Mobile Multi Joint Arm Therapy Exoskelton Robot with Outcome Evaluation and Remote Diagnosis

Arun Chandrakumar K[1], Prof. V. Gopi[2]

[1] II ME Embedded System Technologies, Anna University Chennai, PSNCET, Thirunelveli, Thirunelveli, Tamilnadu, India
[2]Professor, Electronics and Communication Department, Anna University Chennai, PSNCET, Thirunelveli, Tamilnadu, India

Abstract—*Stroke is a major cause of adult disability. Stroke is caused by an interruption of blood flow to the brain resulting in damage to brain cells and can be fatal. The survivors of stroke can experience paralysis or loss of physical strength on one side of the body (hemiparesis) as well as memory problems making it difficult to perform activities of daily living (ADL). Rehabilitation is the main treatment to these disabilities, a process which allows the stroke patient to relearn the best possible use of their limbs and regain independence.*

Here propose an upper limb exoskeleton robot, the IntelliArm[1] which can control the shoulder, elbow, and wrist, with 1) quantitative, objective, and comprehensive multi-joint neuromechanical pre-evaluation capabilities aiding multi-joint/DOF diagnosis for individual patients; 2) strenuous and safe passive stretching of hypertonic/deformed arm for loosening up muscles/joints based on the robot-aided diagnosis; 3) (assistive/resistive) active reaching training after passive stretching for regaining/improving motor control ability; and 4) quantitative, objective, and comprehensive neuromechanical outcome evaluation at the level of individual joints/DOFs, multiple joints, and whole arm.

Keywords: Neurorehabilitation, rehabilitation robotics, Robot-aided diagnosis, robot-assisted therapy. DOF

I. INTRODUCTION

Robotics and mechatronics technology brings a lot of benefits not only in industries, but also in welfare and medicine. It is important that physically weak people are able to take care of themselves in the aging society. We use the exoskeleton robots in different applications such as Military, human amplifiers, defence field etc. around the world. But recent years the researches are concentrating to the field of neuro rehabilitation aiding robots. Diagnosis, physical therapy, and outcome evaluation are important and essential steps of rehabilitation, and are, thus, preferred to be integrated for effective treatment of complex interrelated symptoms of neurological impairment.

As the population of stroke patients continues to grow, providing adequate rehabilitation treatment to patients can be expected to become more and more difficult due to its labour intensive nature. Exoskeleton robots have the potential to meet this growing demand which conventional manual therapy is struggling to cope with. These robots are designed to be worn by the patient, having a similar kinematic structure to the human limb.

Compared to manual therapy, exoskeletons have the potential to provide intensive rehabilitation consistently for a longer duration [6] and irrespective of the skills and fatigue level of the therapist. Exoskeletons may be able to treat the patient without the presence of the therapist, enabling more frequent treatment and potentially reducing costs. In addition, it is possible for an exoskeleton to accurately measure quantitative data to evaluate the patient’s condition. The use of specially designed virtual games with the exoskeleton can provide a more entertaining therapy experience, promoting the patient to put in their own effort into the exercises [7].

There is much less research done on robot-aided diagnosis of sophisticated upper limb multi-joint and multi-DOF (MJMD) impairments, that is simultaneous diagnosis of shoulder, elbow, and wrist joints involving nonhorizontal planes are associated with passive and active movements in stroke survivors.

Rehabilitation robot researches focused on various types robot-assisted therapy:[1] passive stretching to reduce joint/muscle stiffness, excessive cross-joint/DOF coupling, and to increase muscle strength, passive ROM (PROM) and active ROM (AROM) by loosening up joints and muscles that may have shortened muscle fascicles and left-shifted tension-length relationship and (assistive/resistive) active movement training, on which majority of the researches focused to recover motor functions.

