Literature Review Overview

1. **Intuitive Control of a Planar Bipedal Walking Robot (1998)**

Not particularly useful since the context is too far removed from that of the MyPAM. Also, very old. Contains a couple of useful descriptions and definitions:

“An intuitive controller is one which is based on human intuition of the system and an idea of what is going on” – Not actually based in maths but instead based on an intuitive understanding of a system (a bit like fuzzy logic).

**“**A PD (Proportional-Derivative) controller is often described as a controller which pushes in the direction of the error and pushes back with increasing velocity to take some energy out and prevent the system from going too fast. Add the I (Integral) term and the controller keeps pushing harder and harder in the direction of the error until it finally goes away.”

1. **Elastic Bands: Connecting Path Planning and Control (1993)**

Not useful. Proposes a strategy to allow the integration of local obstacle avoidance (by sensor feedback control) with global path planning for mobile robotics. There are no local obstacles for the MyPAM.

1. **The Pendubot: A Mechatronic System for Control Research and Education**

This paper describes the control strategy for an underactuated vertical pendulum. This paper is of little use since it describes the balancing control algorithm, which is not relevant to my application.

1. **On the identification of Inertial Parameters of Robots**

This paper presents a new algorithm for the identification of the inertial parameters and friction coefficients of robots. The algorithm is computationally simple, particularly it does not require to measure or to calculate the joint accelerations.

1. **Modelling, Identification and Control of a Redundant Planar 2-DOF Parallel Manipulator**

Found and downloaded. It looks to contain some useful details and is worthy of further detailed work.

Parallel Manipulators are more complicated, however, so it is not likely that there will be any useful control strategy.

1. **Dynamics and control of a planar 3-DOF parallel manipulator with actuation redundancy**

Actually looks very useful for peripheral knowledge. Describes in good detail Jacobean Matrix implementation for inverse kinematics. Not a relevant control strategy for a 2DOF arm, especially one that is not over actuated.

1. **PERFORMANCE EVALUATION OF TWO-DEGREE-OFFREEDOM PLANAR PARALLEL ROBOTS**

Very much not useful or relevant. No control theories at all.

1. **Extending the capabilities of robotic manipulators using trajectory optimization**

Contains some very useful references that describe and explain trajectory planning for robotic manipulators. I also came across Pontryagin’s maximum principle.

The entire paper is actually very useful and deserves a more detailed review/ source review.

1. **Motion analysis of manipulators with uncertainty in kinematic parameters**

Relatively useful document, deserving of further reading.

1. **A Paradigm shift for rehabilitation robotics**

This provides some good background into rehabilitation robotics, without providing any detail on control strategies. It also introduced me to MIT-MANUS.

1. **Review of Control Strategies for Robotic Movement Training after Neurological Injury**

A very useful overview indeed. Gives a good review of high-level control strategies. Provides advice on continuing research in the last few pages.

1. **Rehabilitation Robotics: Performance-Based Progressive Robot-Assisted Therapy.**

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1. **A Survey on robotic devices for upper limb rehabilitation**

This is an absolute goldmine. It lists devices, as well as the control strategies alongside good citations. Further to this, it contains a glossary of useful terms. I have fully harvested this for sources.

1. **Rehabilitation Robotics: pilot trial of a spatial extension for MIT-manus**

A description of an extension which exploits the modularity of the MIT-Manus robot. Common features of all the MIT-Manus range:

* Compliant Operation
* Impendence Control.

*Impedance control refers to using a control system (actuators, sensors and computer) to*

*impose a desired behavior at a specified port of interaction with a robot, in this case the attachment of the robot to the patient's hand*.

*For robots interacting with the human, the most important feature of the controller is that its stability is extremely robust to the uncertainties due to physical contact. The stability of most robot controllers is vulnerable when contacting objects with unknown dynamics. In contrast, dynamic interaction with highly variable and poorly characterized objects (to wit, neurologically impaired patients) will not de-stabilize the impedance controller above*

1. **Potential of a suite of robot/computer-assisted motivating systems for personalised, home-based, stroke rehabilitation**

Not relevant, not applicable to MyPAM, old and contains no control.

1. **Robot-assisted reaching exercise promotes arm movement recovery in chronic hemiparetic stroke: a randomized controlled pilot study**

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1. **Rehabilitation Robotics Book 2007**

(https://www.intechopen.com/books/rehabilitation\_robotics)

1. **Rehabilitation Robotics Book 2018**

(https://www.sciencedirect.com/book/9780128119952/rehabilitation-robotics)

1. **Robot-Assisted therapy in Stroke Rehabilitation**

Another very useful overview into the effectiveness of rehabilitation robotics. It contains a list of comparisons of the effectiveness of various devices. Key takeaways: a useful list of robots and citations.

