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[Continued on next page]

(54) Title: SOFT EXOSUIT FOR ASSISTANCE WITH HUMAN MOTION

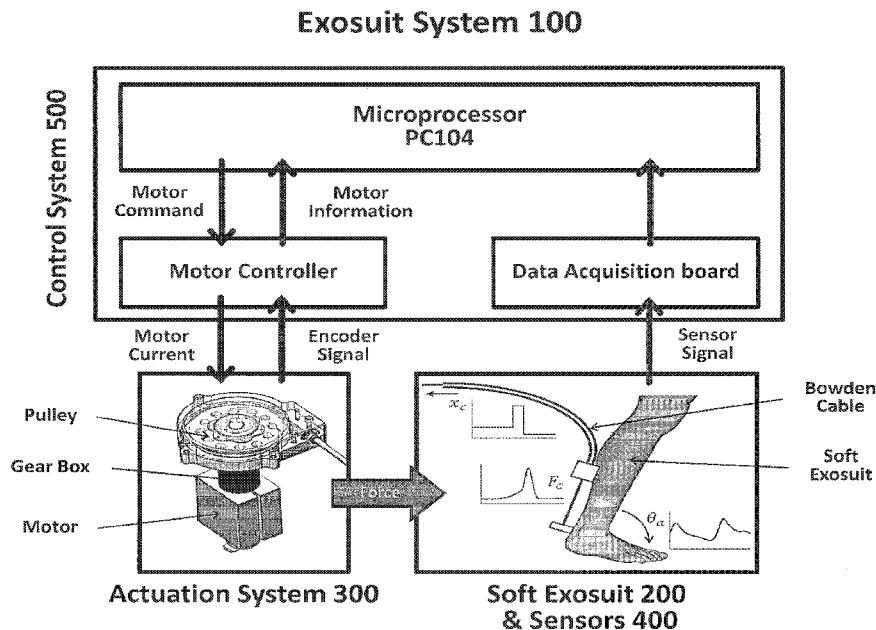


FIG. 1

(57) Abstract: Systems and methods for providing assistance with human motion, including hip and ankle motion, are disclosed. Sensor feedback is used to determine an appropriate profile for actuating a wearable robotic system to deliver desired joint motion assistance. Variations in user kinetics and kinematics, as well as construction, materials, and fit of the wearable robotic system, are considered in order to provide assistance tailored to the user and current activity.

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Previous Correction:
see Notice of 7 July 2016

INTERNATIONAL SEARCH REPORT

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PCT/US 15/51107

A. CLASSIFICATION OF SUBJECT MATTER
 IPC(8) - F03G 7/08 (2016.01)
 CPC - B25J 9/0006
 According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
 Minimum documentation searched (classification system followed by classification symbols)
 IPC (8) - F03G 7/08 (2016.01)
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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
 CPC - A61H3/00, A61H1/0244, A61H2201/1215, A61H2201/5002 (See Keywords Below)
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Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
 Thomsoninnovation.com; Patbase; Google Scholar; Google Patents; Gogole.com; Freepatentsonline; ProQuest Dialog
 Search Terms: assistance, support, motion, joint, hip, ankle, exosuit, desired, required, peak force, power, integral, wearable, gait cycle, actuation profile, maximum, flexion, angle, baseline, heel strike, rotational velocity, change, d

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2014/109799 A1 (PRESIDENT AND FELLOWS OF HARVARD COLLEGE), 17 July 2014 (17.07.2014), entire document, especially Abstract; Para [0015], [0111], [0227], [0282], [0353], [0351]	1-87
Y	US 2013/0310979 A1 (HERR et al.), 21 November 2013 (21.11.2013), entire document, especially Abstract; para [0020], [0101], [0273], [0277], [0297]-[0299]	1-36, 43, 59-60 and 83-87
Y	US 2011/0093089 A1 (MARTIN), 21 April 2011 (21.04.2011), entire document, especially Abstract; Para [0132], [0261], [0284], [0298], [0310]-[0311], [0496].	37-84 and 87
Y	US 2012/0253234 A1 (YANG et al.), 04 October 2012 (04.10.2012), entire document, especially Abstract; Para [0044], [0047], [0061], [0122]-[0123]	3-5, 21-23, 39-41, 63-65 and 85-86
P,A	WO 2014/194257 A1 (PRESIDENT AND FELLOWS OF HARVARD COLLEGE), 04 December 2014 (04.12.2014), entire document,	1-87
P,A	US 2015/0173993 A1 (WALSH et al.), 25 June 2015 (25.06.2015), entire document,	1-87
A	US 2014/0194781 A1 (EINARSSON et al.), 10 July 2014 (10.07.2014), entire document,	1-87
A	US 2010/0038983 A1 (BHUGRA et al.), 18 February 2010 (18.02.2010), entire document,	1-87

Further documents are listed in the continuation of Box C.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier application or patent but published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 15/51107

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I - Claims 1-36 and 85-86 directed to a method and wearable robotic system for assisting motion of a hip joint by monitoring an angle of the hip joint.

