*What is stroke*

Stroke, also known as Cerebrovascular Accident, is the leading cause of disability in the UK according to the Stroke Association (2018). Stroke is classified by 2 mechanisms: Haemorrhagic Stroke and Ischaemic Stroke. Haemorrhagic Stroke occurs when an artery in the brain ruptures, often as a result of high blood pressure. Ischaemic Stroke occurs due to the blockage of an artery in the brain, usually caused by a blood clot or fatty deposits. Both mechanisms lead to cell damage or cell death in the affected region of the brain because of a lack of oxygen (Moskowitz et al, 2010).

The symptoms of Stroke are wide ranging and dependant on which region of the brain has been affected. Different regions of the brain control different behaviour, as shown by figure number:

|  |
| --- |
|  |
| Figure number: Regions of the brain associated with behaviour (Stroke Association, 2018) |

Common symptoms include motor impairment along one side of the body, impairment to speech, difficulties swallowing and impairment to memory. It was found in a study by Sommerfeld et al (2004) that up to 80% of stroke patients initially experience motor difficulties. Van Peppen et al (2004) performed a systematic review which showed that physical rehabilitation is more effective when performed intensively and early after Stroke.

*How prevalent is stroke*

Stroke can occur in people of any age, but it is shown by the (Stroke Association, 2018) that the likelihood of an individual having a Stroke increases with age. According to the Office of National Statistics (2018) the population of the UK is aging, with 26.5% of the population projected to be aged 65 or older by 2041, as shown by figure number:

|  |
| --- |
|  |
| Figure number: Aging population in the UK |

This means that it is reasonable to expect that the total number of Strokes will increase. This will, of course, increase the demand upon the NHS and rehabilitation services.

*Rehabilitation after stroke*

Placeholder

Break from here

*High-level Control Strategy*

*Admittance and Impedance control – accounting for the effects of human-robot interaction.*

The case of a robot physiotherapy device interacting with a human patient should be considered as a coupled mechanical system [13]. This means that the use of a force control strategy or position control strategy is insufficient, since they not account for interaction forces with the patient and are thus inherently unsafe. In order to account for interaction forces, the majority of rehabilitation robotic devices use impedance or admittance control as the low-level control strategy. Impedance and Admittance control involve modulating the dynamic behaviour of the robot alongside position or force control, according to Hogan [Impedance Control: An Approach to Manipulation parts 1-3].

It is generally agreed that a physical system which accepts force inputs and produces position outputs is defined as an admittance [35] [Impedance Control: An Approach to Manipulation parts 1-3]. Hogan further states that Mechanical Admittance can be loosely considered as a dynamic extension of compliance. A physical system which accepts position inputs and produces force outputs is defines as an impedance [35] [Impedance Control: An Approach to Manipulation parts 1-3]. Hogan further states that Mechanical Admittance can be loosely considered as a dynamic extension of stiffness.

The end effector of a mechanically coupled robot is subject to physical constraints, so it is either an admittance or an impedance. If the environment is an admittance, the end effector must be an impedance according to Hogan [Impedance Control of industrial robots].

*What is Admittance Control*

Admittance control is a strategy whereby the force exerted on the end effector is measured, and the robot provides the corresponding displacement [13]. According to Culmer et al [20], it is a common practice to define the relationship as a mass-spring-damper as shown by equation number:

|  |  |
| --- | --- |
|  | Eqn number |

Admittance Control is the low-level design strategy implemented in LIST ROBOTS.

*What is Impedance Control*

Impedance control is a strategy whereby the motion of the end effector is measured, and the robot provides the corresponding force-feedback [13]. As with Admittance control, according to Culmer et al [20], it is a common practice to define the relationship as a mass-spring-damper as shown by equation number:

|  |  |
| --- | --- |
|  | Eqn number |

Impedance Control is the low-level design strategy implemented in LIST ROBOTS.

*A comparison of use cases*

It is agreed by A LOT OF PEOPLE [13] that the advantages and disadvantages of Impedance and Admittance control systems are opposite, which makes sense considering that the definition of a mechanical Impedance is opposite to the definition of a mechanical Admittance.

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