes to move, so that the low level control unit can thus exert control over the device for the latter to move according to the detected movement intention. The vertical detection system presents, in an embodiment, 3 FSRs placed on the grip or handle of the device, allowing estimating the force which the user applies over the device. These values allow estimating when the user supports himself on the structure and determining the normal gait pattern thereof and, consequently, estimate in which situations the latter is affected. Fall risk situations are most likely when the user does not exert or exerts little force on the device and, therefore, this system becomes essential in the fall detection strategy to be implemented. The preferred choice for implementing FSRs for this function is due to there being components with high sensitivity, thus allowing efficiently measuring the minimal deformation values which it is expected to obtain from using the pyramid, being at the same time robust, flexible and with low cost.

[0064] The present description further presents the ability of the user to move correctly in an environment full of possible obstacles to the movement of the user and the device, whereby there must also be included the cases wherein, although the obstacle does not affect the user, it can cause embarrassment in the path of the device. For this, it is necessary for the sensory unit to present a component that is able to analyze distances around the system, being responsible for detecting the object and tracking the distance between the obstacle and the device or robotic pyramid. With this purpose, the use of the LRFs is outlined. This type of sensor is characterized by the emission of laser beams which, when colliding with a possible obstacle, will return to the LRF. The device will use the time lapsed between the emission and reception of the reflected beam to determine the distance at which the obstacle is found. The use of LRFs is due to the efficiency and detection speed thereof, to the ease of use and to not presenting the questions of invasion of privacy associated with other sensors.

[0065] An environment limitation which can lead to an increase in the likelihood of falls and mobility problems is the lack of visibility present in environments with low light, since this reduces the reaction ability of the user to possible obstacles or other conditions. Thus, in an embodiment, the device further presents the implementation of a photoresistor able to analyze the brightness of the environment surrounding the device and, in accordance with the measured values, activate the corresponding component of the actuation system for lighting up the space around the user. This allows reducing the risk of fall in these situations, being a less complex manner of acting to prevent falls.

[0066] The control unit of the device or robotic pyramid is responsible for a great part of the working of the device, receiving information from the sensory unit, processing this information according to the algorithms and strategies defined and sending commands to the actuation unit to enable carrying out the necessary actions. Due to the various abilities included in the device, the control unit is divided into two components: a low level component and a high level one. The low level is responsible for the basic processing of the information received by the sensors for carrying out more elemental functions of the device, such as, for example, the detection of the user's intention of moving or the biofeedback vibrotactile system. Additionally, the functions thereof also include passing information from the sensory unit to the high level component of the control unit, so that these can be used for other algorithms. Additionally, it is in direct communication with the actuation unit, so as to transmit commands resulting from the low level processing or which are received by the high level component. In an embodiment, the low level unit comprises a microcontroller able to carry out said processing at a satisfactory speed for applying the implemented strategies in real time, but which also presents high versatility and efficiency of communication, so as to allow connecting to the various components of the actuation unit, sensory unit and to the high level processing unit. In an embodiment, the high level unit will use information from the sensors for implementing the algorithms with greater complexity than those previously mentioned, being responsible for detecting and preventing falls and for the navigation based on detecting obstacles.

[0067] In an embodiment, due to the greater computer power necessary for carrying out these tasks, this processing component is ensured by the use of a compact and discrete microcomputer implemented in the device or robotic pyramid. Since it is a more complex system than a microcontroller, the microcomputer further presents other functions which could not be carried out by the low level unit, including storage of information relative to the data collected by the sensors and which can subsequently be analyzed to study the behavior of the device and the user. Due to this ability of the high level unit which, together with the cloud used for storage of data, the microcomputer works as the memory unit of the system. In the same manner, another function comprised by the high level unit is the communication and synchronization with other technological systems not built into the device, being the manner of connection established based on protocols without networks, wireless, such as Wi-Fi or Bluetooth.

[0068] In an embodiment, the actuation unit comprises components able to interact with the user and with the surrounding space, due to their action based on the commands sent by the processing unit. Additionally, the action thereof depends directly on the components of the sensory unit, whereby the behavior thereof is a response to the stimuli detected by the device.

[0069] In an embodiment, taking as reference the use of the photoresistor for detecting the brightness of the system, this sends information to the low level processing system. In case it is determined that the value read is below a predefined reference value, there is activated a light source, for example, a photodiode or Light-Emitting Diode (LED) which allows brightening the surrounding environment to ensure the safety of the user. This device is installed next to the photoresistor, so that the measurement of brightness considers the effect of the LED.

[0070] As previously mentioned, the walking aid and fall prevention device implements the use of a biofeedback system for signaling the user in situations of possible danger. Due to the fact that this method implements the use of vibrotactile motors, these should preferably be located in a position of contact with the user, being implemented on the grip or handle of the device.

[0071] In an embodiment, the device comprises a type of tactile mechanism as it is more discrete than other types such as auditive or visual, allied to the fact that it is intuitive and easy to distinguish the different stimuli created. These actuators work together with the sensors used for gait detection, so as to activate the signaling in situations where the gait is affected and can lead to danger for the user.

[0072] Finally, the last actuators to consider are the 3 DC motors installed in the device which, jointly with the omnidirectional wheels installed grant freedom of movement to the apparatus so that this can move according to the user's needs. These actuators are located on the base of the device, and depend on commands received by the axial force sensory units, which are responsible for studying the user's intention of moving and which will subsequently allow the low level processing unit to send information to the motors for displacing the structure according to this intention, and the obstacle detection unit, whereby the LRF information is used by the high level processing for determining possible obstacles to mobility and which will allow using the motors to avoid collision.

[0073] Lastly, it is necessary to refer to the power unit of the system, responsible for providing power to the device (or robotic pyramid) and to the remaining units of which it is composed. In an embodiment, this role is performed by a battery, able to power the system. Considering that most of the components are not able to operate with this level of power the structure presents voltage regulators, which maintain the voltage which is passed to the components at the suitable voltage level which they need, so as to avoid damage to same. In an embodiment, the system further presents an emergency button which turns off the connection between the power and the rest of the system, so as to make available a safety option for when the robotic pyramid is not in use.

