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Robotic ARM control using model predictive control with PID control action

Ajay Ladkat
Research Scholar, Vishwakarma University, Pune, Maharashtra, India

Abstract
Today's fast moving world is now moving towards designing of Robots which gives fast response. The continuous research is now focusing towards the fast response robotics which gives real time feel. This paper presents the research work on robotic hand. In this paper, Control system configuration along with Implementation of Model Predictive Controller (MPC) algorithm is presented.

Keywords: robot sensing systems, proportional integrater differentiator control, servo motors, mobil robots, error correction, decision making, neural network

1. Introduction

There are many applications of Robotic ARM such as manufacturing, automotive, medicine, aerospace, etc. Robotic arm consists of three main parts: Mechanical, electrical and control [1, 2, 3]. These provides four main abilities in robotic arm: Controlling the movement in correct workspace, sensing the information from the environment, being able to intelligent control behavior and processing the data and information between all subparts.

There are several methods for controlling a robot arm, which all of them follow two common goals, namely, hardware/ software implementation and acceptable performance [4, 5]. There are many control strategies for controlling robotic arm. The common aim behind all the control strategies are the accuracy and fast response time. This paper presents MPC with PID control action.

This paper is organized as follows. Section 2 description of the mechanical design. Block diagram, electrical components and sensors are introduced in section 3. Section 4 presents Software module (Model Predictive Control with PID control action). Finally Section 5 concludes paper with experimental results.

2. Mechanical Design

Fig. 1 shows joint configuration of robotic arm. Robotic arm has 3 degree of freedom on each finger. It uses five servo motors, one for each finger. Standard DC servo motors are used for the motion of fingers.

Fig 1: Robotic Hand

Fig. 2 shows Installation of flex sensors on human hand. These sensors are input to the system. Controller accepts signal from the sensor and according to the algorithm written in controller robotic hand performs action.

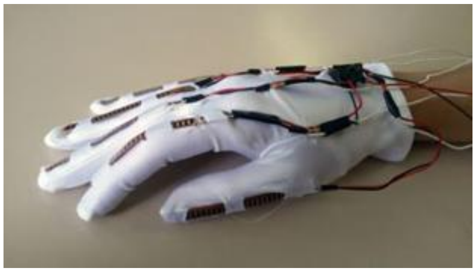

Fig 2: Installation of five flex sensors on Human Hand

3. Block diagram, electrical components and sensors

Fig. 3 shows block diagram of whole system, which shows major part of system: Flex sensor, Servo motor, Bluetooth module and micro-controller.

a) Flex Sensor

Flex sensors (Fig. 4) are used on human hand to detect motion of hand. Five sensors are fixed on fingers of right hand (Fig. 1). Simple amplification circuit is used to drive sensors. With proper signal conditioning circuit output of flex sensor is given to the micro-controller.

Fig 4: Flex Sensor

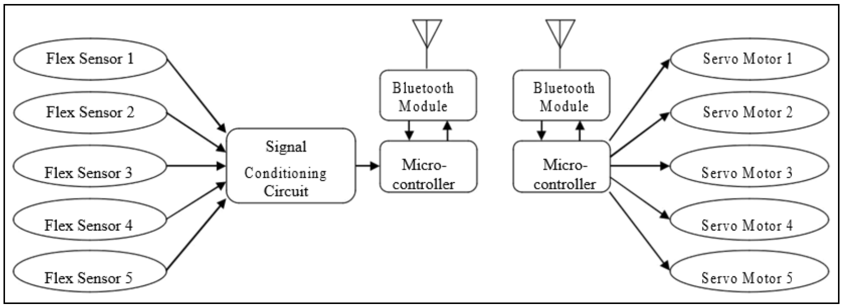

Fig 3: Block Diagram of System

b) Servo Motor

Servo motors are excessively used when there is a need for accurate shaft movement or position. For the movement of robotic hand SG 90 Micro servo motor is used. Installation of servo motor done as per shown in Fig. 1.

