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Review of Sensing and Robot Solutions to Stroke Rehabilitation, Focusing on Upper Limbs

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***Abstract*—The abstract goes here.**

***Index Terms*—Stroke, robot, sensors.**

I. Introduction

THIS review is intended as a resource for people wishing to do further research into robot or sensor systems for rehabilitation of stroke victims with upper limb hemiplegia. Systems based on functional electrical stimulation (FES) will not be covered in this review.

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A. *Effects of a Stroke*

1) Right or Left Hemispherical Stroke: A stroke in the right or left hemispheres of the brain can cause partial or full paralysis down the opposite side of the body (hemiplegia). It can also cause problems with short term memory [1].

Right-hemispherical strokes can also cause the victim to suffer a loss of spatial awareness and an impairment of judgment that manifests as impulsiveness [1].

Left-hemispherical strokes can cause the victim to develop problems with language (aphasia) and may effect their judgment in the opposite way to right-hemispherical victims, with them becoming ponderous and unsure [1].

2) Cerebellar Stroke: A cerebellar stroke affects balance and co-ordination and can cause dizziness and nausea [1], [2].

3) Brain Stem Stroke: Brain stem strokes are the most dangerous as this is the part of the brain that controls essential functions such as your heart, breathing and swallowing [1], [2].

A stroke in the brain stem can also cause full or partial paralysis in either or both sides of the body [1].

B. *Traditional Rehabilitation of Stroke Patients*

The most basic aim of stroke victim rehabilitation is to allow the victim to regain their independence. The management of stroke patients is broken down into three areas: acute care, rehabilitation care and community care [3].

1) Acute Care: This is the stage of care that covers preventing further strokes and making sure the patient is breathing and their heart is beating. The patient's bladder and bowel function should be checked at this stage along with their ability to perform the actions associated with such. The patient should also be brought to a point whereby they can move, albeit with impairments. The last element of care at this stage is emotional support to the patient and their family [3].

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2) Rehabilitation Care: This stage of care is all about improvement, it's about setting goals, developing a plan and then monitoring the patient's progress against these. It is about getting the patient back on their way towards normality or at least towards 'functional independence'. It is also about getting the patient to a stage were they're ready to go home [3].

There are several tests through which the patient's motor and sense function can be evaluated, a popular one is the fuglmeyer test which scores the patient out of 100 for the whole body (66 for upper limbs, 34 for legs). This score can then be used to measure improvement over the course of treatment. [REF]

3) Community Care: This stage of care is all about reintegrating the patient, into the community and potentially into work as well if they had a job. It is also about providing support to the patient and to their family and any carers they might have. The patient should also continue with their rehabilitation plan as it is likely that further improvement can still be achieved [3].

C. *How Sensing / Robots can Help*

Sensor systems for upper limb rehabilitation as they exist at the moment are systems for monitoring position of all or part of the arm, often linked to a game or simulation in a virtual environment. [REF] Robotic systems are similar but are able to actively move the patient's limb through some or all of the degrees of freedom available to it. [REF]

These robots are helpful to rehabilitation because they can provide detailed feedback which provides useful information to the physiotherapist and potentially a sense of achievement to the patient, allowing them to monitor their own progress. Linking the system to a game or simulated environment also helps to improve the patient's motivation. [REF]

There is evidence that use of robots in rehabilitation leads to functional improvements in the patient but there is some question as to whether this is much of an improvement over traditional methods (i.e. not involving a robot). [REF]

1) What they need to be able to do: At the most basic level the system needs to be able to accurately measure and report the position of the limb (or section of limb) that it is to be used to aid in the rehabilitation of.

The system also needs to be safe to use, for sensor systems this means not being sharp or too heavy and for robotic systems this also means that the range of movement it can be driven over needs to be the same as that of the human arm and there should be controls in place to stop the system if it is likely to become dangerous. [REF]

In order for the system to be more effective as a rehabilitation tool it should also be able to support the limb in order to help reduce the likelihood of injury to the patient and it should be comfortable to use for extended periods. [REF]

It has also been shown to be helpful for the system to incorporate some form of interactive virtual environment, such as a game, in order to increase patient motivation and maintain their cooperation. [REF]

II. Sensor Systems

THERE are a wide range of sensors available which can prove useful in mapping the position and other qualities of a limb. [REF] For this study will will consider sensors as the individual components and sensor systems as a collection of such that can be used to gain a more complete picture of the position and activity of a limb.