[0074] After the force sensors allow detecting the forces which are being applied to the structure, it is necessary to process the data received to determine in which direction the user wishes to move and next use this information to exert control over the motors. As referred, this processing is carried out by the low level processing unit, being based on the admission control model.

[0075] In an embodiment, the control model implemented takes into consideration the gait of the user and the forces which the latter applies on the device, which means that the full force system is used to determine what behavior to adopt. After the signals received are processed, there is performed the control of the motors by means of the application of forward kinematics. Initially, it is considered that the user is standing by the device, with his feet aligned with same. When the apparatus detects the walking intention of the user, it will move in this direction to the next phases. Considering that one of the user's legs is injured, there exist two phases: the support phase of the healthy leg, wherein the injured leg moves and that of support to the injured leg, when the healthy leg moves. In both situations, it is necessary that the device remains stationary, so as to support mobility in the best manner. Although the behavior of the device in both phases is similar, the phase of support of the injured leg is the most important one, since in this phase the injured leg will serve as a support point. Being more fragile, this is the phase wherein the support of the device is more necessary, so as to provide the necessary stability. For this reason, the vertical detection system is essential for determining when the user is supporting their weight on the structure.

[0076] After determining the current gait pattern of the user and knowing the direction in which the user wishes to move, it is necessary to transfer these interaction forces for moving the device (or robotic pyramid) by applying forward kinematics, which will be based on the use of kinematics equations to determine the rotation speed to be applied on each motor to provoke the motion of the device in the desired direction. To allow the correct application of this type of algorithms the mass center of the system was considered as the reference center to apply, which in turn makes it possible to estimate the rotation speed that each motor must take to cause the desired movement for the system. Defining the reference as being that which is represented in **Figure 4,** whereby the positive direction of the ordinate axis (axis y) will correspond to the front direction of the movement, and the positive direction of the abscissa axis (axis x) will be the direction corresponding to the device moving to the right. Considering that α, β and γ are the angles which each motor makes relative to the abscissa axis of the reference, then the angles for the movement direction of each wheel, represented by Θ_1, Θ_2 and Θ_3, can be calculated in the following manner:

$$\begin{cases} \Theta_1 = \alpha + 90º \\ \Theta_2 = \beta + 90º \\ \Theta_3 = \gamma + 90º \end{cases}$$

[0077] Having this in mind, the force of the movement in the axis of x (F_x), axis of the y (F_y) and in the vertical direction (F_w), can be given by the following expressions:

$$\begin{cases} F_x = \cos(\Theta_1) * motor_1 + \cos(\Theta_2) * motor_2 + \cos(\Theta_3) * motor_3 \\ F_y = \mathrm{sen}(\Theta_1) * motor_1 + \mathrm{sen}(\Theta_2) * motor_2 + \mathrm{sen}(\Theta_3) * motor_3 \\ F_w = motor_1 + motor_2 + motor_3 \end{cases}$$

[0078] These expressions can next be used to build the following matrix, whereby F represents the components of each wheel for movement and M the contribution of each motor. This matrix represents the distance that the device must move in each distance according to the rotation speed applied to each motor. Using this expression, it is then possible to determine which rotation speed each motor must present for the device to move in the intended direction.

$$\underbrace{\begin{bmatrix} F_x \\ F_y \\ F_w \end{bmatrix}}_{F} = \underbrace{\begin{bmatrix} \cos(\Theta_1) & \cos(\Theta_2) & \cos(\Theta_3) \\ sen(\Theta_1) & sen(\Theta_2) & sen(\Theta_3) \\ 1 & 1 & 1 \end{bmatrix}}_{A} * \underbrace{\begin{bmatrix} motor_1 \\ motor_2 \\ motor_3 \end{bmatrix}}_{M}$$

BRIEF DESCRIPTION OF THE FIGURES

[0079] For an easier understanding, figures are herein attached which represent preferred embodiments that do not intend to limit the object of the present description.

Figure 1: Schematic representation of an embodiment of the device or robotic pyramid with all the structural components thereof and for data acquisition.

Figure 2: Schematic representation of an embodiment of the dimension measurements of the device.

Figure 3: Schematic representation of an embodiment of the main structure of the device, wherein between the upper base **1** and the lower base **2** there are located the omnidirectional wheels **3** and the direct current motors **6.** The connection between the shaft **7** and the upper plate of the base of the device is made by means of three supports **4** and a plate **5** wherein these are welded. The axial force system is found in shaft **7.**

Figure 4: Schematic representation of an exploded view of an embodiment of the components which are located on the lower part of the walking aid device namely, the LRF **8,** the battery **9,** the STM32 plate and the IMU **10,** the controller **12** and the voltage regulators **11, 13.**

Figure 5(a): Representation of an embodiment of the base of the device, with the Cartesian reference located in the mass center of the pyramid (of the device).

Figure 5(b): Representation of the forces involved in the movement of the device.

Figure 6: Representation of the haptic detection system on the handle of the device, wherein there are demonstrated three force detection phases: (a) no contact with null detection; (b) slight contact with small disturbances in detection; (c) support phase, where the forces detected are maximum.

Figure 7: Representation of several embodiments of grip/handle of the device, which comprises FSRs, adapted from the original handle for precise acquisition of vertical forces.

Figure 8: Representation of a working diagram of the closed loop solution implemented for the device.

DETAILED DESCRIPTION

[0080] Falls are the second largest cause of death by injury in the elderly population and result in high costs for the national health system.

[0081] The present disclosure is related to an intelligent robot for preventing falls. The device or robotic pyramid is an intelligent cane-type robot consisting of an autonomous and multifunctional accompaniment device for the user and which allows a quantitative and continuous evaluation of the gait. It can be used in domicile and/or institutional context with the purpose of allowing an effective forecast of the risk of fall by means of sensors and artificial intelligence algorithms.

[0082] The present disclosure is related to a device with omnidirectional movement for gait support. It refers particularly to the device and respective operating method, preferably a robotic pyramid.