Specifications

Weight: 9g
Stall Torque: 1.8 Kgf.cm
Operating Voltage: 4.8V (~5V)

c) Bluetooth Module

Bluetooth is wireless technology standard for exchanging data over short distance. HC-05 module is an easy to use Bluetooth SPP (Serial Port Protocol) module, designed for transparent wireless serial connection setup. This Bluetooth module uses 2.4GHz radio transceiver and base band.

Fig 5: Bluetooth Module

d) Controller

MSP430g2553 is used to control the robotic arm [6]. The algorithm is implemented and tested on same controller. The Texas Instruments MSP430 family of ultra-low-power microcontrollers consists of several devices featuring different sets of peripherals targeted for various applications. The architecture, combined with five low-power modes, is optimized to achieve extended battery life in portable measurement applications. The device features a powerful 16-bit RISC CPU, 16-bit registers, and constant generators that contribute to maximum code efficiency

4. Software module (model predictive control with pid control action)

Model Predictive Control (MPC), an advanced control technique for difficult multivariable control problem. To control a multiple-input, multiple-output process while satisfying inequality constraints on the input and output variables MPC is the best choice. If a reasonably accurate dynamic model of the process is available, model and current measurements can be used to predict future values of the outputs. Then the appropriate changes in the input variables can be calculated based on both predictions and measurements. In essence, the changes in the individual input variables are coordinated after considering the input-output relationships represented by the process model. In MPC applications, the output variables are also referred to as controlled variables or *CVs*, while the input variables are also called manipulated variables or *MVs*. Measured disturbance variables are called as feed forward variable or *DVs*

A block diagram of a model predictive control system is shown in Fig. 6. A process model is used to predict the current values of the output variables. The residuals, the differences between the actual and predicted outputs, serve as the feedback signal to a Prediction block. The predictions are used in two types of MPC calculations that are performed at each sampling instant: set-point calculations and control calculations.

The MPC calculations are based on current measurements and predictions of the future values of the outputs. The objective of the MPC control calculations is to

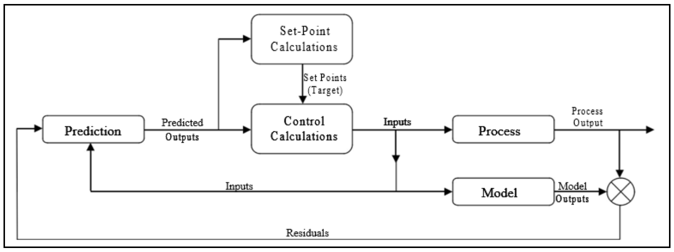

Fig 6: Block Diagram of Model Predictive Control

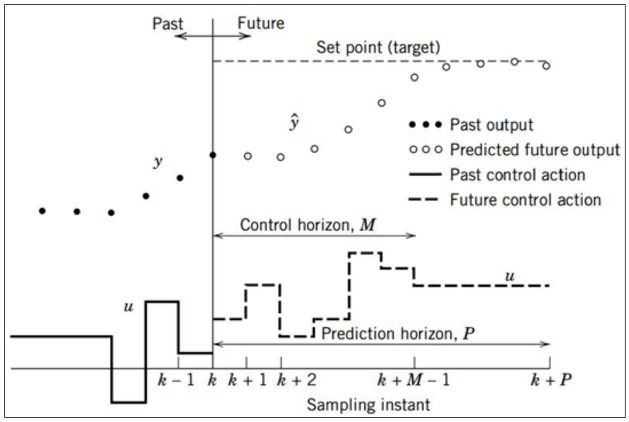

Fig 7: Basic Concept of Model Predictive Control

Determine a sequence of control moves (that is, manipulated input changes) so that the predicted response moves to the set point in an optimal manner. The actual output *y*, predicted output ŷ and manipulated input *u* for SISO control are shown in Fig. 7. At the current sampling instant, denoted by *k*, the MPC strategy calculates a set of *M* values of the input *{u(k+i-1), i=1,2,3,. . . M}*. The set consists of the current input *u(k)* and *M - 1* future inputs. The input is held constant after the M control moves. The inputs are calculated so that a set of P predicted outputs *ŷ (k + i), i = 1, 2 ..., P}* reaches the set point in an optimal manner. The control calculations are based on optimizing an objective function. The number of predictions P is referred to as the prediction horizon while the number of control moves M is called the control horizon.