Group II - Claims 37-84 and 87 directed to a method and wearable robotic system for assisting motion of an ankle joint by monitoring rotational velocity of the ankle of the user.

--- (See Continuation in Supplemental Box) ---

1. As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 15/51107

Continuation of:

Box III. Observations where unity of invention is lacking

The inventions listed as Groups I-II do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:

Special Technical Features:

The invention of Group I included the features of at least one sensor adapted to monitor real-time measurements of an angle of the hip joint to detect when the hip joint reaches a maximum flexion angle; and detect when the angle of the hip joint has reached the maximum flexion angle; in response to detecting that the angle of the hip joint has reached the maximum flexion angle, actuating the wearable robotic system according to the actuation profile to assist with an extension motion of the hip joint of the user, not required in group II.

The invention of Group II included the features of at least one sensor adapted to monitor real-time measurements of a rotational velocity of the ankle of the user to detect a first change in direction of the measured rotational velocity of the ankle joint after the detection of a heel strike; and detecting a heel strike of the user; in response to detecting the first change in direction of the measured rotational velocity of the ankle joint, actuating the wearable robotic system according to the actuation profile to assist with an plantar flexion motion of the ankle joint of the user, not required in group I.

Common Technical Features

Groups I-II share the technical features of at least one sensor adapted to monitor real-time measurements; at least one processor that is adapted to obtains computer executable instructions stored on a non-transitory medium that when executed by the at least one processor causes the wearable robotic system to: determining a desired peak force or integral power to be generated by a wearable robotic system during a current gait cycle of a user; generating an actuation profile according to which the wearable robotic system may be actuated to deliver the desired peak force or integral power to the body of the user; actuating the wearable robotic system according to the actuation profile to assist.

However, the shared technical features does not represent a contribution over prior art as being obvious by US 2013/0289452 A2 to Smith et al. (hereinafter 'Smith'), 31 October 2013 (31.10.2013) in view of US 2011/0105966 A1 to Kazerooni et al. (hereinafter 'Kazerooni'), 05 May 2011 (05.05.2011).

Smith teaches at least one sensor adapted to monitor real-time measurements (Para [0007], [0023] - sensor system attached to the skeleton joint system; the sensor system can determine if the user of the exoskeleton is standing up); at least one processor that is adapted to obtains computer executable instructions stored on a non-transitory medium that when executed by the at least one processor causes the wearable robotic system to (Para [0106]- computer-readable medium containing computer program code, which can be executed by a computer processor for performing any or all of the steps): determining a desired peak force or integral power to be generated by a wearable robotic system during a current gait cycle of a user (Para [0087]- allow the system to determine how much force the system is placing on the body in order to allow the system to feed back into the control system); actuating the wearable robotic system to assist (Para [0029], [0050]- exoskeleton system 100 can include the actuation system 106 for actuating the skeleton joint system 102; The control system 500 is for determining when or how an actuation system is activated and powered.).

Kazerooni teaches generating an actuation profile according to which the wearable robotic system may be actuated to deliver the desired peak force or integral power to the body of the user (Para [0007], [0076]-[0077] - create a torque profile such that the force from the leg support in the swing phase onto the corresponding wearer's lower limb is in the direction of the wearer's lower limb swinging velocity; the hip actuator of the swinging leg support should create a torque profile such that the torque from the swinging leg support onto the person's corresponding lower limb is in the direction of the person's swing velocity); actuating the wearable robotic system according to the actuation profile to assist (Para [0084]- This torque is then produced by hip actuators 145 and 146 during their respective swing phases).

As the common features were known in the art at the time of the invention, this cannot be considered a common technical feature that would otherwise unify the groups.

Therefore, Groups I-II lack unity under PCT Rule 13.

* Note - Claim 87 is interpreted to depend from claim 37 instead of claim 1 as written, for proper antecedent basis of "the ankle joint."