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Requirement of Wearable Robots in Current Scenario

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ABSTRACT

Wearable robotics is gradually becoming an emerging research field and a few applications of wearable rehabilitation robots have been proposed in the literature to reinstate activities of daily life (ADL) in people suffering from motor disorders. This paper discusses the classification of wearable robots, technologies involved in wearable robots, human robot physical interaction. There is brief description of technologies involved in the wearable robotics such as kinematic compatibility between human limbs and wearable robots, application of load to humans and control of human-robot interaction. Wearable robot technologies include sensor technologies, actuator technologies and portable energy storage technologies. Few wearable robots instances have been discussed with regard to their mechanism, software, system architecture, and user interface and safety issues.

Key words: Actuators, upper limb exoskeleton, lower limb exoskeleton, physical human robot interaction, encoders

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INTRODUCTION

The first company that produce industrial robot was Unimation founded by Joseph F.Engelberger in 1962 with the basic inventions of George devol. He has been called the father of robotics. Robots are categorized by their time frame. In 1970's first generation robot was introduced, which was stationary, nonprogrammable, electromechanical device without sensor. In 1980's second generation robots were introduced and it can contain sensors and programmable controllers. After 1990 the third generation robots were introduced. They are more advanced. Wearable robots are designed to be worn by people. Designs of wearable robots are as per body shape and function of human body. Wearable robots are able to assist in lifting of heavy objects which are normally not able to lift, jumping, running, walking etc. These can be used for medical concern, old age people and military concern also.

Wearable robots are person-oriented robots. They can be defined as those worn by human operators, whether to supplement the function of a limb or to replace it completely. Wearable robots may operate alongside human limbs, as in the case of orthotic robots or exoskeletons, or they may substitute for missing limbs, for instance following an amputation. Wear ability does not necessarily imply that the robot is ambulatory, portable or autonomous. Where wearable robots are no ambulatory, this is in most instances a consequence of the lack of enabling technologies, in particular actuators and energy sources.

- *Empowering Robotic Exoskeletons:* These were also known as extenders. The reason behind it is that they extend the strength of the human hand beyond its expected ability even as maintaining human control of the robot. With the help of anatomy, a singular and specific aspect of extenders is the extension of the ability of the human operator's upper limb is more to do with reach than power, master –slave robot configurations occur, generally in teleportation scenarios.
- *Orthotic robots:* An orthosis is a mechanical structure that maps on to the anatomy of the human limb. Its function is to reinstate weak or lost functions in human body, e.g. following a disease or a neurological condition, to their natural levels. The robotic counterparts of orthosis are robotic exoskeletons. The function of the e0xoskeleton is to complement the ability of the human limb and restore the handicapped function.
- *Prosthetic robots:* Prosthesis is an electromechanical device that substitutes for lost limbs after amputation. The robotic counterparts of prostheses take the form of electromechanical wearable robotic limbs and make it possible to replace the lost limb function in a way that is closer to the natural human function. This is achieved by intelligent use of robotics technologies in terms of human –robot interaction (comprising sensing and control) and actuation.

A wearable robot can be seen as a technology that extends, complements, substitutes or enhances Human function and capability or empowers or replaces (a part of) the human limb where it is worn [1-4].

HUMAN–ROBOT PHYSICAL INTERACTION

Wearable robot is the intrinsic interaction between human and robot. This interaction, in its simplest manifestation, implies a physical coupling between the robot and the human, leading to the application of controlled forces between both actors. The actions of the two agents must be coordinated and adapted reciprocally since unexpected behaviors of one of them during interaction can result in severe injuries. A classic example of physical interaction is exoskeleton-based functional compensation of human gait [5].

Physiological Factors

Proprioceptors generate a sense of position, a sense of movement and a sense of force. That sensitivity is essential to orientate movements and to be aware of the position of the limbs when exploring objects. In human–robot interaction, hepatics refer to the use of robotic interfaces and devices for force feedback in human–computer interfaces. Proprioceptive and touch senses have an important role in the context of hepatic application. The sensors directly implicated in touch perception are mechanoreceptors, which are stimulated by mechanical forces. Mechanoreceptors can detect pressure, touch, vibration, strain and tactile sensation and are mostly located in the human skin [6].