[0083] The present disclosure is related to a device with omnidirectional movement to support a user's gait, comprising:

a controller;
a shaft with a grip for support by the user; and
a base which comprises:

an upper plate and a lower plate for supporting electronic components including said controller,
at least three wheels to support the base, and
at least three electric actuators for acting on said wheels;

wherein the controller is configured for controlling the actuators for acting on said wheels for correction of the user's gait;
wherein the actuators are distributed between the upper plate and the lower plate;
wherein the grip comprises a plurality of vibrotactile motors for providing feedback to the user; wherein the shaft is connected to the upper plate of the base by a connection element.

[0084] In an embodiment, the present disclosure is related to a gait support device for a user, which comprises: a shaft **7** which allows support for the user; a connection element **5** which transmits the forces between the device and the user; three fixing elements 4 which provide structure to the device; at least two base plates **1,2** for electronic components; at least three electric actuators **6** which allow correction of the gait; at least one omnidirectional wheel **3** for each actuator used, which allow creating an omnidirectional base, essential for corrections/actuation in limited spaces, allowing aid and movement of the user according to their needs.

[0085] In an embodiment, the base is stable and self-supporting in the vertical position, waiving the need for external or additional components. Thus, when the device is at rest, it does not tend to unbalance, since it maintains the mass center contained within its own support base.

[0086] In an embodiment, the device is adjustable, enabling the complete customization of the physical form thereof to meet the needs of different users. This level of customization aims at providing a maximum adaptation to the user, thus promoting higher efficacy and ergonomics of the device. Preferably, the shaft of the device is height adjustable. This allows the user, by means of clear orientations, to adjust the height of the shaft so as to use the device correctly, thus avoiding negative consequences associated with inadequate height, such as incorrect posture.

[0087] In an embodiment, the system for continuous evaluation and detection of the gait and fall risk in real time is carried out by means of the use of algorithms for movement control.

[0088] In an embodiment, the monitoring of spatiotemporal parameters of the device and the user is carried out so as to provide a broad and continuous analysis. This approach aims at evaluating and recording the relevant variables along space and time, thus offering a complete vision of the interactions between the robotic device and the user which are extremely important for helping the control and decision algorithms towards an efficient fall prevention.

[0089] In an embodiment, the increase of the motor function of the user is obtained by means of a biofeedback system in real time, based on vibrotactile units.

[0090] In an embodiment, the device allows automatic and autonomous adjustment to the user's gait pattern, using sensors to dynamically adapt the configuration thereof and optimize the moving experience in a customized and efficient manner.

[0091] In an embodiment, the device allows reducing the cognitive load during the use of the device by means of the implementation of a navigation system, which allows detecting possible obstacles to their movement, signaling and stopping the movement of the device/user, avoiding potential collisions, based on the use of LRFs.

[0092] In an embodiment, the environment lighting unit comprises an environmental light detection system which allows adjusting the intensity in real time, according to the context in which the user is located.

[0093] In an embodiment, the device comprises actuation on the *Internet of Medical Things* (IoMT) mode.

[0094] In an embodiment, the device comprises systems able for the implementation of wireless protocols.

[0095] In an embodiment, algorithms and systems previously indicated, powered by a sensory unit which allows detecting the orientation, tilt, acceleration and speed by means of the use of an IMU; detecting forces applied to the device by means of the use of FSRs, being possible to detect the user's movement intention and create the gait pattern of the user.

[0096] Said controller can be a microcontroller, a computer, or any type of data processor, namely, an electronic data processor. In an embodiment, the algorithms and systems previously indicated are supported by a low level control unit, supported by a microcontroller. In an embodiment, the algorithms and systems previously indicated are supported by a high level control unit, supported by a microcomputer.

[0097] In an embodiment, the algorithms and systems previously indicated are supported by a local storage unit.

[0098] In an embodiment, the algorithms and systems previously indicated are supported by a local storage unit in a cloud.

[0099] In an embodiment, the algorithms and systems previously indicated are supported by an energy power unit further composed by voltage limiters which ensure safety to the different components which act simultaneously.

[0100] In an embodiment, the implementation of the safety system allows cutting off the power between the power unit and the remaining systems by activating a button.

[0101] In an embodiment, the protection of the systems and components previously mentioned is ensured by means of a coating or shroud which isolates these surrounding environment elements, thus ensuring the preservation and integrity of same.

[0102] In an embodiment, the coating or shroud is made of metal.

[0103] In an embodiment the coating or shroud is made of steel or aluminum or carbon fibers.

[0104] In an embodiment, the components integrated in the device are totally independent from external hardware for the correct working of the algorithms and systems previously indicated, allowing greater freedom and universality of use on the part of the user.

[0105] In an embodiment the device uses IoMT systems [Internet of Medical Things] and wireless protocols, provided with omnidirectional wheels for optimizing the position and providing an adjustable support base in real time, stimulating balance. It uses an IMU and FSRs for precisely detecting the orientation, tilt, acceleration and the forces applied on the device, enabling the identification of the user's intention of moving and creating customized gait patterns. Operating with low and high level control units, and supported by local and cloud storage, the device stands out by prioritizing the detection and prevention of falls through the real time analysis of the data captured.

[0106] **Figure 1** represents an embodiment of the device.

[0107] **Figure 2** represents an embodiment of the device, wherein the height of same is of 1061 cm and the base width is 388 cm. The height and width can be variable, according to whom they are destined.

[0108] **Figure 3** represents an embodiment of the device, being represented the upper plate of the base **1** and the lower plate of the base **2** wherein there are located the omnidirectional wheels **3** and the direct current motors **6.** The connection between the shaft **7** and the upper plate of the device is made by means of three fixing elements or supports **4** and a sheet plate **5** where they are welded. The axial force system is found in shaft **7.**

[0109] In an embodiment, the shaft **7** is adjustable, namely adjustable in height, for a better support on the part of the user.

[0110] In an embodiment, **Figure 5(a)** shows the base of the device, with the Cartesian reference located in the mass center of the pyramid, namely the mass center of the device. This figure shows the numbering of the motors (1 to 3) and the respective angles α, β and γ which each motor makes relative to the abscissa axis of the reference.

