

The Picked and Placed Control of the Objects for a Pneumatic X-Y Servo Platform by Integrating Image Processing Techniques and a Fuzzy Sliding Mode Controller Design

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Abstract—In this paper, integrated a image processing techniques and a fuzzy sliding mode control design for a pneumatic X-Y servo platform system was proposed to realize the picked and placed control of the objects. The key feature of this control scheme is by means of immediately modulated the boundary layer sliding surface and fuzzy function design to improve the steady state error of time response effect. Then, use the image pattern recognition technique to determine the loading and unloading object positions, and drive the Z axis device to active the picking and placing control of the objects to obtain automatic loading-unloading device performance. The validity of the proposed control scheme is verified through practical testing on an experimental pneumatic cylinder X-Y axis servo system device and CCD video camera. In the cases of the step position command input, the test results show that the proposed control scheme and object image pattern recognition technique are capable of reaching the picking and placing precision control of the object.

Keywords— *image processing; fuzzy sliding mode control; pneumatic; pattern recognition; picking and placing control*

I. INTRODUCTION

Recently, due to the technological advance, the pneumatic system has been extensively applied in automation fields and automatic production machines. Such as optical electrical industry, medicine industry, packing industry, and foodstuff industry, which production process always needs the pneumatic system convert the compressed air to the mechanical energy power. Owing to the air is easy acquired, low polluted, high-speed activity, and provided a large effective power energy, the pneumatic systems are always adopted in many automation industries. Sometimes, the picked and placed control of the objects for the production process are needed in many automation equipment applications, the pneumatic servo position control is still more considerable. To automatic accurate the picked and placed objects, the image recognized technique are often been addressed. In this paper, the image recognized technique and fuzzy sliding mode controller design

are integrated to realize the picked and placed objects control for a pneumatic x-y table system.

However, the pneumatic air is compressible, and the pneumatic system has many nonlinear characteristics, such as the mass flow rate parameters variable and the servo valve dead zone problems [1], there have many challenges in designing a controller for the pneumatic servo control system. To reach a better precision control, there are many nonlinear control strategies have been proposed to deal with the pneumatic servo system, for examples, sliding mode control [1][2], fuzzy control[3], and iterative learning control [4],[5],[6]. Due to its robustness against parameter variations and external disturbance, sliding mode control has been an effective means for controlling nonlinear systems with uncertainties [2]. The traditional sliding mode control always design a boundary layer of the sliding surface to eliminate undesired chattering control input [2]. However, there have some problems to be solved, such as the chattering can be made negligible if the width of the boundary layer is chosen large enough, the guaranteed tracking precision will deteriorate if the available control boundary layer width is limited. For the purpose of obtaining the high tracking accuracy, a thin boundary layer is required. And others, the most commonly used design is the linear sliding surface defined by polynomials with repeat roots [2]. Such sliding surfaces are short of sufficient adjustable free parameters, especially in lower order systems.

In this paper, we designed a switching boundary layer and with adjustable parameters free sliding surface of the sliding mode control scheme [1] for the pneumatic cylinder position servo control system to realize and improve the regulating and tracking control performances. To realize the picking and placing precision control of the objects, the image recognized technique was adopted to identify the pattern position, through the video camera, NI-8252 interface card, and LabVIEW vision and motion builder assistance, the objects pattern center point will be recognized. To accomplish the picked and placed of the objects option, an experimental pneumatic cylinder X-Y axis servo system device is constructed. The proposed

controller and the process measuring data were all implement by Pentium IV PC through an NI-6024E interface card with RTW Window target tool box of the Matlab Simulink software designed. Through the test results show that the proposed control scheme is capable of improving the tracking precision of the pneumatic cylinder position control, and for the objects pattern image recognized help, the precision control of picking and placing of the objects with pneumatic system has been come true. The paper is organized as follows: Section 2 a pneumatic cylinder servo system modeling will be constructed, and Section 3 a main control law, fuzzy sliding mode controller design, is also described. Section 4 a pattern image recognized system will be formed with pneumatic servo platform. Experimental results are presented in Section 5, and conclusions are drawn in Section 6.

II. PNEUMATIC CYLINDER SERVO SYSTEM MODELLING

Consider a pneumatic cylinder position servo system which mainly consists of a servo valve and a pneumatic cylinder. Fig.1 shows the structure of pneumatic servo system, the upper portion is a proportional servo valve which actuate the below cylinder with the compressed air flowing into the chamber by the spool displacement x_v of servo valve, hence the pneumatic cylinder can be arrived at any desire position. In general, the response of servo valve is faster than the response of pneumatic cylinder, the orifice area will be proportional to the control input, u , which can be considered as $A_o = K_a K_v u$, where K_a is constant of valve displacement, and K_v is gain constant of valve spool displacement. According to Mocloy & Martin [7],[8] proposed the fluid compressible mass flow rate through the orifice store in chamber can be given by