Aspects of Wearable Robot Design

- *Safety:* It is paramount for PHRI to guarantee safe operation. The WR should avoid unnatural or arbitrary movements, for instance excessive excursions that could hyperextend or hyper flex human joints.
- *Actuator performance:* WRs (Wearable Robots) serve a large number of applications. The particularities of each application define the constraints in the design of the actuator system. For instance, rendering hectic sensations imposes strict requirements on the actuator design.
- *Ergonomics and comfort*: One of the challenges in the design of wearable robots is the ability to adapt to the specific needs and ergonomic particularities of humans. The WR and the human’s biological joints must be exactly aligned for proper operation. Misalignment of joints could generate interaction forces and may produce pressure sores on the skin of the wearer [7].
- *Application of loads to humans:* PHRI (Physical Human Robot Interaction) causes the transmission of loads to the human musculoskeletal system through soft tissues. This raises the question of the intensity, the mode and the areas on the human body where it is possible to apply loads. It is a topic that requires special attention since it defines how the wearable robot is to be coupled to the human limb [8].
- *Control strategies*: PHRI in wearable robots involves the cooperation of two dynamic control systems, i.e. human motor control and robot control, in a closed loop system. Both systems should be able to adapt to each other in order to achieve a common goal stably.
- *Ease of use:* Final solutions should be easy to don, adjust, use and remove. This imposes constraints with regard to the size and weight of the WR.

APPLICATION OF LOAD TO HUMANS

The function of most wearable robots relies on the application of loads to the human musculoskeletal system through soft tissues. Inadequate application of forces can cause problems such as fatigue to the user, a temporary loss of strength and energy resulting from hard physical or mental work. It has been demonstrated that a continuous application of mechanical loads to human limbs originates from a loss of endurance, and this must be taken into account [9]. The application of loads to humans raises two main concerns:

I. Human Tolerance of Pressure

Excessive pressure is one of the main concerns related to the application of loads to the body. The application of loads by the robot to the skeleton produces contact pressures that can compromise safety and comfort. In this regard, two aspects relating to the pressure applied have been defined: pressure distribution and pressure magnitude.

The relationship between applied pressure and comfort is complex. Comfort is defined as a state of being relaxed and feeling no pain, but in fact there is no objective way to quantify comfort. Pressure deforms tissues and this deformation is sensed by skin receptors. This dynamic response means that pressure perception is dependent on the dynamics of the process whereby the pressure is applied [10-12]. The literature describes three parameters for measuring human tolerance of pressure:

- *Pressure pain threshold (PPT):* PPT is defined as the limit of pressure above which a person feels pain. Perceived pain caused by a high local external pressure is often a limiting factor during work and activities of daily living, and for that reason PPT is a fundamental factor.
- *Maximum pressure tolerance (MPT):* MPT is defined as the ratio between forces applied and probe area. Since maximum pressure tolerance depends on the contact area, at high force levels a larger area may cause greater discomfort than a smaller area when stimulated with the same magnitude of pressure [13].
- *Pressure discomfort threshold (PDT):* PDT is the limit of pressure above which uncomfortable sensations are felt. Various different methodologies can be used to gauge this parameter. Generally, external pressure is applied on the body part and the threshold when the pressure sensation becomes uncomfortable is recorded. This kind of measurement is useful for calculating the best possible pressure distribution.

II. The Mechanical Characterization of Soft Tissues

Contact stiffness is a key factor in the transmission of loads from the wearable robots to the body of human. Soft tissues present between the human body and wearable robot mediates this transmission. Consequently, performance of wearable robots depends on the important role play by soft tissues. The soft tissues most commonly concerned with the transmission of forces in wearable robot applications are as muscles, skin, ligaments, fat, nerves, tendons and blood vessels. These are non homogeneous, nonlinear viscoelastic, anisotropic, quasi-incompressible tissues when cause to experience major deformation. In the term of mechanical, soft tissues may be described as a combination of viscoelastic and nonlinear elastic elements [14].

