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# Automatic Tuning of an Accurate Position Controller for Pneumatic Actuators

Sarmad Aziz and Gary M. Bone
Department of Mechanical Engineering
McMaster University
Hamilton, Ontario, Canada, L8S 4L7
gary@mcmaster.ca

**Abstract**

The high power-to-weight ratio and low cost of pneumatic actuators makes them attractive for robotics applications, however achieving fast, accurate position control with them is difficult. Furthermore, tuning the controller (and/or obtaining process models) requires extensive expertise and time. In this paper, a novel automatic tuning methodology for the accurate position control of pneumatic actuators is described. The methodology combines off-line model based analysis with on-line iteration. Experiments performed on three actuators with distinct open-loop dynamics verified the auto-tuner's effectiveness. The auto-tuning required 1/50 of the time needed for manual tuning and only non-expert supervision. The performance of the auto-tuned actuators is comparable to that achieved by other researchers using more complex and expensive hardware.

## 1. Introduction

Pneumatic actuators offer several advantages over electromechanical and hydraulic actuators for positioning applications. These include: lower cost, high power-to-weight ratio, cleanliness, ease of maintenance, and a readily available power source. When applied to robotic manipulators, the high power-to-weight ratio of pneumatic actuators will allow greater payloads to be carried by the same size arm. This, in combination with their low cost, make pneumatic actuators of great interest for robotic applications.

Unfortunately, pneumatic actuators are subject to high friction forces, deadband (due to stiction), and dead time (due to the compressibility of air) which make fast, accurate position control difficult to achieve. Controllers have been developed for this application by many researchers (please see [1] and [2] for reviews of pneumatic position control research). Many of these systems, though successful, use expensive servo valves and pressure sensor feedback loops. Van Varseveld and Bone [1] developed a system employing inexpensive on/off solenoid valves with a novel Pulse-Width Modulation (PWM) scheme which achieved comparable performance to these systems at a substantially lower cost (~60%).

One problem with all of the position controllers developed for pneumatic actuators is the difficulty in tuning (and/or developing process models in some cases) the controller for good performance. Since considerable expertise is required, this is both time consuming and costly. The same tuning may not even be suitable for two cylinders of the same make and model, since their dynamic behaviour will not be identical due to the effect of manufacturing tolerances on their coefficients of friction. As a result, there is a strong need for an automatic tuning methodology for pneumatic position controllers.

A number of methods have been developed previously to automatically tune PID controllers. The most well known method is by Ziegler and Nichols [3]. Hang, Astrom and Ho [4] describe a refinement to the Ziegler-Nichols tuning formula which greatly reduces overshoot/undershoot. These methods are not applicable to the accurate position control of pneumatic actuators, however, in that standard PID cannot achieve the requisite performance [5]. Adaptive control is a potential alternative to auto-tuning, but it does not guarantee

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