[0111] In its turn, **Figure 5(b)** represents a simulation of forces (F1 to F4) which can be interpreted by the kinematic equations for performing the movement of the wheels (1 to 3), allowing the device to move in the most varied directions and rotate over itself.

[0112] **Figure 6** refers to the results of an embodiment of the haptic detection system on the handle of the device, wherein there are demonstrated three phases of the force detection: **a)** no contact with null detection; **b)** slight contact with small disturbances in detection; **c)** support phase, where the forces detected are maximum. It is verified in the graphic that the system provides a precise and sensitive tactile response, reflecting the force variations during the different detection phases.

[0113] **Figure 7** represents a plurality of grip/handle variations of the device whereby in **a)** the handle comprises three force sensitive resistors (FSR), in **b)** the sensors are coated with three 3D printed parts for better targeting of the force, in **c)** the handle is coated with a 3D printed part to isolate the sensors and in **d)** there is observed a section view of the handle with the elements described in a), b) and c). These representations are adapted for the precise acquisition of vertical forces.

[0114] **Figure 8:** Representation of an operating diagram of the closed loop solution implemented for the device.

[0115] Next, there will be described the working method of the device for gait support.

[0116] In a preferred embodiment, initially, after the user acquires the device and adjusts the handle considering the dominance (that is, preferred hand of the user for operating the device), as well as the handle height, the device is turned on and, next, there are performed the following steps:

1. The user must remain stable and in an upright position next to the device for 5 seconds, for the calibration routine of the data for acceleration of the device to be carried out, as well as the laser data.

2. During the calibration routine, there are collected values from the accelerometer of the device, for calculating an average, and distance values measured by the laser, for an initial interpretation of the position of the user relative to the robotic pyramid. The calculated average value allows determining a stable and initial acceleration value for

each use of the device.

3. The calculated acceleration value is used in the calibration of the acceleration data acquired after this phase.

4. After the calibration routine takes place, the user can carry out his tasks freely and the device continues with the analysis of the gait, the intention of moving and the detection of the gait phases, following the next calibration phases.

5. Whenever the user leans on the device, that is, whenever there is detected a determined vertical force, the device will remain motionless to provide support to the user.

6. When the user desires to move, a force is applied in the direction of the movement of the handle of the device. The detection of the application and direction of these forces results in the movement of the device in the desired direction.

7. When there occurs an unbalance, detected by the sensory unit, the control unit of the device activates the motors of the omnidirectional wheels to position the device so as to provide the adequate support to the user, prioritizing their safety and comfort.

8. The data of the different components of the sensory unit which are acquired during the use are saved in the memory unit.

[0117] After the device has been used it is possible to access the control unit, namely the high level, with the purpose of obtaining the data saved in the sensory unit. The control unit is able to send data via online to a cloud. Next, these data are analyzed, by means of an interface, which allows analysis of the collected data and estimated metrics.

[0118] Optionally, another actuation mode includes a closed loop vibrotactile stimuli delivery strategy, contemplating the following steps:

1. After positioning himself next to the device, the user is able to select the vibration frequence and which vibratory units to activate, through a phone app or other mobile device, which communicates with the device through Bluetooth.

2. During the calibration routine, there are collected acceleration values of the device, for calculating an average, and distance values measured by the laser, for an initial interpretation of the position of the user relative to the walking aid device. The calculated average value allows determining the stable and initial acceleration value for each use of the device.

3. The calculated acceleration value is used in the calibration of the acceleration data acquired after this phase.

4. After the calibration routine takes place, the user can carry out his tasks freely and the device continues with the analysis of the gait, the detection of the intention of moving and the detection of the gait phases, following the next calibration phases.

5. Whenever the user presents a gait considered abnormal, the handle will present vibration in an attempt to correct a behavior considered as a fall risk.

6. If obstacles are detected in the path of the walking aid device, there will be generated a vibratory response in the handle so as to warn the user.

7. In case the user has their hand on the handle of the walking aid device, but has not moved for a long while, a vibratory stimulus is performed with the purpose of stimulating the movement of the user.

8. The data of the different components of the sensory unit associated with the handle and the shaft of the device are acquired during use, being subsequently saved in the memory unit.

[0119] In an embodiment, it is also possible to follow the following steps to access the device by means of one of the two graphic interfaces developed (for example Android and C# Visual Studio):

1. Subsequently to the due adjustment of the handle, considering both the dominance of the user as the height of the same, and the device being turned on, there is performed the pairing between the device and the graphic interface

(for example, cellphone or computer) by means of Bluetooth, which is integrated in the robotic pyramid.

2. Selection of the parameters which it is intended to analyze, by means of the respective graphic interface buttons. There can be selected the frequency of vibration (according to the range which is perceived by the human being), the vibration time interval and the vibratory pattern.

[0120] This utilization mode allows analyzing which vibration frequency a certain user can perceive in their hand. It is further possible to determine the minimum interval which each user requires to fully perceive the vibrotactile stimuli in the stimulated zone in question. There is added, once more, that the data of the gait are being collected, by means of the laser acquisition and the force sensors. In the same manner, this fact allows accessing the data acquired in the high level control unit or in a computer, where there can be carried out the calculation of the gait parameters.

[0121] Finally, it is further possible for the device to operate only as a gait monitoring system, where the gait data are acquired, saved in the memory unit and, next, in a computer, duly analyzed and parametrized. All the data can be kept in a database with reference to each user.

[0122] Whenever used in this document, the term "comprises" or "comprising" is meant to indicate the presence of features, elements, integers, steps and components mentioned, but does not preclude the presence or addition of one or more other features, elements, integers, steps and components, or groups thereof. The present invention is of course in no way restricted to the embodiments described in this document and a person with average skills in the art may foresee many possibilities of modifying the same and of substituting technical features for equivalent ones, depending on the requirements of each situation, as defined in the appended claims. The following claims define additional embodiments of the present description.

