Modeling And Position Control Of Scara Type 3D Printer

Ahmet Saygın Ogulmuş, Abdullah Çakan, Mustafa Tınkır

Abstract: In this work, a scara robot type 3D printer system is dynamically modeled and position control of the system is realized. For this aim; computer aided design model of three degrees of freedom robotic system is created using SolidWorks program then obtained model is exported to MATLAB/SimMechanics software for position control. Also mathematical model of servo motors used in robotic 3D printer system is included in control methodology to design proportional controllers. Uncontrolled and controlled position results are simulated and given in the form of the graphics.

Index Terms: Dynamic modeling, position control, Scara robot, 3D printer, proportional controller, simulation

1 Introduction

3D printing is a manufacturing method that is recently used to build three dimensional objects by using digital CAD files. Three dimensional objects is contain successive layers. Creating successive layers process continue until the 3D object is created completely. Thin layers cross section areas form the whole object horizontally. First of all virtual model of the object whatever you want to manufacture is created by using computer aided design (CAD) software like SolidWorks or 3D scanner is used. 3D scanners create a 3D digital copies of any object you want to manufacture with 3D printers [1]. Nowadays 3D printers vary according to differences of types and are developed rapidly and used in homes and industry. Unfortunately in serial production, printing of long parts such as wing, billiard cue or golf clubs can be hard or impossible using current printer technology. For this purpose, in this study it is aimed that common industrial robot type Scara is used with a three dimensional printer technology to provide modular and economical printer. Proposed Scara type robotic 3d printer system is given in Figure 1. According to Figure 1 Scara type robotic system has three degrees of freedom and it is actuated by three servo motors to do one vertical and two horizontal motions. Feeding system for 3d printing is placed to back of robot and it is extended at the end of the robotic arm. The objective of system is that robot can follow the given trajectory of digital cad file from program to print desired solid model. Therefore robotic system must be controlled with minimum position error. In literature review, different studies are realized about Scara robots and 3D printer technology. But the most important and similar studies are considered and given in this study. Some researchers investigated dynamic modeling and control of Scara type robotic systems [2-3]. The others studied about different 3D printer models [4-7].

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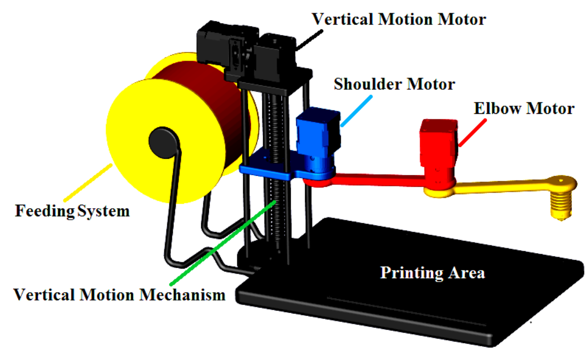

Figure 1. *MATLAB/Simmechanics model of Scara type 3D printer.*

This paper presents position control of a scara robot type 3D printer system that is dynamically modeled. For this; computer aided design model of proposed Scara robot is created by using SolidWorks program to obtain dynamic behavior using MATLAB/SimMechanics software. In this way, two engineering programs are used to achieve different type modeling technique without mathematical equations. Moreover mathematical model of servo motors used in robotic 3D printer system is considered in control methodology. Three PID (proportional-integral-derivative) controllers are designed in MATLAB/Simulink program for position control and controller gain parameters are optimized according to input and output of closed loop block diagram. This study is first step of Scara type 3D printer project and only position control simulations are realized and controller performances are given in the form of the graphics.

2 Modeling and Control

Modeling and control methodology of this paper is given in Figure 3. Difference of study from literature works is differential equations of motion of robotic system are not used and all system dynamics are obtained by using ability of SolidWorks and MATLAB programs. Also control simulations are realized with this way. DC servo motor is used both rotational and translational motion in the Scara type 3D Printer system.

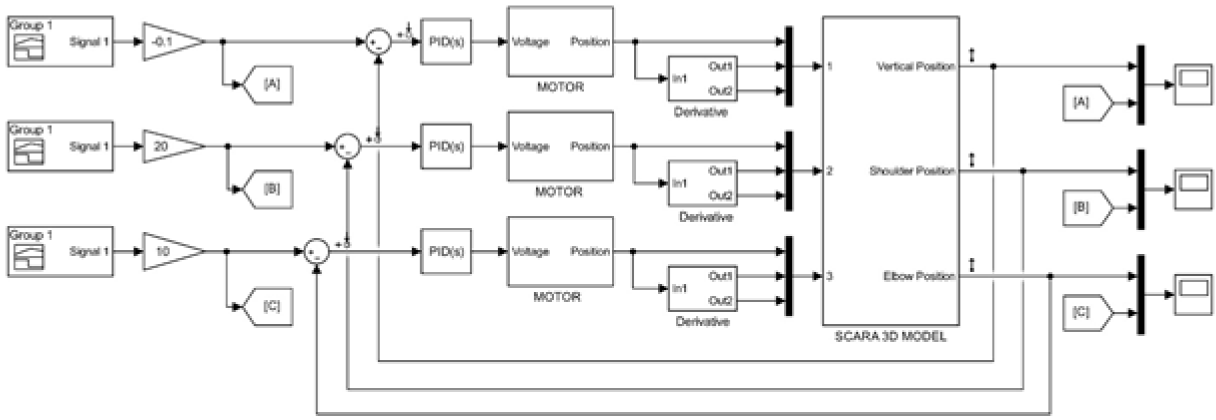

Figure 2. *MATLAB/Simmechanics model of Scara type 3D printer.*

The free body diagram and electrical components of the DC motor are shown in Figure 4. Where J is moment of inertia, b is motor viscous friction constant, R is electric resistance and L is electric inductance.