$$\dot{M}_a = C_{da} C_{ma} A_{oa} P_s / \sqrt{T_s} \quad (1)$$

$$\dot{M}_b = -C_{db} C_{mb} A_{ob} P_b / \sqrt{T_b} \quad (2)$$

where, C_{da} and C_{db} are left and right chamber's discharge coefficient respectively, C_{ma} and C_{mb} are left and right chamber's mass flow parameter respectively, A_{oa} and A_{ob} are left and right chamber's orifice area respectively, P_s and P_b are left and right chamber's upstream stagnation pressure respectively, T_s and T_b are left and right chamber's upstream stagnation temperature respectively. However, the mass flow parameters of C_{ma} and C_{mb} have the following calculation:

If $\frac{P_{vc}}{P_o^*} > \left(\frac{2}{\gamma+1}\right)^{\frac{\gamma}{\gamma-1}} \approx 0.528$, the C_{ma} and C_{mb} indicate as

$$C_m = \sqrt{\frac{2\gamma}{R(\gamma+1)} \left\{ \left(\frac{P_{vc}}{P_o^*}\right)^{\frac{2}{\gamma}} - \left(\frac{P_{vc}}{P_o^*}\right)^{\frac{\gamma+1}{\gamma}} \right\}}$$

where, P_{vc} and P_o^* are the orifice static pressure and upstream stagnate pressure respectively, R is the gas parameter, and γ is the ratio of specific heat. If $\frac{P_{vc}}{P_o^*} \leq \left(\frac{2}{\gamma+1}\right)^{\frac{\gamma}{\gamma-1}} \approx 0.528$, than

$$C_m = \left(\frac{2}{\gamma+1}\right)^{\frac{\gamma}{\gamma-1}} \sqrt{\frac{2\gamma}{R(\gamma+1)}} \approx 0.0405 \cdot$$

Fig.2 shows the relationship between of C_m parameter value and $\frac{P_{vc}}{P_o^*}$ value. It can be shown that the C_m parameter is

alternated when the orifice gas flow rate decreased. Applying the Law's Conservation of energy [9]

$$\sum \dot{M}_{in} h'_{in} - \sum \dot{M}_{out} h'_{out} + \left\{ \frac{dQ}{dt} - \frac{dW}{dt} \right\} = \frac{dE}{dt} \quad (3)$$

where, $\dot{M}_{in}, \dot{M}_{out}$ are mass flow rate of entering the control volume and leaving out the control volume respectively, h'_{in}, h'_{out} are enthalpy of entering the control volume and leaving out the control volume respectively, Q is rate of heat transfer into the chamber, W is kinetic energy for the moving position, E is total of internal energy of the chamber, Eq.(3) can be written as

$$C_p \dot{M}_a T_a - P_a \frac{dV_a}{dt} + \frac{dQ}{dt} = \frac{d}{dt} (C_v P_a V_a T_a) \quad (4)$$

where, C_v is the specific heat value of the air beside constant volume, P_a is the pressure of left chamber, assuming no heat flow in to control volumes, then dQ/dt is small can be ignored, we have

$$\frac{dP_a}{dt} = \frac{\gamma R T_a}{A_a y} \dot{M}_a - \frac{\gamma P_a}{y} \frac{dy}{dt} \quad (5)$$

where, A_a is the cross-sectional area of the left chamber, and y is the displacement of cylinder moving. With the similar procedures to the right chamber of cylinder, we have

$$\frac{dP_b}{dt} = -\frac{\gamma R T_b}{A_b (l-y)} \dot{M}_b + \frac{\gamma P_b}{(l-y)} \frac{dy}{dt} \quad (6)$$

where, l is maximum displacement of pneumatic cylinder, A_b is the cross-sectional area of the right chamber, and P_b is pressure of right chamber. Then the pneumatic cylinder motion equation can be obtained as follows [8],

$$P_a A_a - P_b A_b - b \frac{dy}{dt} - F_f \text{sgn}(\dot{y}) - F_L = m \frac{d^2 y}{dt^2} \quad (7)$$

where, b is damping coefficient, F_f is force due to friction, and F_L is force due to external loading. Substituting (5),(6) into (7) can be obtained as follows

$$\frac{d^3 y}{dt^3} = \frac{\gamma R}{m} \left[\frac{T_a}{y} \dot{M}_a + \frac{T_b}{1-y} \dot{M}_b \right] - \frac{\gamma}{m} \left[\frac{A_a P_a}{y} - \frac{A_b P_b}{1-y} \right] \frac{dy}{dt} - \frac{b}{m} \frac{d^2 y}{dt^2} - \frac{\dot{F}_f}{m} \text{sgn}(\dot{y}) - \frac{\dot{F}_L}{m} \quad (8)$$

