



US006379393B1

(12) **United States Patent**
Mavroidis et al.

(10) **Patent No.:** **US 6,379,393 B1**
(45) **Date of Patent:** **Apr. 30, 2002**

(54) **PROSTHETIC, ORTHOTIC, AND OTHER REHABILITATIVE ROBOTIC ASSISTIVE DEVICES ACTUATED BY SMART MATERIALS**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/395,623**

(22) Filed: **Sep. 14, 1999**

Related U.S. Application Data

(60) Provisional application No. 60/100,127, filed on Sep. 14, 1998.

(51) **Int. Cl.**⁷ **A61F 2/70**; A61F 2/66

(52) **U.S. Cl.** **623/25**; 623/57

(58) **Field of Search** 623/25, 24, 57, 623/58, 59, 60, 61, 63, 64, 66

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,866,246	A *	2/1975	Seamore et al.	623/25
4,246,661	A *	1/1981	Pinson	623/25
4,685,928	A *	8/1987	Yaeger	623/64
5,062,857	A *	11/1991	Berringer et al.	623/25
5,314,495	A	5/1994	Kovacs	
5,413,611	A	5/1995	Haslam, II et al.	
5,888,213	A	3/1999	Sears et al.	
6,090,139	A *	7/2000	Lemelson	623/2.1
6,109,852	A *	8/2000	Shahinpoor et al.	414/1

OTHER PUBLICATIONS

“A Clinical Experience with a Hierarchically Controlled Myoelectric Hand Prosthesis with Vibro-Tactile Feedback”. Kyberd, P.J., Mustapha, N., Chappell, P.H., *Prosthetics and Orthotics International*, 1993, 17, 56-64.

“Shape Memory Alloy Actuated Robot Prostheses: Initial Experiments”. Pfeiffer, C., DeLaurentis, K. and Mavroidis, C., *Proceedings of the 1999 IEEE International Conference of Robotics and Automation*, Detroit, MI, May 1999.

(List continued on next page.)

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(57) **ABSTRACT**

The present invention is directed to state-of-the-art medical devices using smart materials and related emerging technologies under development for robotics. In particular, the present invention is directed to the development of rehabilitative (i.e. prosthetic, orthotic, surgical) devices actuated by smart material artificial muscles to increase the dexterity and agility of an artificial limb or a dysfunctional body part, so that movement of the limb more accurately simulates movement of a human appendage. A kinetic assistive device is provided which is constructed of a lightweight material (such as aluminum) and has a plurality of smart material actuators attached thereto. A system for detecting environmental stimulation of the device is provided in electrical communication with such actuators to effect movement of said device in response to detection signals produced thereby. The system includes a plurality of sensors, such as proximity detectors, accelerometers, tactile sensors and the like which are mounted on the assistive device and which provide data to computer-controlled command circuitry. This data can be encoded and used to control the movement of the assistive device via the actuators to more accurately predict the performance of the device in relation to that of an actual human limb.

66 Claims, 31 Drawing Sheets