WEARABLE ROBOT TECHNOLOGIES

The interface between human and robot can exchange signals in order to drive an action, provide feedback for human motor control and monitor the status of the HRI (Human Robot Interface) and its surroundings. When defining reliable sensors for a wearable application it may be useful to analyze a wide range of candidate measurement devices. Measurement requirements for a system may consider or combine accurate tracking of movement or force, quantification of the review of actuator technologies focuses on principles, practical availability and limitations analyses and compares the most suitable portable energy storage technologies to enable WR technologies to maintain the status of the HRI [15].

The measurement of angular position or a linear displacement of a given joint or segment is a fundamental requirement. The sensing technology that is selected for a wearable robot depends heavily on the specifics of the target application. Various techniques can be considered to build sensors for joint and segment positions in wearable robots. This section discusses a wide range of sensor technologies suitable for wearable applications, including encoders, magnetic sensors, potentiometers, linear variable differential transformers (LVDTs), electro goniometers and MEMS inertial sensing devices.

Encoders: Linear or rotary encoders are electromechanical transducers that measure absolute or relative motion. Linear motion is converted into rotary motion via toothed belts, pinion gearings or cable control. Encoders are classified as incremental or absolute. A relative encoder (also called an incremental encoder) typically uses an optical switch to generate an electrical pulse when radial lines in a disc pass through its field of view External electronic circuits are required to count the pulses and determine the relative angle. This transducer cannot determine the direction of rotation without placing additional sensors. It is more suitable for applications where reliability and resolution are not critical [16].

Potentiometers and LVDTs: Composed of a variable resistive material, potentiometers are the simplest position transducers. An electrical contact causes variation of the measured voltage potential. Rotary potentiometers are suitable for direct measurement of a joint angle with an analogue output. Potential dividers can be used for signal conditioning. The advantage of the potential divider as opposed to a variable resistor series within source is that dividers are capable to vary the output voltage from maximum voltage to ground within the mechanical range of the potentiometer. Problems of signal quantization and sliding noise are the main drawbacks in precision rotary potentiometers [17]. One example of integration in a wearable device is the force controllable ankle foot orthosis to assist drop-foot. Position sensing within an exoskeleton is the linear variable differential transformer (LVDT), which is a relatively simple electrical transducer with high resolution and reliability however, it is less cost-effective at stroke lengths greater than approximately 7 cm. Induction of current through a secondary coil caused by current driven through a primary coil generates a differential voltage .A conditioning circuit (voltage regulator and sine wave generator) is required to drive the primary coil. LVDTs can be configured as rotary devices and are typically available for full-scale travel of up to 120◦ of rotation. Several conditioning solutions are commercial. The main drawback of an LVDT is the nonlinearity of the output signal versus the input measured. Examples of LVDT applications include measurement of probe deflection for teleported Nano manipulation and spring length measurement for force estimation in a gait rehabilitation robot. Table summarizes the main comparative features of the sensor systems described for measurement of joint position [18].

Table 1 - Comparison of Joint Position Transducers

Transducer / Features	Potentiometer	LVDT	Hall effect transducer	Encoder
Linearity (%)	0.2–2	0.1–0.25	1–2	0.01
Resolution (µm)	5	0.25	0.1	0.25
Cost	Low	Medium	Low	High
Life	Low	Medium	High	High
Robustness	Medium\low	Medium	Medium	High

WEARABLE UPPER LIMB ROBOTS

The main function of the arm is to position the hand for functional activities. The hand must be able to reach any point in space, especially any point on the human body, in such a way that the person can manipulate, draw on and move objects towards or away from the body. The upper arm, forearm and hand segments have a high degree of mobility; for a detailed analysis of upper limb kinematics. The upper limb is one of the most anatomically and physiologically complex parts of the body. The upper limb is very important because it is able to execute cognition-driven, expression-driven and manipulation activities.