Then, Substituting (1),(2) into (8),

$$\frac{d^3 y}{dt^3} = -\frac{\gamma}{m} \left[\frac{A_a P_a}{y} - \frac{A_b P_b}{1-y} \right] \frac{dy}{dt} - \frac{b}{m} \frac{d^2 y}{dt^2} - \frac{\dot{F}_f}{m} \text{sgn}(\dot{y}) - \frac{\dot{F}_L}{m} + \frac{\gamma R C_d C_m K_a K_v}{m} [P_s \sqrt{T_s} - P_b \sqrt{T_b}] u \quad (9)$$

where, u is control input, Eq.(9) is a real model of the pneumatic position control system, it's shown that the model is a nonlinear and coefficient variable system. In the Section 3, a multi-variable design sliding surface with switching

boundary later of sliding mode control scheme will be developed to deal with the pneumatic servo system and improving the tracking precision.

III. FUZZY SLIDING MODE CONTROLLER DESIGN

To highlight the main point of the design sliding mode control, we consider the following simple n th-order SISO nonlinear uncertain system [2]:

$$^{(n)}y = f(y, \dot{y}, \dots, y^{(n-1)}, t) + g(y, \dot{y}, \dots, y^{(n-1)})u \quad (10)$$

where $u, y \in R$, are the input and output, respectively; $f, g: R^n \rightarrow R$ are smooth functions. Assume that f is not completely known but can be written as $f = \hat{f} + \Delta f$, where $\hat{f}$ is the nominal part and Δf is the uncertain part which is bounded by a known function F , i.e., $|\Delta f(x, t)| \leq F(x, t)$, where $x := [x_1, x_2, \dots, x_n]^T = [y, \dot{y}, \dots, y^{(n-1)}]^T$, and the control gain $g(x)$ is unknown but confined in certain constant range; i.e. $0 < \beta^{\min} \leq g(x) \leq \beta^{\max}$. where $\beta^{\min}, \beta^{\max}$ are given constants, time-varying or state-dependent functions.

The control object is to find a continuous sliding control u such that the output y of (10) will approximately track a desired signal, y_d , which is assumed to be n th-order continuously differentiable and all of its derivatives are uniformly bounded, i.e., $\lim_{t \rightarrow \infty} y(t) = y_d(t)$. Given the tracking error $e(t) := y(t) - y_d(t)$, For any $\lambda_m > 0$, where $m = 1, \dots, n$, the generalized error as

$$s(t) = \left(\frac{d}{dt} + \lambda_1 \right) \left(\frac{d}{dt} + \lambda_2 \right) \dots \left(\frac{d}{dt} + \lambda_n \right) \xi_e(t) \quad (11)$$

where $\xi_e(t) = \int^t e(\tau) d\tau$, the integral of tracking error. Eq. (11) provides a useful transformation so that the original n^{th} -order tracking problem can be transformed into an equivalent 1st-order stabilization problem in S variable. Differentiating S with respect to t and adding the term $\lambda_{n+1}s$ yields

$$\begin{aligned} \dot{s} + \lambda_{n+1}s &= \left(\frac{d}{dt} + \lambda_1 \right) \dots \left(\frac{d}{dt} + \lambda_n \right) \left(\frac{d}{dt} + \lambda_{n+1} \right) \xi_e(t) \\ &= e^{(n)}(t) + c_1 e^{(n-1)}(t) + \dots + c_{n+1} \xi_e(t) \\ &= f(x) + g(x)u - x_d^{(n)}(t) + c_1 e^{(n-1)}(t) + \dots + c_{n+1} \xi_e(t) \\ &= \hat{f} + \Delta f + c_1 e^{(n-1)}(t) + \dots + c_{n+1} \xi_e(t) - x_d^{(n)}(t) + g(x)u \end{aligned} \quad (12)$$

where $c_1 = \lambda_1 + \lambda_2 + \dots + \lambda_{n+1}$, and $c_{n+1} = \lambda_1 \lambda_2 \dots \lambda_{n+1}$. Multiplying s in the both sides of Eq.(12), we have

$$\begin{aligned} s\dot{s} &= -\lambda_{n+1}s^2 + [\hat{f} + \Delta f + c_1 e^{(n-1)} + \dots + c_{n+1} \xi_e - x_d^{(n)} + gu]s \\ &= -\lambda_{n+1}s^2 + [\hat{f} + \Delta f + \hat{w} + gu]s \end{aligned} \quad (13)$$

where $\hat{w} = c_1 e^{(n-1)} + \dots + c_{n+1} \xi_e - x_d^{(n)}$. The feedback control u for Eq. (13) was designed as

$$u = G(\hat{u} + v) \quad (14)$$

where $G := \frac{1}{\sqrt{\beta^{\min} \beta^{\max}}}$, $\hat{u} = -\hat{f} - \hat{w}$, $v = -K \text{sat}\left(\frac{s}{\Phi}\right)$. Clearly,