Claims

1. Device with omnidirectional movement for supporting a user's gait, which comprises:

a controller (12);
a shaft (7) with a grip for support of the user; and
a base which comprises:

an upper plate (1) and a lower plate (2) for supporting electronic components including said controller,
at least three wheels (3) for supporting the base, and
at least three electric actuators for acting on said wheels;

wherein the controller is configured for controlling the actuators for acting on said wheels (3) for correction of the user's gait;
wherein the actuators are distributed between the upper plate (1) and the lower plate (2);
wherein the grip comprises a plurality of vibrotactile motors for providing feedback to the user;
wherein the shaft is connected to the upper plate of the base by a connection element.

2. Device according to the previous claim which comprises a plurality of movement sensors arranged on the base for monitoring the movement of the device.

3. Device according to the previous claim wherein the movement sensors comprise an inertial measurement unit (10) arranged on the base.

4. Device according to any of the previous claims wherein the connection element comprises a plate (5) and at least three fixing elements (4).

5. Device according to any of the previous claims comprising one or more, in particular three or more, force sensors arranged on the grip to detect forces exerted on the grip.

6. Device according to the previous claim wherein the force sensor or sensors are arranged on the grip for detection of a vertical force, in particular a force exerted by the user on the grip in a direction parallel to the shaft (7), and wherein the force sensor or sensors are force sensitive resistors.

7. Device according to any of the previous claims wherein the shaft (7) comprises one or more, in particular four or more, force sensors, for detecting the forces exerted on the shaft.

8. Device according to the previous claim wherein the force sensor or sensors are arranged on the shaft for detection of directional forces exerted on the shaft (7) by the user in a direction perpendicular to the shaft, and wherein the force sensor or sensors are force sensitive resistors.

9. Device according to any of the previous claims which comprises a laser distance measurer (8) arranged on a surface of the upper plate (1) for measuring the distance between the device and an obstacle and/or between the legs of the user.

10. Device according to any of the previous claims which comprises a light source, preferably a photodiode.

11. Device according to any of the previous claims which comprises at least one photoresistor for detecting brightness and activating the photodiode when the value of the signal obtained is less than a pre-defined value, preferably the photoresistor being arranged on the shaft (7).

12. Device according to any of the previous claims wherein each of the wheels (3) is an omnidirectional wheel.

13. Method of operating a device with omnidirectional movement for support to a user's gait,

wherein the device comprises:

a controller (12);
a shaft (7) with a grip for support of the user, wherein the shaft is connected to the upper plate of the base by a connection element and wherein the grip comprises a plurality of vibrotactile motors for providing feedback to the user;
a base which comprises:

an upper plate (1) and a lower plate (2) for supporting electronic components,
at least three wheels (3) for supporting the base, and
at least three electric actuators for acting on said wheels;

wherein the method comprises the controller (12) executing the following steps:

acquiring, from each sensor of the plurality of sensors, a signal received from the grip and the shaft (7);
determining from the acquired signals the user's movement;
controlling the actuators for acting on the wheels for correcting the user's gait.

14. Method according to the previous claim wherein the controller is configured for detecting a vertical force, in particular a force exerted by the user on the grip in a direction parallel to the shaft (7), by means of one or more, particularly three or more, force sensors arranged on the grip for detecting forces exerted on the grip.

15. Method according to claim 13 or 14 wherein the controller is configured for detecting directional forces exerted on the shaft (7) by the user in a direction perpendicular to the shaft, by means of one or more, in particular four or more, force sensors, for detecting the forces exerted on the shaft.