Wearable orthosis for tremor assessment and suppression (WOTAS): Tremor is a type of movement disorder that has a considerable impact on the quality of people life. It can affect the jaw, face, head, voice or upper and lower extremities. Tremor affecting the upper limbs is of particular interest, since it can be very disabling as regards leading an independent life. It is just a symptom associated with some abnormal cerebral lesions or neurological conditions and degenerative diseases, including Parkinson’s disease, orthostatic tremor, essential tremor, ethylic intoxication, cerebellar diseases, and others. As well as medication, rehabilitation programmers and surgical interventions, it has been shown that the application of biomechanical loading to tremor movement can suppress the effects of tremor on the human body. Starting from this principle, the wearable orthoses for tremor assessment and suppression (WOTAS) device was presented, within the framework of the DRIFTS project, as a promising solution for subjects who cannot use medication to suppress the tremor. The mechanical design of the elbow and wrist joints is similar to other orthotic solutions and is based upon hinges, as they model the anatomical elbow and wrist joints reasonably well. The axis of rotation for the elbow joint is situated on the line between the two epicondyles. The axis of rotation for the wrist joint is situated on the line between the capitates and lunette bones of the corpus. The mechanical design for the pronation–supination movement is more complex.

There are no passive orthoses capable of achieving tremor suppression, because tremor is intrinsically dynamic. Passive orthoses used as tremor suppression mechanisms tend to lose their alignment instead of suppressing tremor. To find out the points of the upper limb where to apply dynamic forces, i.e. the points where the arm supports should be placed for the physical interface between the actuators and the arm, a number of biomechanical and physiological factors have to be considered [19]. 1. Sensor 2. Actuators and 3. Control Architecture.

WEARABLE LOWER LIMB ROBOT

Lower limb and full-body exoskeletons are wearable devices that can be categorized according to their particular application as assistive strategy: for human power augmentation or for human impaired movement [20].

Lower limb exoskeletons for functional compensation of pathological gait:
Assistive systems to restore gait have been proposed as an alternative to functional electrical stimulation (FES) for muscle activation and can be broadly classified as: (a) improved mechanisms such as orthotic hinges with braking or clutching functionalities (b) exoskeleton robots for training limbs in stroke and incomplete paraplegics and (c) control systems acting on a single joint to correct a specific dysfunction This case study presents the biomechanical aspects considered in the design of the exoskeleton, the sensor, actuator and control systems, and the results of its application in clinical cases. It introduces the ESBIRRO exoskeleton, an extension of GAIT consisting of a bilateral leg exoskeleton device aimed at improving current hip–knee–ankle–foot orthoses (HKAFOs) and incorporating the limit-cycle walking strategy [20].

Pathological gait and biomechanical aspects:
Absence of the necessary muscle activity on body segments can lead to bodily collapse. To overcome this problem, the robotic orthosis must compensate for the missing moment of force around the joint with the aim of stabilizing and compensating for the lack of muscle strength. The exoskeleton with the actuators should apply the external joint moment to the body segments in an appropriate way. Here the most suitable external force systems for the two joints are considered [20].

CONCLUSIONS

As per the above literature, emphasis is laid on this dual interaction and biomechatronic approach to wearable robotics. Since bio inspiration is a fundamental part of bio mechatronics, particular human biological and functional structures, may influence the design of wearable robots. Human mechanics is then introduced as a source of information for designing wearable robots. Increasing miniaturization, chiefly in component design, so that more compact sensor, actuator and energy storage technologies can be adopted. Miniaturization will pave the way for lower energy consumption by these technologies. This is possible to establish wireless communication networks from which wearable robotics can acquire advantage. Physical human robot interaction and cognitive interaction should naturally detect user intention as an input to control the robot. Where the borderline between artificial and biological components eventually disappears and the biological and artificial components are closely interfaced. Wearable devices modify dry heat exchange by convection, conduction and radiation and the transfer of damp by evaporation. Such modifications can increase sweating through heat accumulation in the body parts covered by a wearable device; sweat can accumulate between the body and the wearable device and may cause discomfort and maceration of the epidermis.