$0 < \beta^{-1} \leq gG \leq \beta$, and $0 < \beta^{-1} \leq (gG)^{-1} \leq \beta$, where $\beta = \sqrt{\beta^{\max} / \beta^{\min}}$. Whenever $|s| \geq \Phi$, where Φ is the width of the boundary layer, the following result can be obtained

$$s\dot{s} \leq -\lambda_{n+1}s^2 - (gGK - |1 - gG| |\hat{f} + \hat{w}| - |\Delta f|) |s| \quad (15)$$

If we choose K as follows,

$$K \geq \beta(\eta + F) + (\beta - 1) |\hat{f} + \hat{w}| \quad (16)$$

where $\eta > 0$, then Eq.(15) becomes

$$s\dot{s} \leq -\lambda_{n+1}s^2 - \eta |s| \quad (17)$$

Using the Lyapunov function candidate

$$V(s) = \frac{1}{2} s^2, \quad (18)$$

it can be shown that, whenever $|s| \geq \Phi$,

$$\dot{V} \leq -\lambda_{n+1}s^2 - \eta |s|. \quad (19)$$

This ensures that any trajectory starting from any initial point will reach the boundary layer, $\forall |s| \leq \Phi$, in finite time.

Consequently, the guaranteed tracking precision will be

$$|e(t)| \leq \frac{\Phi}{\lambda_1 \lambda_2 \dots \lambda_n} \quad (20)$$

whenever $|s| \leq \Phi$.

For smoothness (to reduce chattering) of the control input signal, larger width of the boundary layer is preferred. However, for better tracking accuracy, a boundary layer with smaller width is required [1]. In this paper, the concept of varying width of the boundary layer is proposed, which takes simultaneously the advantages of both the smoothness of the control inputs and the better tracking accuracy. First, let $\Phi = \Phi(|e|)$ and the control input (14) is rewritten as follows

$$v = -K \text{sat}\left(\frac{s}{\Phi(|e|)}\right) \quad (21)$$

We let Φ_1 and Φ_2 are two different boundary layers, $0 < \Phi_2 < \Phi_1$, and ε_1 and ε_2 are two different error, $0 < \varepsilon_2 < \varepsilon_1$. For the relationship of absolute error, $|e|$, and boundary layer Φ are shown in (22)

$$\begin{cases} |e| \geq \varepsilon_1, & \Phi = \Phi_1 \\ \varepsilon_2 \leq |e| \leq \varepsilon_1, & \Phi = \Phi_a \\ |e| \leq \varepsilon_2, & \Phi = \Phi_2 \end{cases} \quad (22)$$

$$\Phi_a = \Phi_2 + \left(\frac{|e| - \varepsilon_2}{\varepsilon_1 - \varepsilon_2} \right) (\Phi_1 - \Phi_2)$$

Therefore, if the initial state is outside the boundary layer, $|s| \geq \Phi_1$, it will be attracted to the boundary layer of sliding surface. Furthermore, if the absolute value of the tracking error is smaller than ε_1 , the boundary layer is changed from Φ_1 to Φ_a , and when the absolute value of the tracking error is smaller than ε_2 , the boundary layer is fixed at Φ_2 , such that the tracking precision and the chattering of the control input signal are improved significantly.

Remark: The widths Φ_1 , Φ_2 of boundary layer can be determined, respectively, as follows.

(1). By trial-and-error, the width of the boundary layer Φ is decreased till a visible Chattering of the control input signal occurs and then set $\Phi = \Phi_1$.

(2). A positive constant error ε_1 and ε_2 are used to define the switching threshold of the tracking error such that the width of the boundary is continuously changed from the Φ_1 to the smaller value Φ_2 , which is a small enough that the chattering of the control input does not happen and the tracking error precision will be improved.

For $n = 2$ and $\lambda = 1$, the guaranteed tracking error bounds are depicted in Fig. 3, where the real-line region represents the error bound of the proposed sliding mode control with varying boundary layer, while the dash-line region represents that of the conventional sliding mode control with fixed boundary layer. Obviously, the guaranteed steady-state tracking error by using the proposed sliding mode control with switching boundary layer is effectively reduced as shown in Fig. 3.