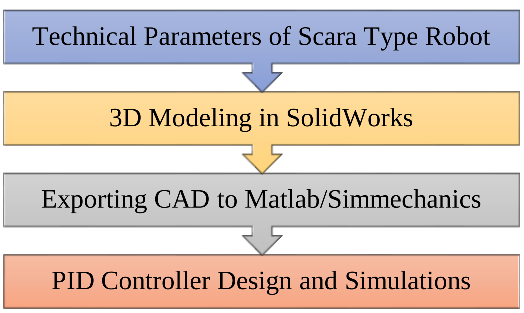

Figure 3. *Working strategy of the paper*

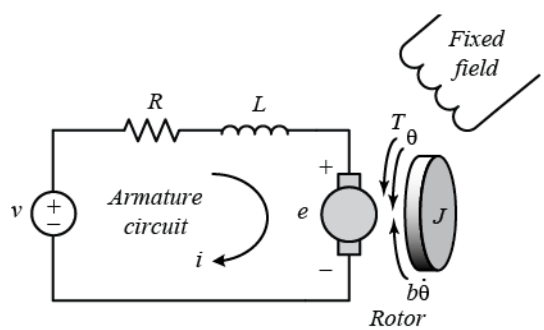

Figure 4. *Free body diagram of the DC Motor*

In motor modeling, the input of the system is the voltage (V) applied to the dc motor and the output of the system is the motor rotational position (theta). The assumed rigid components of the motor are as shaft and rotor. Angular velocity of the DC motor is proportional to the friction torque while using viscous friction model. This model is created in MATLAB/Simulink and it is added to control scheme of proposed system given in Figure 2.

3 Results and Discussion

MATLAB/SimMechanics model of Scara type 3D printer system is given in Figure 4. The parameters of actuators used in system are given in Table 1. In this system 3 Dc motors are used for vertical and horizontal motions. Vertical, shoulder and elbow motions of robot are controlled using tuned PID controllers. Three PID controllers are used for each actuated motion. For this aim; three desired motion inputs are given to see position control performance of proposed controllers. Also PID controllers gain parameters are optimized according to system response and found as Kp=12.66, Ki=1.08 and Kd=2.77. Desired vertical motion is chosen as -10 cm. displacement after 2 seconds given in Figure 5. Also PID controlled and uncontrolled system responses are shown in together in Figure 6. As seen from Figure 6 it can be said that PID controlled system reached to desired vertical position after 2.5 seconds without steady state error. However uncontrolled system does not trace desired input signal. From this result, vertical motion control of Scara type 3d printer is achieved successfully using tuned PID controller. Moreover shoulder and elbow motion control results of the Scara type 3d printer system are given in Figure 7 and Figure 8 respectively. From these results it can be said that robot reached to desired 200 shoulder and 100 elbow positions after 3.5 seconds and 3.7 seconds without steady state errors respectively. On the other hand uncontrolled system responses for shoulder and elbow are insufficient like vertical motion result. Also PID controlled motor voltage changes are given in Figure 9.

Table 1*. Parameters of The DC Motor*

Moment of inertia of the motor	2.825E-6 kg.m2
Viscous friction constant of motor	3.2077E-6 N.m.s
Force constant of motor (Kb)	0.0255 V/rad/sec
Torque constant of motor (Kt)	0.0374 N.m/Amp
Electric resistance of motor (R)	4 Ohm
Electric inductance of motor (L)	2.75E-6H