REFERENCES

[1] Abbott Alison, Biological Robotics: Working out the Bugs, *Nature 445* **2007**, 7125: 250-253.
[2] Pons, José L, *Emerging Actuator Technologies: A Micromechatronic Approach*, John Wiley & Sons, **2005.**
[3] Rabischong, P, Robotics for the Handicap.ed, *Proceedings of the IFAC on Control Aspects of Prosthetics and Orthotics*, **1982**, p. 163–167.
[4] Alami R, A Albu-Schaeffer, A Bicchi, R Bischoff, R Chatila, A De Luca, A De Santis et al, Safe and Dependable Physical Human-Robot Interaction in Anthropic Domains: State of the Art and Challenges, *Proc IROS*, **2006**, Vol 6, No 1.
[5] Rocon E, A F Ruiz, R Raya, A Schiele, J L Pons, J M Belda-Lois, R Poveda, M J Vivas and J C Moreno, *Human–Robot Physical Interaction*, Wearable Robots: Biomechatronic Exoskeletons, **2008**, p. 127-163.
[6] Despopoulos A and S Silbernagl, *Color Atlas of Physiology*, 4th edition, Thiem Medical Publisher, **1991.**
[7] Schiele A Vander and Helm FCT, Kinematic Design to Improve Ergonomics in Human Machine Interaction, *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, **2006**, 14(4): 456–469.
[8] Lemay M, Hogan N and Dorsten JW, Issues in Impedance Selection and Input Devices for Multipoint Powered Orthotics, *IEEE Transactions on Rehabilitation Engineering*, **1998,** 6(1): 102–105.
[9] Sasaki D, Noritsugu T and Takaiwa M, Development of Active Support Splint Driven by Pneumatic Soft Actuator (ASSIST), *Proceedings of the IEEE International Conference on Robotics and Automation*, **2005**, p. 520–525.
[10] Landis E, *Micro-Injection Studies of Capillary Blood Pressure in Human Skin*, Heart, **1930**, 15: 209–228.
[11] Krouskop TA, Williams R, Krebs M, Herszkowicz MS and Garber S, Effectiveness of Mattress Overlays in Reducing Interface Pressures during Recumbency, *Journal of Rehabilitation Research and Development*, **1985**, 22(3): 7–10.
[12] Dandekar K, Raju BI and Srinivasan MA, 3-D Finite-Element Models of Human and Monkey Fingertips to Investigate the Mechanics of Tactile Sense, *Journal of Biomechanical Engineering*, **2003**, 125: 682–691.
[13] Goonetilleke RS and Eng T, Contact Area Effects on Discomfort, *Proceedings of the 38th Human Factors and Ergonomics Society Conference*, **1994**, p. 688–690.
[14] Maurel W, *3D Modelling of The Human Upper Limb Including the Biomechanics of Joints, Muscles and Soft Tissues*, PhD Thesis, Ecole Polytechnique Federale de Lausanne, Switzerland, **1998.**
[15] Moreno J, Bueno L, Pons J, Baydal-Bertomeu J M, Belda-Lois J M, Prat J M and Barberá R, Wearable Robot Technologies, *Wearable Robots: Biomechatronic Exoskeletons*, **2008**, 165-200.
[16] Sooyong L, Jangwook L, Woojin C, Munsang K, Chong-Won L and Mignon P, A New Exoskeleton Type Masterarm with Force Reflection: Controller and Integration, *Proceedings of the IEEE/RSJ International Conference on Intelligent Robots and Systems*, **1999**, vol 3, 1438–1443.
[17] Blaya J and Herr H, Adaptive Control of a Variable-Impedance Ankle–Foot Orthosis to Assist Drop Foot Gait, *IEEE Transactions on Neural Systems Rehabilitation Engineering*, **2004,** 12: 24–31.
[18] Veneman JF, Ekkelenkamp R, Kruidhof R, Vander Helm, FCT and van der Kooij H, A Series Elastic and Bowden-Cable-Based Actuation System for use as Torque Actuator in Exoskeleton-Type Robots, *International Journal of Robotics Research*, **2006**, 25: 261–281.
[19] Pons J L, E Rocon, A F Ruiz and J C Moreno, Upper-Limb Robotic Rehabilitation Exoskeleton: Tremor Suppression, *INTECH Open Access Publisher*, **2007.**
[20] Moreno J C, E Turowska, J L Pons, D P Ferris, K De Roy, K Yamamoto, T F Bastos-Filho et al, Wearable Lower Limb and Full-Body Robots, *Wearable Robots: Biomechatronic Exoskeletons*, **2008,** p. 283-321.