In section 2, the pneumatic cylinder position system model is a three-order nonlinear system, let

$$f_m(y, \dot{y}, \ddot{y}) = -\frac{\gamma}{m} \left[\frac{A_a P_a}{y} - \frac{A_a P_a}{1-y} \right] \frac{dy}{dt} - \frac{b}{m} \frac{d^2 y}{dt^2} - \frac{\dot{F}_f}{m} \text{sgn}(\dot{y}) - \frac{\dot{F}_L}{m} \quad (23)$$

$$g_m(y, \dot{y}, \ddot{y}) = \frac{\gamma R C_d C_m K_a K_v}{m} [P_s \sqrt{T_a} - P_b \sqrt{T_b}] \quad (24)$$

Then, the system model can be rewritten as follows

$$\overset{(3)}{y} = f(y, \dot{y}, \ddot{y}) + g(y, \dot{y}, \ddot{y})u \quad (25)$$

Let the tracking error be $e(t) = y(t) - y_d(t)$, and $\overset{(3)}{e} = y - y_d$, the error equation can be obtained as follows

$$\begin{aligned} \overset{(3)}{e} &= f(y) + g(y)u - y_d \\ &= \overset{(3)}{\hat{f}}(y) - y_d + \Delta f(y) + g(y)u \end{aligned} \quad (26)$$

Defined the generalized error as

$$\begin{aligned} s &= \left(\frac{d}{dt} + \lambda_1 \right) \left(\frac{d}{dt} + \lambda_2 \right) \left(\frac{d}{dt} + \lambda_3 \right) \int e d\tau \\ &= \ddot{e} + a_1 \dot{e} + a_2 e + a_3 \int e d\tau \end{aligned} \quad (27)$$

where, $a_1 = (\lambda_1 + \lambda_2 + \lambda_3)$, $a_2 = (\lambda_1 \lambda_2 + \lambda_2 \lambda_3 + \lambda_1 \lambda_3)$, $a_3 = \lambda_1 \lambda_2 \lambda_3$, we have

$$\begin{aligned} \overset{(3)}{s} + \lambda_4 s &= \left(\frac{d}{dt} + \lambda_1 \right) \left(\frac{d}{dt} + \lambda_2 \right) \left(\frac{d}{dt} + \lambda_3 \right) \left(\frac{d}{dt} + \lambda_4 \right) \int e d\tau \\ &= e + b_1 \ddot{e} + b_2 \dot{e} + b_3 e + b_4 \int e d\tau \\ &= \overset{(3)}{\hat{f}}(y) + g(y)u + \Delta f(y) - y_d + b_1 \ddot{e} + b_2 \dot{e} + b_3 e + b_4 \int e d\tau \end{aligned} \quad (28)$$

where, $b_1 = \lambda_1 + \lambda_2 + \lambda_3 + \lambda_4$, $b_2 = \lambda_1 \lambda_2 + \lambda_2 \lambda_3 + \lambda_3 \lambda_4 + \lambda_1 \lambda_4 + \lambda_2 \lambda_4 + \lambda_3 \lambda_4$, $b_3 = \lambda_1 \lambda_2 \lambda_4 + \lambda_2 \lambda_3 \lambda_4 + \lambda_1 \lambda_3 \lambda_4 + \lambda_1 \lambda_2 \lambda_3$, $b_4 = \lambda_1 \lambda_2 \lambda_3 \lambda_4$,

The feedback control u was designed as

$$u = G(\hat{u} + \hat{v}_f) \quad (29)$$

where, $\hat{u} = -\overset{(3)}{\hat{f}}(y) - \hat{w}$, $\hat{v}_f = -K \cdot \text{fuzzy} \left(\frac{s}{\Phi(|e|)} \right)$. In this paper, we

change the conventional sliding mode controller's saturation function $v = -K \text{sat} \left(\frac{s}{\Phi} \right)$ replaced by $\hat{v}_f = -K \cdot \text{fuzzy} \left(\frac{s}{\Phi(|e|)} \right)$. Fig. 4

shows the conventional linear saturation function, if it is replaced by the fuzzy function as shown in Fig. 5, it will improve the precision control performance. For the input output membership function are all design by the triangle function as shown as Fig. 6 and Fig. 7. The fuzzy rules of the input output function are proportional relationship as following:

input={NVB, NB, NM, NS, ZE, PS, PM, PB, PVB}

output={NVB, NB, NM, NS, ZE, PS, PM, PB, PVB}

where NVB= Negative Very Big, NB = Negative Big, NM = Negative Medium, NS = Negative Small, ZE = Approximately Zero, PS = Positive Small, PM = Positive Medium, PB = Positive Big, PVB= Positive Very Big.

We choose

$$K \geq \beta(\eta + M) + (\beta - 1) |\hat{f} + \hat{w}| \quad (30)$$

where, $\eta > 0$, satisfying the inequality:

$$s\dot{s} \leq -\lambda_4 s^2 - \eta |s| \quad (31)$$

IV. IMAGE PATTERN RECOGNIZED SYSTEM AND PNEUMATIC SERVO PLATFORM CONSTRUCTED

The image pattern recognized system and pneumatic servo platform structure shows as Fig. 8. In the pneumatic platform system above has built a CCD video camera to recognize the objects pattern. The pneumatic servo platform moving control is following the captured image pattern shape center point coordinates by CCD camera with IEEE 1394E transmission line and PCI-8252 interface card to PC. The digital image

