

## SMA-actuated catheter systems

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# SMA-actuated catheter systems

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## 1 Introduction

Steerable catheter systems have a dominant role in minimal invasive treatments of cardiovascular diseases. Typically, catheters are steered through simple mechanical pull-wire systems. These systems have the disadvantage that they have restricted directionality and limited shape control. The use of Shape Memory Alloy (SMA) actuators, integrated in the tip of the catheter, enables the realization of extremely accurate and flexible catheters. Thereby, SMA-actuated catheter systems allow for quicker and more advanced minimal invasive surgeries.

## 2 Shape Memory Alloy for Actuation

Shape Memory Alloy (SMA) is a lightweight material with considerable higher actuation strain and work output than other active materials such as (high strain) piezo-materials [1]. For this reason SMA-actuators have a great potential in micro-robotic systems, such as catheters, and are the point of interest in this work.

SMA is able to recover from large deformation by changing crystallographic structure. This change in structure is stress and temperature dependent and has highly nonlinear contributions to the material dynamics. Additionally, the material suffers from a hysteresis effect [2].

The crystallographic transformation, and thus the actuating movement, is typically controlled by applying Joule heating to a SMA-wire.

## 3 Physical Modeling of SMA-actuators

A non-linear physical model for SMA-actuators has been derived, characterized and validated. The model accurately describes macroscopic behavior of the material.

By using a suitable class of transformation dynamics, parameters in the model are engineering-based and can be determined with standard material characterization tests [3].

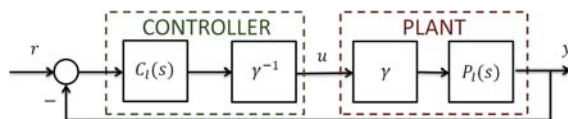


Figure 1: Nonlinearity Compensation

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## 4 Nonlinearity Compensation

As previously stated, the high actuation stroke of SMA-actuators is a result of crystallographic changes in the SMA material. In order to fully address the nonlinear dynamics that dominate this crystallographic change, it is proposed to rewrite the model from Section 3 in a Hammerstein representation with a static nonlinearity  $\gamma$  and a linear part  $P_l(s)$ . The latter allows for compensation of the non-linearity in the control action, provided that the nonlinearity is invertible. The proposed methodology is depicted in Figure 1. Similar strategies have been successfully implemented for other active materials with alike non-linearities [4] [5].

Note that a Hammerstein description for SMA-actuators also yields a possibility for parametric system identification [6]. Parametric identification provides model parameters and thereby makes extensive material characterization tests redundant. The latter is not only of great value for control engineers, but also for material scientists that are interested in accurate and quick material characterization.

## 5 Overview

In future work, the possibilities of the proposed framework of Hammerstein-representation and parametric identification have to be investigated. Furthermore, both control design and extension to 3D actuators (multiple wires) have to be addressed in order to allow for multi-directional steering of SMA-based catheter systems.

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