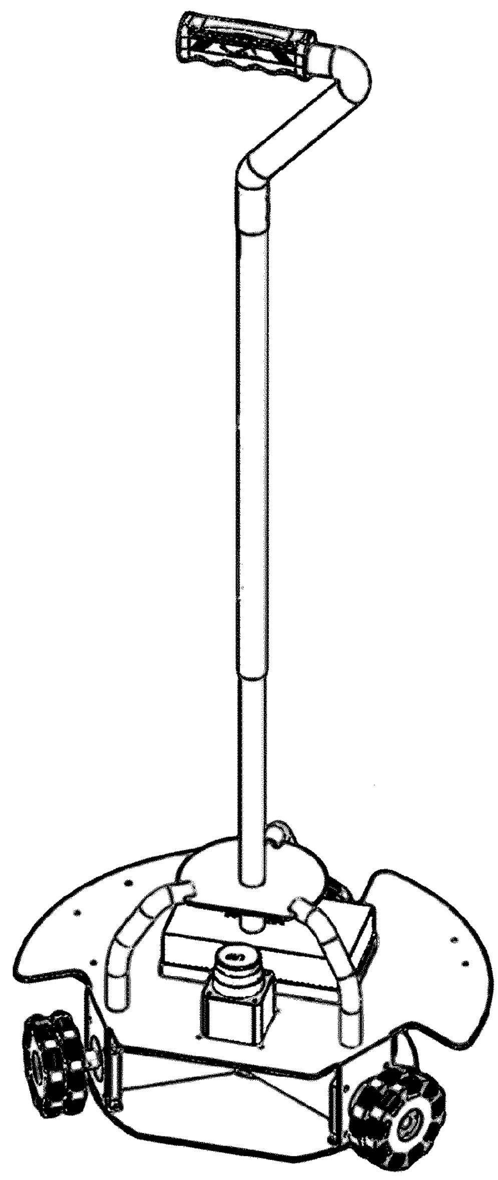

Fig. 1

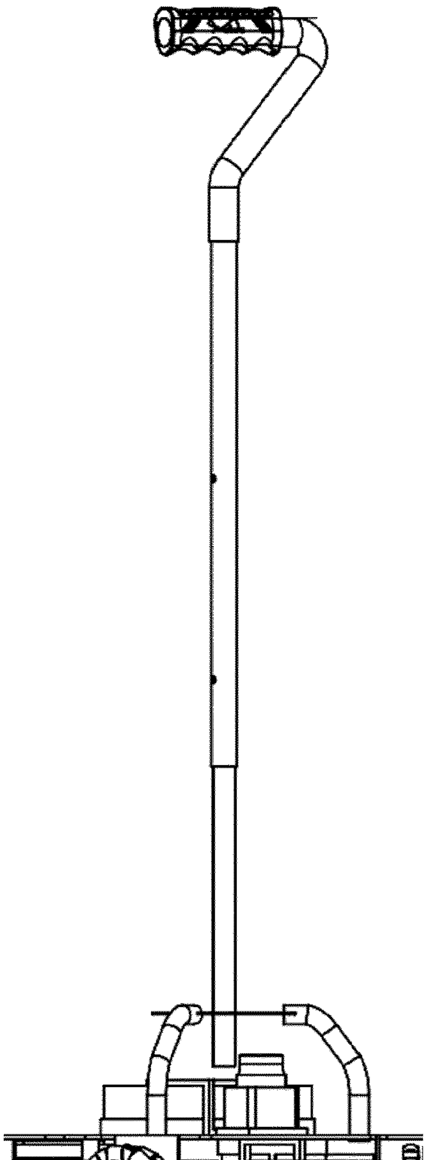

Fig. 2

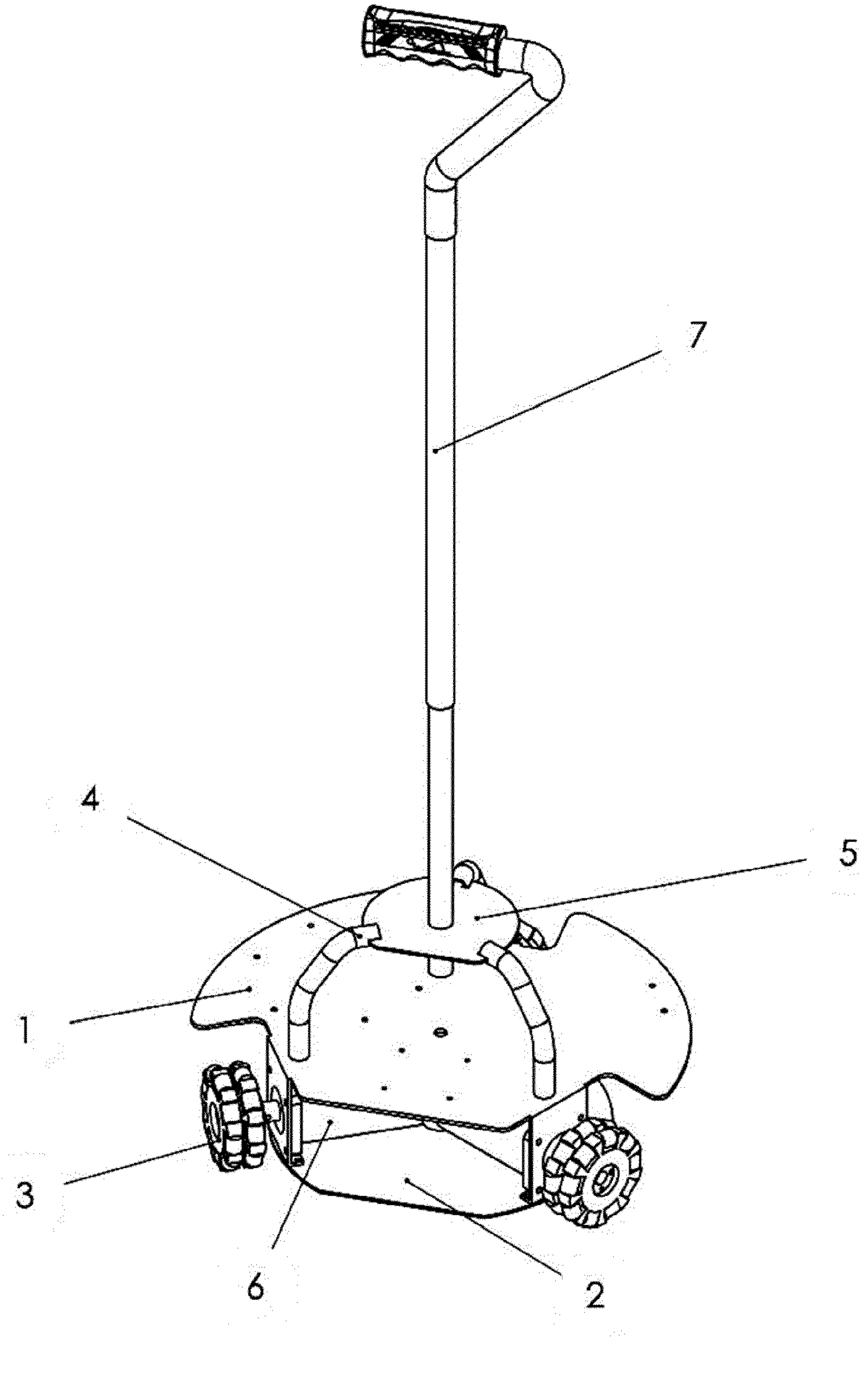

Fig. 3

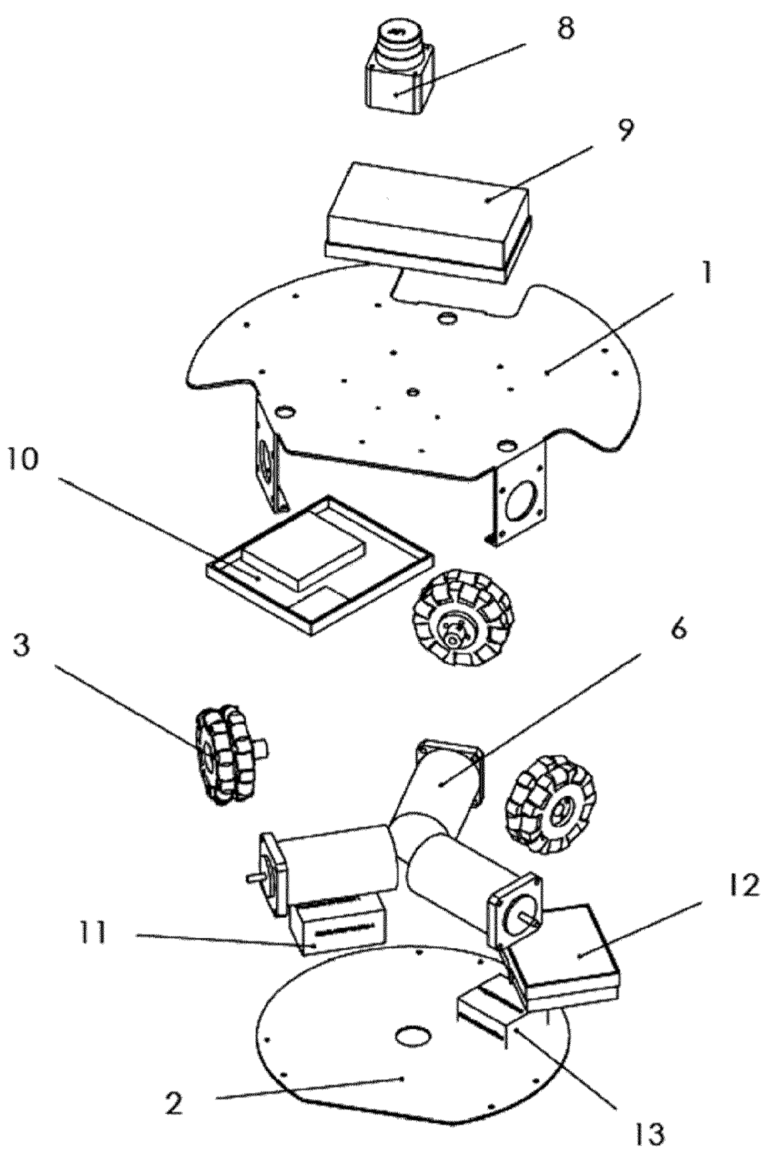

Fig. 4