signal can be calculated the object pattern center point coordinates by LabVIEW software design program. Then, passing the calculated objects pattern center point coordinates which can be looked as a position command of the pneumatic cylinder to the fuzzy sliding mode controller which design by Matlab Simulink program, and through the NI-6024E AD/DA card with servo valve to drive the cylinder to control the pneumatic cylinder moving position. All of the X-Y axis cylinder position feedback signals are adopted by linear scale resistance. In the end point of the X-Y axis cylinder, there have a vertical Z-axis can be moved up and down, and the end point of vertical Z-axis have sucking disc vacuum device which can be accomplished the objects loading and unloading. So, the picked and placed precision control of the objects for a pneumatic X-Y servo platform by integrating image pattern recognized and fuzzy sliding mode controller design can be achieved. For the image pattern recognized scheme process can be shown in Fig. 9. First, the object pattern image will be captured by CCD video camera. Second, mask the image with threshold method and filter the noise image, then detect the pattern edges of the image. Third, using geometric template matching method recognized the picking object. And, the last step is calculating and sending out the object shape center point coordinate by gravity method.

V. EXPERIMENTAL RESULTS AND DISCUSSION

The following parameters of sliding mode controller in practical test as:

$$a_1 = 0.5, a_2 = 50, a_3 = 0.5, b_1 = 0.008, b_2 = 0.11, b_3 = 1.5, \beta = 1.8, \\ \eta = 0.05, M = 0, \Phi_1 = 10, \Phi_2 = 0.1, \varepsilon_1 = 0.1, \varepsilon_2 = 0.05, G = 2$$

This paper, using Matlab/Simulink software design the variable boundary layer of fuzzy sliding mode controller, and adopt the LabVIEW software with vision and motion builder to recognize the object pattern image and calculate the object pattern center point coordinate from CCD video camera. Thus the precision control of the picked and placed of the objects for the pneumatic servo platform system can be achieved. In the experimental test, there are four different shape objects, which have triangle, circle, squire, and trapezoid in the pneumatic servo platform shown as in Fig. 10-(1), we can accurately pick the squire shape object and precisely place to the circle object location. The detail process is shown in Fig. 10-(2) to Fig. 10-(5). In Fig. 10-(6) to Fig. 10-(11) shows the trapezoid shape object has been precisely picked and accurately placed it to the triangle shape object location. All of these picked and placed actions are driven by the X-Y axis pneumatic cylinder servo platform and CCD video camera. Fig. 11 shows the X axis pneumatic cylinder position control response, and the tracking error response is shown in Fig. 12. Identically, the Y axis pneumatic cylinder position control response and tracking error response are shown in Fig. 13 and Fig. 14. From the X axis and Y axis tracking error results show that the tracking errors are approximately smaller than $\pm 0.5\text{mm}$.

VI. CONCLUSIONS

In this paper, we propose a variable boundary layer of fuzzy sliding mode controller scheme for the pneumatic cylinder X-Y

axis servo platform system to realize precision position control. And apply CCD video camera to capture the object pattern image and recognize its center point coordinate position technique to provide the picked and placed of the objects performance.

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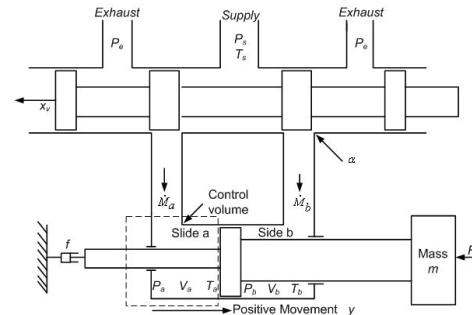


Fig. 1 The pneumatic cylinder servo system.

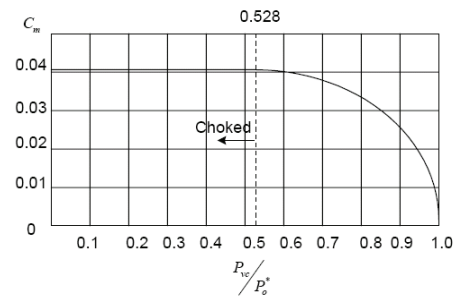


Fig. 2 The C_m parameter value varying with the ratio of pressure.

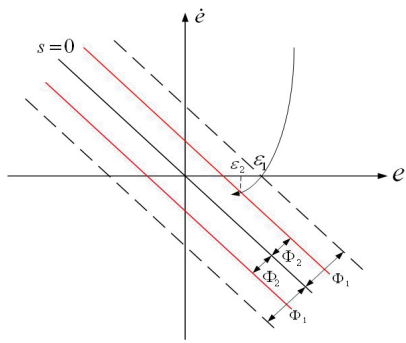


Fig. 3 The variable boundary layer of sliding surface.

