MODELING AND CONTROL OF MCKIBBEN ARTIFICIAL MUSCLE – APPLICATION OF MODEL PREDICTIVE CONTROL AND GENETIC ALGORITHMS

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1 Members of GuIT (Gruppo Italiano Utilizzatori di TeX e LaTeX)

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ACRONYMS

PID Proportional-Integrative-Derivative

MPC Model Predictive Control

Part I

THESIS

1 INTRODUCTION

1.1 BACKGROUND AND MOTIVATION

The current state of the art in hydraulic actuators consists almost entirely of oil driven valves, pistons and motors. However, this kind of actuator cannot be used in some particular applications, such as power assist systems and rehabilitation: they have significant heaviness and rigidity, because of their mechanical structure and motorization [1]. In this context, it is problematic to share a robot working space with humans around it, and so this kind of actuator cannot be used to actuate, for example, orthotics.

McKibben muscles were invented by Joseph L. McKibben to motorize pneumatic art orthotics. They in general consist of an inner rubber tube enclosed in a braided outer nylon sleeve. These muscles can be used as actuators of rehabilitation systems due to the following advantages:

- Light weight
- High power to weight ratio
- High flexibility
- Low cost
- Low environmental impact

However, there are drawbacks: it is well known that the muscle has poor control performance due to the existence of strong nonlinearities, such as hysteresis and saturation characteristics. Furthermore, the wear of the materials (nylon sleeve and rubber tube) may cause a shorter lifetime with respect to other actuators.

1.2 MODELLING OF MCKIBBEN ARTIFICIAL MUSCLE

As already mentioned, the control of McKibben muscles is not easy to achieve. A PID control solution may be developed, but it has flaws: the parameters of the controller will have to be tuned different types of muscles and for various loads. This is generally not an acceptable solution for this kind of application.

Thus, model-based control techniques are better suitable for this job. The plant model needs to be very precise for the control to be effective, and to do so identification techniques are used to get a first linear approximation of the model. Later, a hysteresis component is added to this linear model, to keep track of the nonlinearities added by the hysteretic behaviour of the muscle. Adding a hysteresis component to a linear model makes it more complex, so the choice of an appropriate hysteresis modelling technique is crucial to achieve good control performance.

This allows to get a model having good fit with respect to the real one and apply a model-based control approach, namely the **Model Predictive Control** (MPC). Further details about the developed controller are in Chapter 5, and the theory behind MPC can be found in Appendix A.

1.3 AIM OF THE STUDY

The aim of this dissertation is to get precise control of the displacement for a tap water-driven McKibben artificial muscle. To do so, a list of steps will be followed:

1. *Derivation of a Simple Linear Model*
   Using linear identification techniques, it is possible to map the input pressure to the output displacement, and get a precise yet simple linear model of the muscle. While in pneumatic artificial muscles it is required to take into account the temperature dynamics and the compressibility of air, using water as the muscle allows to disregard them. This grants a simpler model of the muscle.

2. *Introduction of a Hysteresis Component*
   The linear identification method grants a very simple yet linear model that does not take nonlinearities into account. The biggest source of nonlinearity for the McKibben muscle is hysteresis. A hysteresis component is added to the linear model, so that it will better follow the actual behaviour of the muscle. This step is essential to get good control performance.

2 COMPOSITION OF THE THESIS

3 TAP WATER-DRIVEN MCKIBBEN ARTIFICIAL MUSCLE

4 MODELLING OF MCKIBBEN ARTIFICIAL MUSCLES

5 CONTROLLER DESIGN

Part II

APPENDICES

A APP A

BIBLIOGRAPHY

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