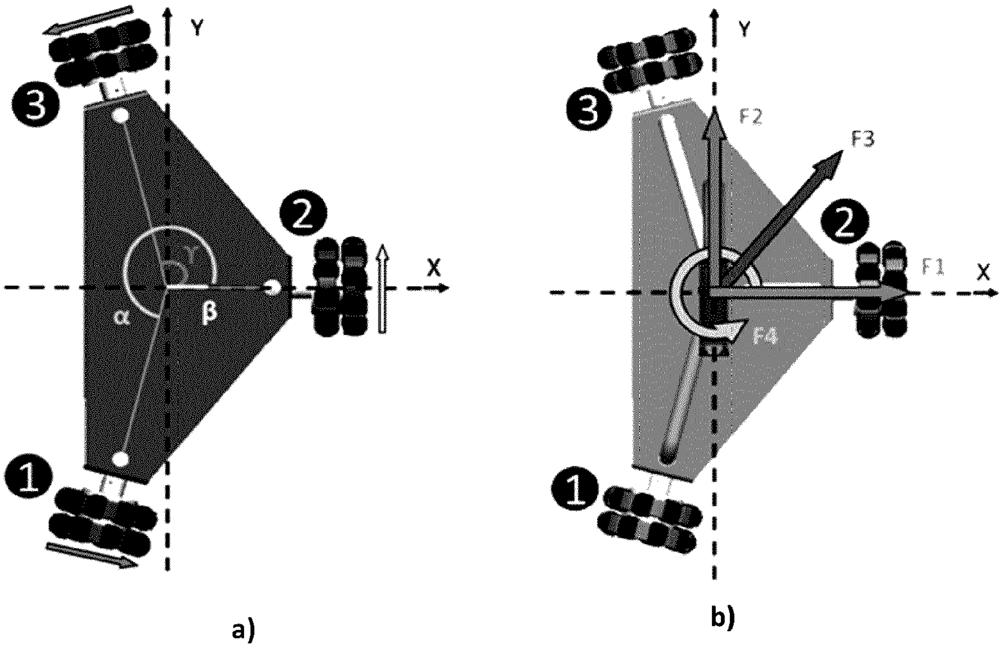
Y
3
2
X
α
β
γ
1
a)
Y
3
F2
F3
2
F1
X
F4
1
b)

Fig. 5

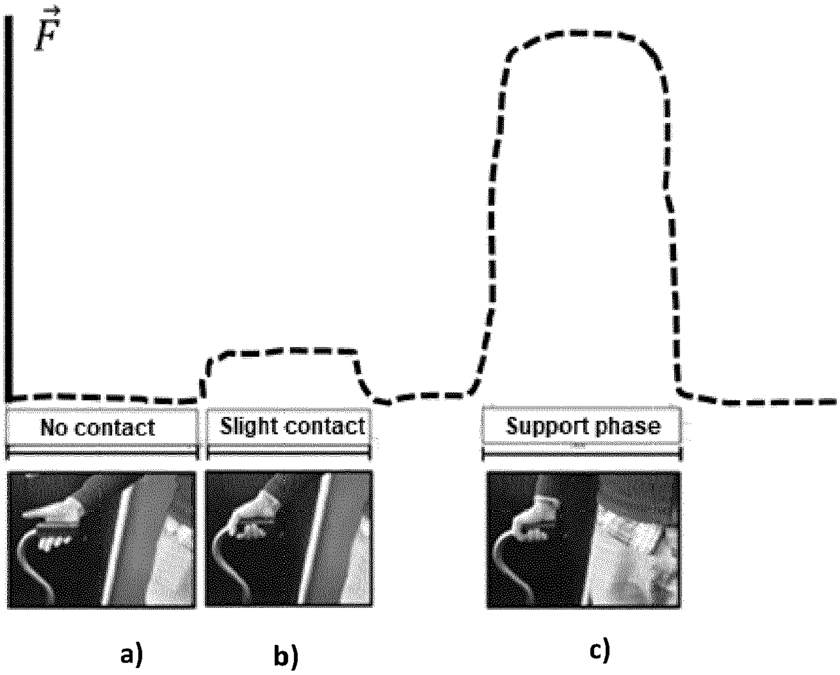
$\vec{F}$
No contact
Slight contact
Support phase
a)
b)
c)