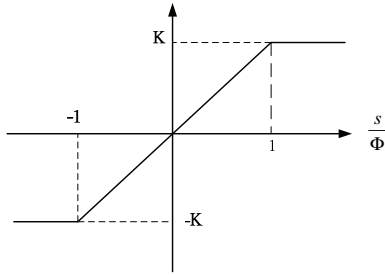


Fig. 4 The sliding mode conventional saturation function.

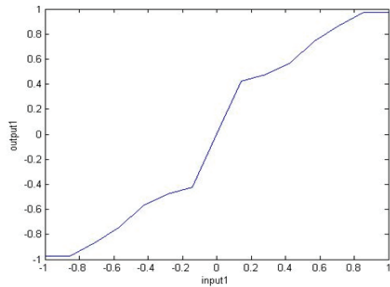


Fig. 5 The Fuzzy saturation function.

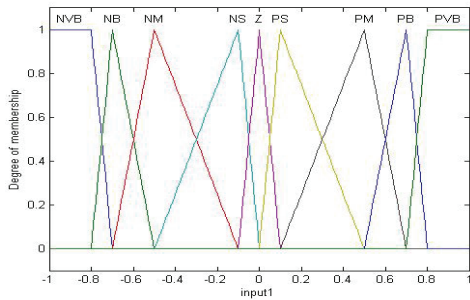


Fig. 6 The fuzzy input membership function.

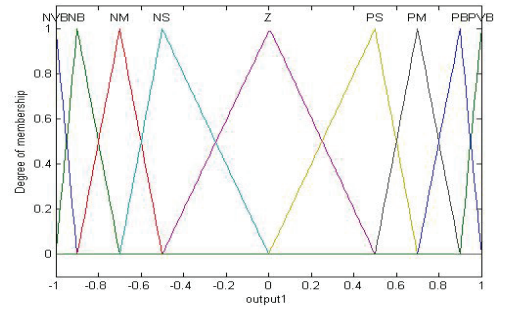


Fig. 7 The fuzzy output membership function.

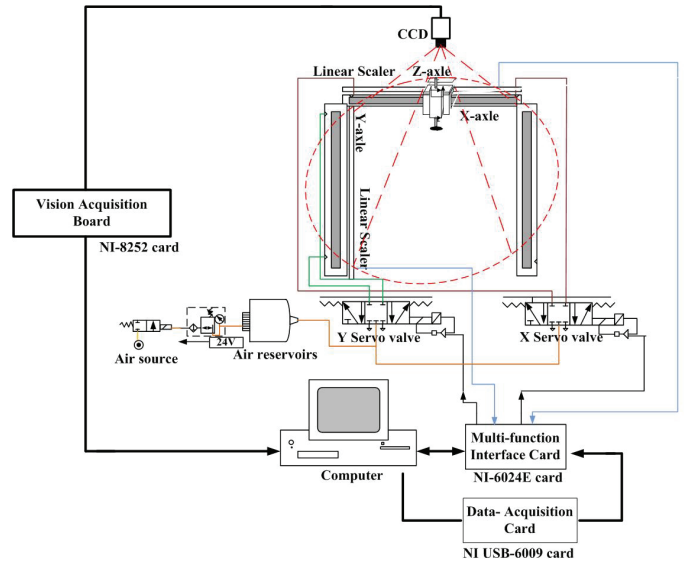
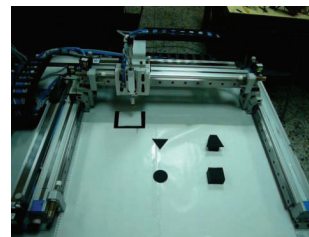


Fig. 8 The pneumatic cylinder servo control with image pattern recognition system diagram



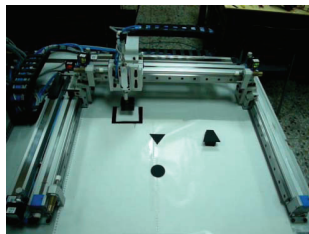
Fig 9 The object pattern image recognition process flow chart



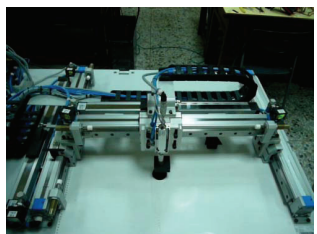
(1)



(2)



(3)



(4)