Exoskeletons have a structure which resembles the human upper limb, having robot joint axes that match the upper limb joint axes and can be attached to the upper limb at multiple locations. Multiple interfaces may allow the exoskeleton to fully determine the upper limb posture and controlled torques to be applied to each joint separately. It may be possible for exoskeletons to target specific muscles for training by generating a calculated combination of torques at certain joints

The purpose of this paper was to address the need and develop a mobile multijoint arm therapy exoskeleton robotrobot, the IntelliArm, aiming to conduct four-step neurorehabilitation

II. RELATED WORK

A systematic comparison of the devices is difficult because of the variability of the robotics and movement's complexity of the upper limb. Robotics allows patients to intensify repetitive task specific training programme in neurorehabilitation.[2] For out-patients speed training on treadmill (TT) with body weight support (BWS) improves walking velocity and endurance, although the personnel requirements, necessary to provide TT, may limit its application. For the upper extremity there are also exoskeleton (e.g. Armor, WREX) and end-effector systems3 (e.g. MIT-Manus, Bi-Manu-Track, Reha-Slide, Amadeo).

Exoskeletal robots in order to assist the motion of physically weak persons such as elderly persons or handicapped persons. In our previous research, a prototype
of a two degree of freedom exoskeletal robots for shoulder joint motion assist have been developed since the shoulder motion is especially important for people to take care of themselves in everyday life. An effective fuzzy-neuro controller, a moving mechanism of the center of rotation (CR) of the shoulder joint of the exoskeletal robot, and intelligent interface in order to realize a practical and effective exoskeletal robot for shoulder joint motion assist.

The shoulder is the most mobile joint in the human body. While this joint is normally modelled as a single ball-and-socket connection, in reality it is a complex series of joints packaged in a compact volume [3]. Movement of the clavicle, scapula, and humerus all contribute to the rotation and translation of the shoulder [4]. Due to the complexity and mobility of the shoulder, it is the joint in the upper extremity most prone to injury. While injury to the shoulder girdle can usually be treated with physical therapy, traditional therapy techniques are limited in their ability to control the motion of the shoulder and to accurately measure the joint stresses imposed by exercise.

III. PROPOSED SYSTEM

This paper proposes an upper limb exoskeleton robot for rehabilitation treatment of patients with neuromuscular disorders [5]. Robotic therapy research has shifted towards exoskeleton robots. Exoskeletons have a structure which resembles the human upper limb, having robot joint axes that match the upper limb joint axes. Exoskeletons are designed to operate side by side with the human upper limb, and therefore can be attached to the upper limb at multiple locations.

The IntelliArm can independently control the following four DOFs of human arm [1]: the shoulder horizontal adduction-abduction (H.Add-H.Abd)[1], elbow flexion-extension (Fl-Ex) in horizontal plane, forearm pronation-supination (Pr-Su), and wrist Fl-Ex [Fig. 1(b) and (c)]. For shoulder H.Add-H.Abd, elbow Fl-Ex, and wrist Fl-Ex DOFs, each DOF is driven by a dc motor with a built-in encoder and a zero-backlash harmonic gear (HarmonicDrive) system aligned with the corresponding human arm joint axis. Since stroke survivors often develop pronation deformity of the forearm, it is important to control and move the forearm in a proper range of pronation. The forearm was mounted to a circular guide through a forearm brace. For the controlled movement of forearm Pr-Su DOF, a dc motor with a built-in encoder is used to transmit the power through two stages of transmission: a cable-driven transmission, output shaft of which is connected to the circular guide by cables, after a precision harmonic gear located between the cable-driven transmission and the motor shaft.

A six-DOF—four active DOFs and two passive DOFs—upper limb neurorehabilitation exoskeleton robot,
the IntelliArm, was developed for clinicians to aid MJMD diagnosis and outcome evaluation as well as to assist physical therapy based on the robot-aided diagnosis.

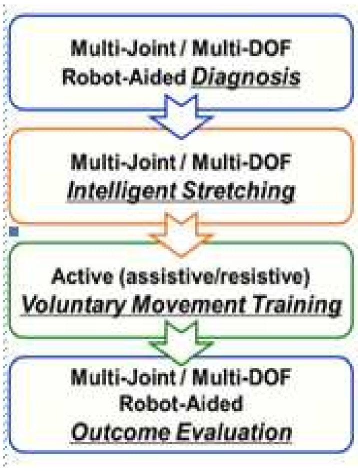

Fig.1. Steps for the robot mediated upperlimb neuro rehabilitation.