A distinguishing feature of MPC is its *receding horizon approach*. Although a sequence of *M* control moves is calculated at each sampling instant, only the first move is actually implemented. Then a new sequence is calculated at the next sampling instant, after new measurements become available; again only the first input move is implemented. This procedure is repeated at each sampling instant.

The flowchart in Fig. 8 is implemented in micro-controller MSP430g2553. Program is written in Code Composer Studio V5.x for MSP430. Signals from five flex sensors are attached to the analog input pins of micro-controller. According to implemented algorithm servo motors are controlled. For wirelessly controlling of robotic hand from actual hand Bluetooth module is connected on both ends.

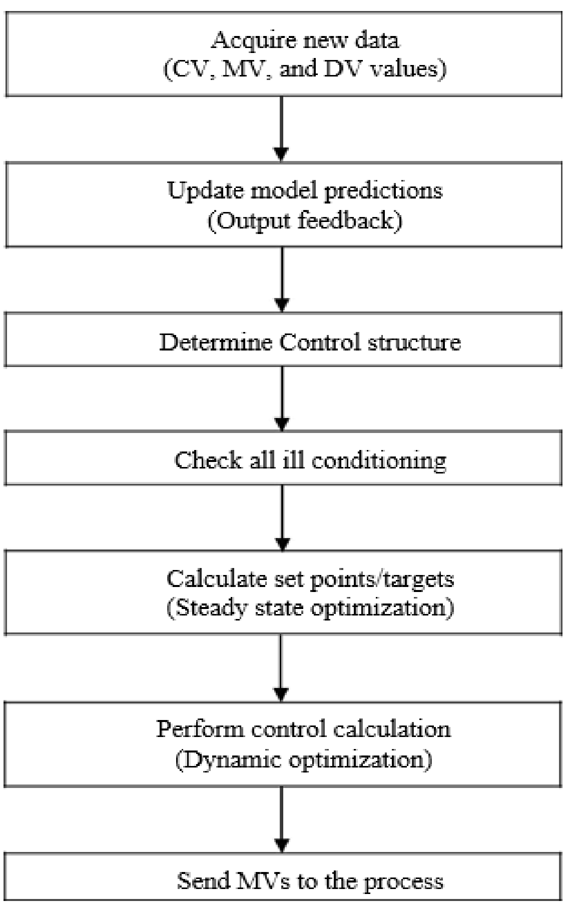

Fig 8: Flowchart for MPC with PID control action

5. Experimental results and conclusion

Robotic arm and human hand have connected to each other through Bluetooth link. Model Predictive Control along with PID action has been implemented and tested. The results are as shown in Fig. 9.

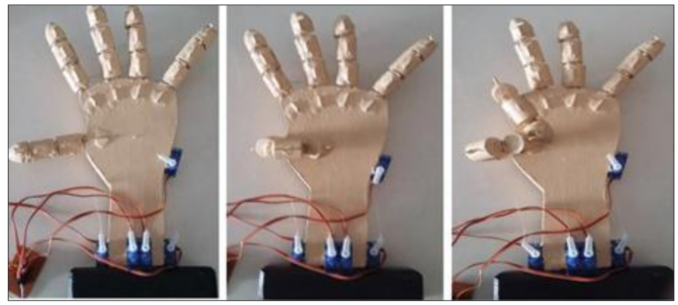

Fig 9: Experimental Results performed on Robotic ARM

Model predictive control offers several important advantages: (1) the process model captures the dynamic and static interactions between input, output, and disturbance variables, (2) constraints on inputs and outputs are considered in a systematic manner, (3) the control calculations can be coordinated with the calculation of optimum set points, and (4) accurate model predictions can provide early warnings of potential problems.

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