A. Position/Movement Sensors

1) The sensors: The most common sensor type used for this purpose is the accelerometer. Accelerometers measure the effect of acceleration on a mass in free-fall. A standard construction method for accelerometers for use at the correct range and frequency of human motion is to have a test mass on a damped spring and have the deflection of this mass move one plate of a capacitor thus changing its capacitance [REF: acc].

These devices are usually MEMs devices constructed in silicone but it is also possible to manufacture larger devices (mm scale) using PCB techniques at potentially lower cost [REF: acc].

It is also interesting to note that an accelerometer at rest will show an acceleration of 1 g upwards as the acceleration it measures is relative to the free-falling mass and from the reference point of said mass the casing of the accelerometer appears to be acceleration upwards at a rate of 1g.

2) How they're used: Most usually accelerometers are used to measure the acceleration of whatever they're attached to. If the initial position and velocity are known then it should be possible to calculate the position and velocity from the acceleration via integration although the errors accrued in this process may make using accelerometers this way to estimate body position may not be feasible [REF: feasible].

One system that uses accelerometers to recognise the action being performed by the patient is described in [REFto: upper limb motion recognition...]. This system uses two 3-axis accelerometers one attached at the wrist and one above the bicep [REF]. Both these sensors transmit their values via wireless modules to a computer where these values are analysed [REF]. This system doesn't map limb position into 3D space but instead uses the output of the sensors whilst the patient is performing an action from their rehabilitation routine and uses this to classify the action [REF].

B. Angle Sensors

1) The sensors: The most usual method for measuring angle is with a potentiometer as their resistance changes as they are rotated which is simplicity itself to measure. In order to accurately measure the angle of a joint by this method the potentiometer has to be properly aligned with the joint. Misalignment is one of the many causes of error in systems that use such angle sensors that has to be carefully compensated for [REF].

It is possible to use accelerometers as angle sensors relative to gravity, this could also be described as a tilt sensor. Angle of a joint can be measured by putting a sensor either side both aligned and calculating the difference [REF: anglesacc].

2) How they're used: What they're used for and example of systems using them this way ...

C. Force Sensors

1) The sensors: Mapping force (gripping/pushing): QTCs, force resistors, ...

2) How they're used: What they're used for and example of systems using them this way ...

III. Robotic Systems

ROBOTIC systems are systems that are able to not only measure the position of the limb but also to actively move it. This allows such systems to physically guide a patient's arm through the required movement. It also allows the system to provide varying amounts of support to the patient as they perform an action. [REF]

A. End-effector

An end-effector system is a system that is anchored at one end and measures the position of the other end relative to this. [REF] The end that is free to move is usually attached to the patient's wrist and thus it's position in 3d space can be tracked and controlled (via actuation) which allows the system to monitor the performance of an action and show variations. [REF]

[examples of end-effector systems and what they can do]

End-effector systems with a single attachment point give no information on the position and alignment of the rest of the limb. Some systems exist with two contact points (e.g. the wrist and the upper arm) in order to get more information but this is still limited. [REF]

B. Exoskeleton

Exoskeletal systems are systems that are built around shape and degrees of freedom of the limb. [REF] They allow much more information to be gathered about the limb as they allow for more sensors to be placed and more degrees of freedom to be monitored and controlled. [REF] It is, however, harder to provide support to the limb through a pure exoskeletal system, for this reason the systems are often hybrids; with one end of the exoskeleton attached to and end-effector system. [REF]

One such hybrid system is the ARMin rehabilitation robot which has an end-effector system for the shoulder attached to an exoskeleton for the elbow and the forearm. [REF] The system has 4 active degrees of freedom and 2 passive with which to measure and guide the position and movement of the patient's arm. [REF] The ARMin system is also highly adjustable at many points in its structure so that it can be changed to fit patients of different sizes. [REF]

The ARMin system is also and example of a system that uses interactive games in order to increase patient's motivation and compliance. [REF] The ARMin system was piloted on healthy subjects and the results of a questionnaire following this provide evidence for incorporating games increasing motivation. [REF]

IV. Vision Based Systems

V. Discussion

Discussion goes here

VI. Conclusion

The conclusion goes here.

Appendix A
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Appendix one text goes here.

Appendix B

Appendix two text goes here.

Acknowledgment

The authors would like to thank...

References

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John Charlesworth Biography text here.