For pre-evaluation, physical therapy, and outcome evaluation, the upper arm, forearm, and hand of the subject were then strapped to the corresponding braces while aligning the subject's shoulder, elbow, and wrist joint axes with the corresponding IntelliArm's mechanical axes. The IntelliArm's elbow and wrist flexion-extension mechanical axes, where the corresponding two servomotors are located, can be adjusted along the upper arm and forearm of the IntelliArm for different human arm lengths.

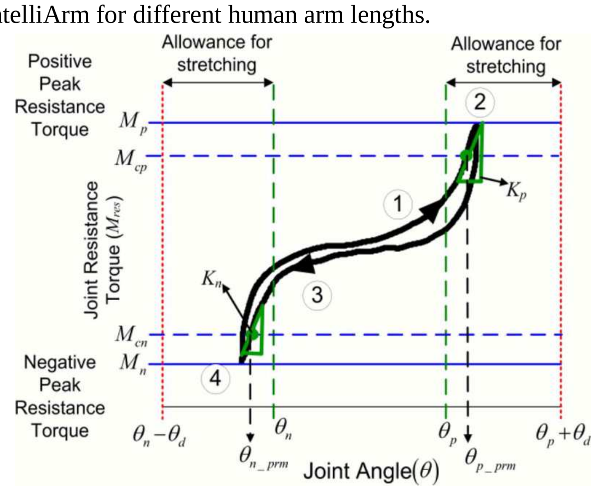

Fig. 2. Angle-resistance torque relationship curve of a joint.

To minimize reflex contributions and manifest the passive mechanical changes of muscles/joints the IntelliArm passively moved one targeted joint/DOF at a time among the four controlled DOFs of the subject's arm throughout its ROM with a controlled slow speed about five cycles, until its joint/DOF RT, , reached its pre-specified positive peak RT (PRT), , or negative PRT , (paths 1 and 3 in Fig. 2); and if reached either or , then the movement direction was reversed after few seconds (s) of holding of the joint/DOF at the position. During this individual joint/DOF movement, all other nontargeted joints/DOFs were immobilized at their selected initial positions, and the torques and angles at all four joints/DOFs were recorded simultaneously.

Compared to the present system, it has some additional features, such as voice control, Xbee, RFID reader. The voice control provides the user to operate the system. The existing system has no control provided in user. Xbee is used for the transmission and reception of information from the machine and the database. RFID is used for login the machine. .The main drawback of the present system does not provide uniqueness because different patients have different stroke values, so the operator is manually entering the data's of every patients. This drawback is overcome in the proposed system. In the proposed system every user have provide an user id, when a user is entered in to the machine, the id is entered and a signal corresponding to this id is sent to the main database of the hospital .If it is a valid id then the corresponding stoke values are send back to the machine through a transceiver unit. These values are loaded into the controller and machine starts to run. The proposed system also provides an additional control to the user through the voice. In the present system only an on/off control is provided by the user. The user cannot set the number of cycles of operation, but in the proposed system we have set the cycles of operation through a voice input.

IV. SOFTWARE & HARDWARE DETAILS

The HI-TECH C Compiler for PIC10/12/16 MCUs is a free-standing, optimizing ANSI C compiler. It supports all PIC10, PIC12 and PIC16 series devices, as well as the PIC14000 device and the enhanced Mid-Range PIC® MCU architecture.

The command-line driver is called PICC™ and is the application that can be invoked to perform all aspects of compilation, including C code generation, assembly and link steps. Even if we use an IDE to assist with compilation, the IDE will ultimately call PICC.

Although the compiler applications can be called explicitly from the command line, using PICC is the recommended way to use the compiler as it hides the complexity of all the internal applications used and provides a consistent interface for all compilation steps. PICC distinguishes source files, intermediate files and library files solely by the file-type, or extension. HI-TECH C Compiler for PIC10/12/16 MCUs supports a number of special features and extensions to the C language which are designed to ease the task of producing ROM-based applications.