1. **A Control Strategy for Upper Limb Robotic Rehabilitation with a Dual Robot System**

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1. **Haptic Device System for Upper Limb Motor and Cognitive Function Rehabilitation: Grip Movement Comparison between Normal Subjects and Stroke Patients.**

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1. **A Rehabilitation Robot With Force-Position Hybrid Fuzzy Controller: Hybrid Fuzzy Control of Rehabilitation Robot**

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1. **Robot-Aided Neurorehabilitation**

Describes the MIT-MANUS Device:

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| Figure 23.1: MIT-MANUS |

MIT-MANUS uses impedance control to ensure gentle, compliant behaviour. The

2-dof consists of a direct-drive five bar-linkage SCARA (selective compliance assembly

robot arm) mechanism.

The low-level control implementation is described in good detail and uses a mixture of both kinematic and kinetic feedback.

1. **Impedance Control: an approach to manipulation**

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1. **A robotic workstation for stroke rehabilitation of the upper extremity using FES**

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1. **Robotic Assistance of an Active Upper Limb Exercise in Neurologically Impaired Patients**

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1. **Upper Limb Robot-Assisted Therapy in Chronic and Subacute Stroke Patients**

Describes a methodology for assessing the effectiveness of the InMotion 2.0, which is a device similar to the myPAM.

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| Figure 27.1: Testing methodology for effectiveness of InMotion 2.0 |

There is no description of the control algorithm for the device beyond stating that it is ‘Assist as needed’.

1. **Recent Development of Mechanisms and Control Strategies For Robot Assisted Lower Limb Rehabilitation**

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1. **A new haptic workstation for neuromotor rehabilitation**

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1. **ACT3D exercise targets gravity-induced discoordination and improves reaching work area in individuals with stroke**

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1. **Development of Isokinetic and Iso-contractile Exercise Machine "MEM-MRB" Using MR Brake**

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1. **“Hybrid-PLEMO” Rehabilitation System for upper limbs with Active/Passive feedback force**

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1. **Quasi-3-DOF Rehabilitation System for Upper Limbs: Its Force-Feedback Mechanism and Software for Rehabilitation**

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1. **Design of a forearm rehabilitation robot**

This article discusses the design of a forearm rehabilitation robot which both passively and actively exercises a forearm through both pronation and supination.

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| Figure 34.1: forearm rehab robot |

2 fuzzy logic controllers were used. One for passive mode and one for active mode.

There is very good detail about the controller design in the article.

1. **Unified Impedance and Admittance Control**

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1. **Understanding and treating arm movement impairment after chronic brain injury: Progress with the ARM Guide**

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1. **Effects of Robot-Aided Bilateral Force-Induced Isokinetic Arm Training Combined With Conventional Rehabilitation on Arm Motor Function in Patients With Chronic Stroke**

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1. **Design, Implementation and Clinical Tests of a Wire-Based Robot for Neurorehabilitation**

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1. **Design and control of two planar cable-driven robots for upper-limb neurorehabilitation**

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1. **Robot-aided neurorehabilitation of the upper extremities**

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1. **Smart portable rehabilitation devices**

Not useful. Describes 2 lower limb devices, and a passive upper limb device.

1. **A haptic-robotic platform for upper-limb reaching stroke therapy: Preliminary design and evaluation results**

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1. **Robotic Devices for Movement Therapy After Stroke: Current Status and Challenges to Clinical Acceptance**

Too old. No technical details. Not useful.

1. **Modelling and Evaluation of Human Motor Skills in a Virtual Tennis Task**

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1. **A Novel Robot Neurorehabilitation for Upper Limb Motion**

This paper describes a robot very similar in composition to the myPAM.

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| Figure 45.1: similar to myPAM |

There is a small amount of useful maths in here, but unfortunately the control algorithm is not described.

1. **Universal haptic drive: A robot for arm and wrist rehabilitation**

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1. **Assistive Control System Using Continuous Myoelectric Signal in Robot-Aided Arm Training for Patients After Stroke**

This paper describes a robot very similar in composition to the myPAM (but with only 1 DoF), with EMG sensors as additional control inputs.

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| Figure 47.1: similar to myPAM, but with additional sensors. |

The device uses measured torque, EMG signals and measured position as control inputs.

1. **Design of a Mobile, Inexpensive Device for Upper Extremity Rehabilitation at Home**

Using SEAs (series elastic actuators) for a MARIONET robot. The mechanics is described in detail, but the control strategy is not.

1. **A Simple Robotic System for Neurorehabilitation**

Describes the MEMOS system, a planar robot with a cartesian configuration:

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| Figure 49.1: MEMOS |

Usefully, the low-level control algorithm is provided. User applied X and Y forces are combined with position measurements. The control algorithm is as follows:

Where the first term is essentially Hooke’s Law (patient input) and the second term is essentially the motor input (where delta relates to assistance parameters).

Overall, fairly a useful document. Rather simplistic system.

1. **Design of a new 5 d.o.f. wire-based robot for rehabilitation**

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1. **Design and implementation of an assistive controller for robotic rehabilitation systems.**

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1. **Development and Implementation of an End-Effector Upper Limb Rehabilitation Robot for Hemiplegic Patients with Line and Circle Tracking**

This is a brilliant paper, and is the absolute gold standard of what I was looking for. It describes in good detail both the kinematic and kinetic models, as well as the low level control strategies implemented. It is also relatively recent (2017).