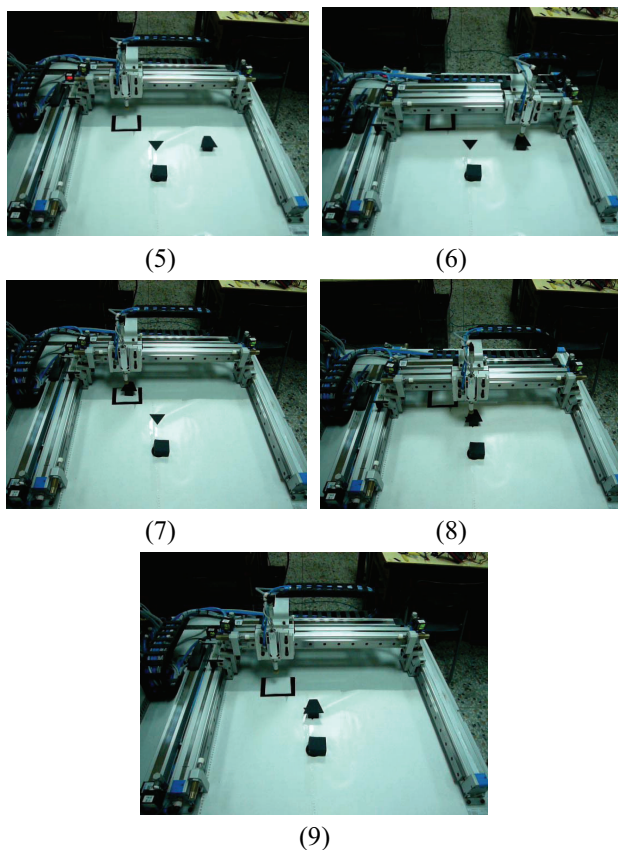


Fig. 10 The picked and placed control of the objects for the pneumatic cylinder servo system action diagram.

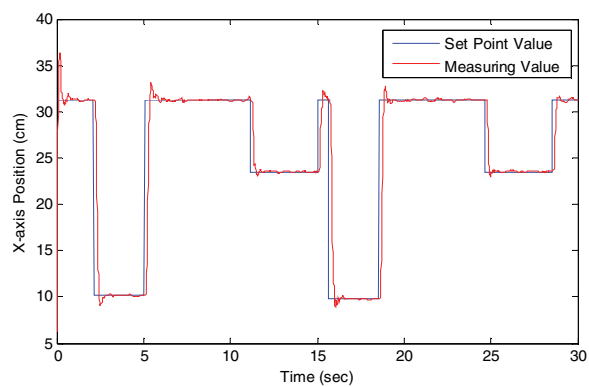


Fig. 11 The X-axis pneumatic cylinder response diagram.

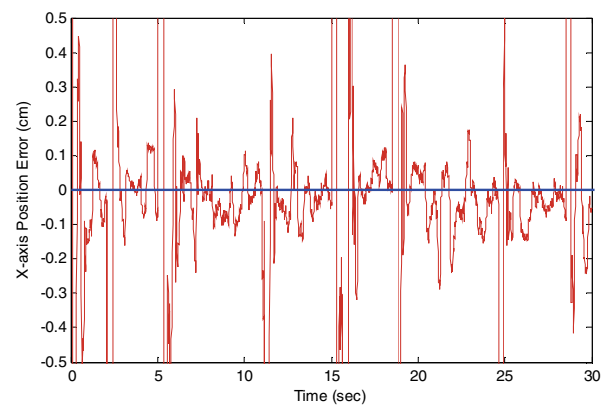


Fig. 12 The X-axis pneumatic cylinder tracking error response diagram.

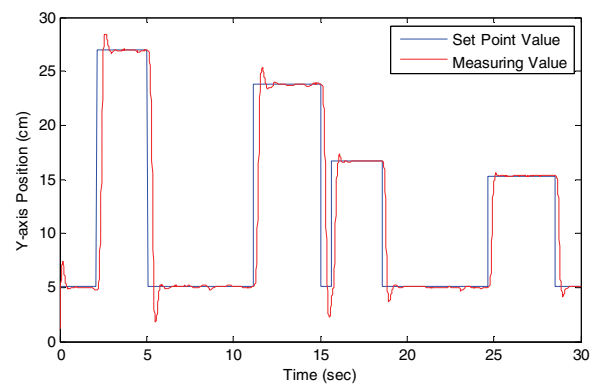


Fig. 13 The Y-axis pneumatic cylinder response diagram.

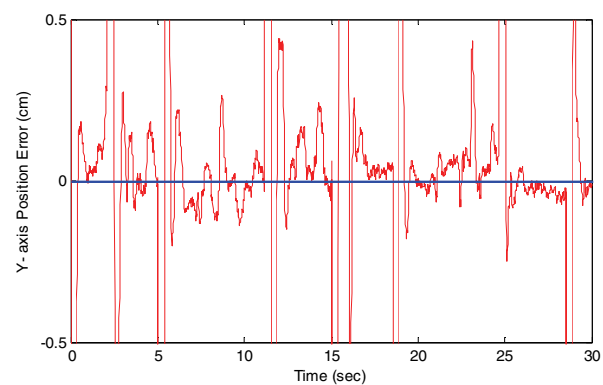


Fig. 14 The Y-axis pneumatic cylinder tracking error response diagram.