The macro assembler included with HI-TECH C PRO for PIC10/12/16 MCU Family assembles source files for PIC 10/12/14/16/17 MCUs. It describes the usage of the assembler and the directives (assembler pseudo-ops and controls) accepted by the assembler in the source files. Although the term "assembler" is almost universally used to describe the tool which converts human-readable mnemonics into machine code, both "assembler" and "assembly" are used to describe the source code which such a tool reads.

The application name of the linker is HLINK. In most instances it will not be necessary to invoke the linker directly, as the compiler driver, PICC, will automatically execute the linker with all necessary arguments. Using the linker directly is not simple, and should be attempted only by those with a sound knowledge of the compiler and linking in general. The compiler often makes assumptions about the way in which the program will be linked. If the aspects are not linked correctly, code failure may result. If it is absolutely necessary to use the linker directly, the best way to start is to copy the linker arguments constructed by the compiler driver, and modify them as appropriate. This will ensure that the necessary startup module and arguments are present.

V. ADVANTAGES

There are many advantages of exoskeletons and this number can only be expected to grow in the future as the technology expands. Currently the two biggest applications in the exoskeleton are the military and the medical field.

Israeli paratrooper, Radi Kaiof, has been paralyzed for the past 20 years and recently has been able to use the ReWalk exoskeleton designed by Israeli engineer Amit Goffer. It allows him to be able to stand and walk around out of his wheelchair. This is something currently impossible with any other technology. The benefits of a technology that can help paralyzed individuals to walk are endless. First of all, it improves their health because the body is meant to work in an upright posture. Secondly it helps people psychologically. In military application a fully functional exoskeletons suit could help soldiers to load weapons on to planes, move other equipment, and even punch through doors and barriers. The future and success of military grade exoskeletons is dependent on the ability of engineers to develop suits that are more power efficient and a standalone power source that can provide power for an extended period of time.

Another advantage of exoskeletons may be in the workplace. Factory workers using exoskeletons could lift large amounts of weight all day without fatigue. This would allow for more work to be done by fewer workers and increase productivity while at the same time reducing strain on the worker. This could also lead to several disadvantages similar to what we are seeing with robot technology in factories today; the need for less workers means less jobs available.

Ease of Mobility is the Challenging future of this project. All the human arm joint angles and torques of interest can be directly measured and computed. Voice recognized controllable command operation Range of motion (ROM) with exoskeleton robots might be larger than that with EE type robots. The EMG signal based enhanced operation is the research side of my project.

VI. RESULT

The IntelliArm's MJMD evaluation capabilities aiding diagnosis can provide valuable information on 1) which joints and which DOFs have significant changes in the neuro-mechanical properties; 2) which joints lose independent control [e.g., loss of individuation with NRMDS, which may have a potential correlation with MSS ; 3) what are the abnormal couplings; and 4) whether the impairment is due to deficits in passive muscle properties or active control capabilities. Thus, the clinicians can make more informed decision on the type, intensity, and duration of therapy of each patient. Moreover, the prescribed type, intensity, and duration of therapy can be realized with the same robot by utilizing its passive stretching and (assistive/resistive) active movement training capabilities. Further, the outcome of the therapy can also be evaluated with the same robot in a consistent manner. In short, the IntelliArm may possibly be used for all steps of neurorehabilitation seamlessly as a convenient tool.

VII. CONCLUSION

An upper limb exoskeleton neurorehabilitation robot, the IntelliArm, was developed, aiming to support clinicians and patients in all four steps of neurorehabilitation (Fig. 1) with the following novel integrated capabilities: 1) quantitative, objective and comprehensive MJMD pre-evaluation capabilities aiding diagnosis (e.g., single and cross-joint evaluation of PROM and stiffness in passive movement, and loss of individuation in active movement) for individual patients; 2) strenuous and safe passive stretching of hypertonic/deformed arm for loosening muscles/joints based on the robot-aided diagnosis; 3) (assistive/ resistive) active reaching training after passive stretching for regaining/improving motor control ability; and 4) quantitative, objective, and comprehensive outcome evaluation at the level of individual joints/DOFs, multiple joints/DOFs, and whole arm.

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