Fig. 6

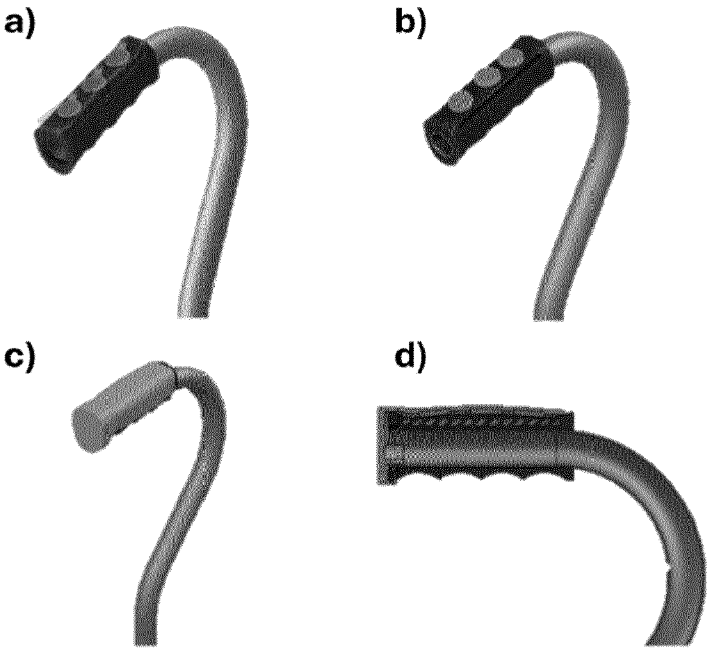
a)
b)
c)
d)

Fig. 7

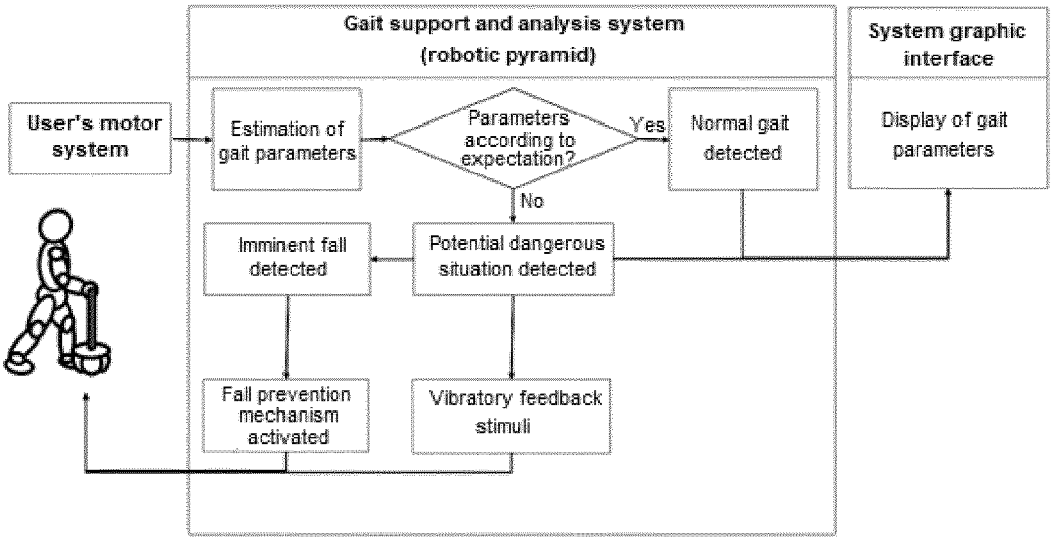
Gait support and analysis system
(robotic pyramid)
System graphic interface
User's motor system
Estimation of gait parameters
Parameters according to expectation?
Yes
No
Normal gait detected
Display of gait parameters
Imminent fall detected
Potential dangerous situation detected
Fall prevention mechanism activated
Vibratory feedback stimuli

Fig. 8

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 24 17 4194

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	CERQUEIRA RODOLFO ET AL: "Engineering a Safer Future: Electronic Design and Validation of a Cane-Type Robot for Fall Prevention", 2023 IEEE INTERNATIONAL CONFERENCE ON AUTONOMOUS ROBOT SYSTEMS AND COMPETITIONS (ICARSC), IEEE, 26 April 2023 (2023-04-26), pages 193-198, XP034349593, DOI: 10.1109/ICARSC58346.2023.10129613 [retrieved on 2023-05-26]	1-8, 10-15	INV. A61H3/04
Y	* pages 194-198; figures *	9	
Y	JP 2015 217155 A (UNIV MEIJO) 7 December 2015 (2015-12-07) * paragraphs [0018] - [0020]; claims; figures *	1-15	
Y	CN 107 015 564 A (UNIV HUAZHONG SCIENCE TECH) 4 August 2017 (2017-08-04) * claims; figures *	1-15	
			TECHNICAL FIELDS SEARCHED (IPC)
Y	CN 107 693 314 A (UNIV HUAZHONG SCIENCE TECH) 16 February 2018 (2018-02-16) * claims; figures *	1-15	A61H
Y	CN 102 551 994 A (UNIV HUAZHONG SCIENCE TECH) 11 July 2012 (2012-07-11) * pages -; claims; figures *	1-15	
Y	JP 2005 000501 A (YASKAWA ELECTRIC CORP) 6 January 2005 (2005-01-06) * claims; figures *	1-15	

The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
Munich	26 August 2024	Shmonin, Vladimir

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

EP 24 17 4194

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

26-08-2024

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 2015217155 A	07-12-2015	JP 6333059 B2 JP 2015217155 A	30-05-2018 07-12-2015
CN 107015564 A	04-08-2017	NONE	
CN 107693314 A	16-02-2018	NONE	
CN 102551994 A	11-07-2012	NONE	
JP 2005000501 A	06-01-2005	NONE	

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- CN 110575371 A **[0013]**
- US 20130041507 A1 **[0013]**
- CN 112137847 **[0014]**
- KR 20160144193 A **[0014]**
- CN 104382307 A **[0014]**
- JP 2015217155 A **[0017]**
- CN 107015564 A **[0017]**
- CN 107693314 A **[0017]**