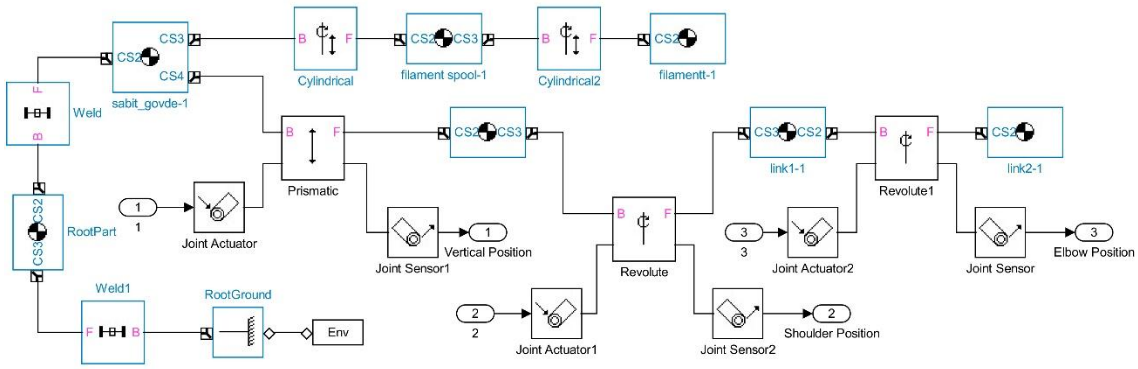

Figure 5. *MATLAB/Simmechanics model of Scara type 3D printer.*

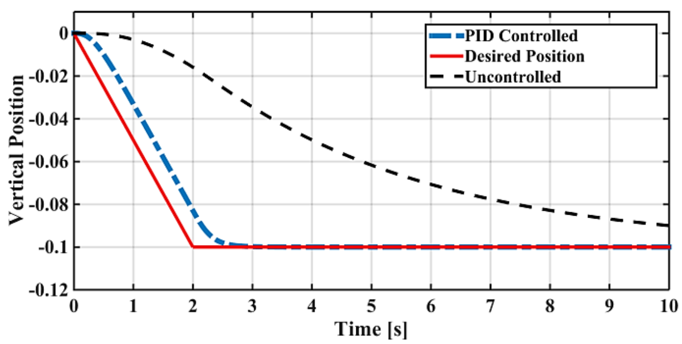

Figure 6. *Vertical position control of Scara type 3D printer.*

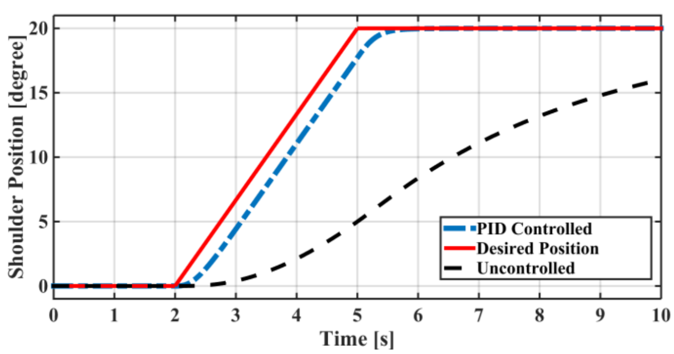

Figure 7. *Shoulder position control of Scara type 3D printer.*

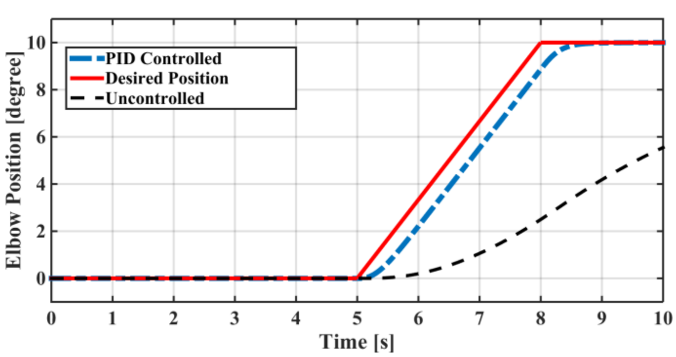

Figure 8. *Elbow position control of Scara type 3D printer.*

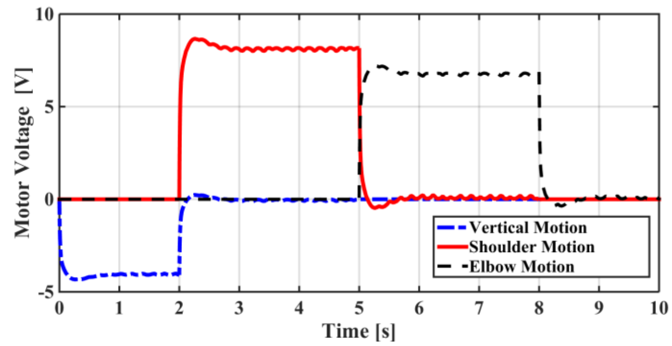

Figure 9. *Motor voltage change of PID controlled system.*

According to Figure 9 it can be said that designed PID controllers supplied system motion control effectively in voltage limits of used actuators while system is running.

4 Conclusion

In this paper, different type dynamic modeling and position control of a Scara robot type 3D printer system is realized. For this aim; computer aided design model of proposed Scara robot is created using SolidWorks program to obtain dynamic behavior using MATLAB/SimMechanics software. In this way, two engineering programs are used to achieve different type modeling technique without mathematical equations. Moreover mathematical model of servo motors used in robotic 3D printer system is considered in control methodology. Three PID controllers are designed in MATLAB/Simulink program for position control and controller gain parameters are optimized according to input and output of closed loop block diagram. As a result of the paper, accuracy of proposed modeling technique is verified by simulations. Also controller's performances and effectiveness are investigated and examined; position control results of the proposed system are presented separately for uncontrolled and controlled in the form of graphics. The main contribution of the paper to the literature is that different type modeling approach is implemented and PID controllers are designed and used in control methodology. Moreover it is first step of Scara type 3D printer project and also obtained results are useful and capable of being improved for experimental study

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