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Experimental analysis of 3D gantry crane system via optimal PID and PD controller by PSO

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ABSTRACT – A 3D INTECO gantry crane system is used for lifting and moving loads horizontally, lowering and releasing the gripper to the original position. There are two main problems which occurred in the system which are positioning the desired position and minimize the payload oscillation. In order to overcome this problem, a controller is implemented. In this paper, a control strategy of PID and PD controller tuned by Particle Swarm Optimization (PSO) is presented. PID controller is used to control the trolley movement to reach at the precise desired position and PD controller is used to control the undesired oscillation from the payload while moving the load. The results shown that through the experimental platform, the trolley reached the desired position with low payload oscillation.

1. INTRODUCTION

A crane system is used frequently to move load in factories and harbours. The trolley at the crane is used to move the load to the desired target without causing any undesired oscillation. However, controlling the crane manually by human will tend to excite sway angles of the hoisting line and degrade the overall performance of the system.

In this paper, the implementation of Proportional-Integral-Derivative (PID) and Proportional-Derivative (PD) controller in the 3D INTECO gantry crane system had been proposed. PID controller as feed-back structure aims to control the trolley movement in order to achieve the desired position whereas PD controller as the feed-forward structure used to minimize the oscillation during the movement. The parameters of these controllers are obtained by tuning via Particle Swarm Optimization (PSO). Performances of the proposed control schemes are discussed in terms of the precise positioning of payload and reduction in the payload oscillation.

2. 3D GANTRY CRANE DESCRIPTION

Figure 1 shows the experimental of 3D gantry crane system. The crane consists of a payload hanging on a cable, wound by a motor mounted on a trolley. The payload is lifted and lowered in the *z*-direction. The horizontal motion in *x*-direction are capable for the rail and trolley. Not only that, the trolley is able to move in horizontal along the rail in the *y*-direction. There are three DC motors in the system which used for travelling, traversing and hoisting in *x*, *y* and *z* axes respectively. The system is controlled directly by a PC with RT-DAC4/PCI multipurpose digital I/O board.

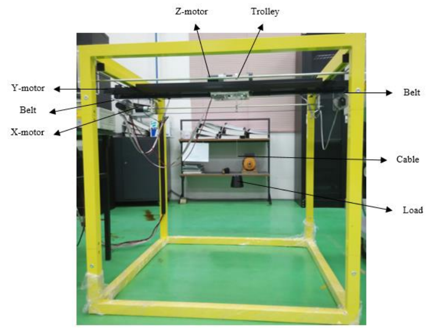

Figure 1 3D INTECO gantry crane.

Figure 2 shows the schematic representation of 3D gantry crane system [1,2]. There are five identical encoders measuring five state variables; x_w represents the distance of the rail with the cart from the center of the construction frame; y_w is the distance of the cart from the center of the rail; R denotes the length of the lift-line; α represents the angle between the y axis and the lift-line; β is the angle between the negative direction on the *z*-axis and the projection of the lift-line onto the *xz*-plane.

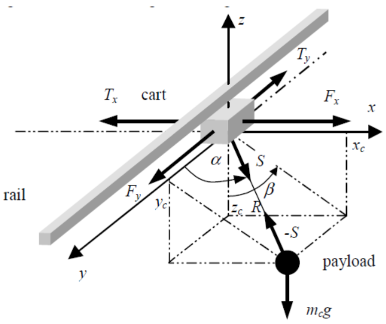

Figure 2 Schematics of 3D gantry crane system.

The dynamic equations of motion in gantry crane system in the y-direction obtained as [1] where y_t is position of trolley and y_p is position of payload oscillation. Parameters of the gantry crane system are tabulated as in Table 1.

$$\ddot{y}_t = \left(\frac{F_x}{m_w} - \frac{T_x}{m_w}\right) + \left(\frac{m_c}{m_w}\right)\left(\frac{F_z}{m_c} - \frac{T_z}{m_c}\right)\cos\alpha \qquad (1)$$

$$\ddot{y}_p = \ddot{y}_t + \left(\ddot{R} - R\dot{\alpha}^2\right)\cos\alpha - \left(2\dot{R}\dot{\alpha} + R\ddot{\alpha}\right)\sin\alpha \qquad (2)$$

Table 1 Parameters of gantry crane system [1].

Parameters	Unit	Values
Payload mass	m_c	1.0 kg
Trolley mass	m_w	1.155 kg
Moving rail mass	m_s	2.20 kg
Gravity	g	9.81 ms^{-2}
Friction force at x-axis	T_x	100 Nsm^{-1}
Friction force at y-axis	T_y	82 Nsm^{-1}
Friction force at z-axis	T_z	75 Nsm^{-1}
Length of cable	R	0.5 m

3. CONTROL SCHEME

Figure 3 illustrated the block diagram of control scheme in the gantry crane system. There are two types of controllers which are PID and PD controller. PID controller is designed in feed-back structure which is implemented to control the trolley in order to reach the desired position. Besides, PD controller is constructed as feed-forward structure used to control the oscillation of the angle which created from the system while moving the payload to the desired position. The parameters in these controllers are optimized by the meta-heuristics method which is PSO with 20 agents and 100 iterations. The optimized parameters of PID (K_P, K_I and K_D) and PD (K_{Ps} and K_{Ds}) controller is tabulated in Table 2.

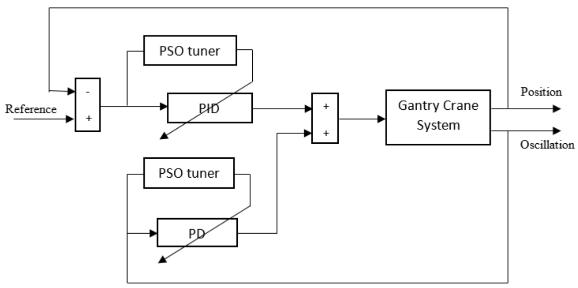

Figure 3 Block diagram of control scheme.

Table 2 Optimized PID and PD Parameters.

Parameters	Values
K_P	20.9716
K_I	10.8455
K_D	4.4700
K_{Ps}	5.0092
K_{Ds}	0.0704

4. RESULTS AND DISCUSSION

4.1 Trolley position

Figure 4 shows the trolley position in the gantry crane system which controlled by the PID controller. After having an overshoot of 19.63%, the system started to settle down at 6.90 seconds and reached the desired position of 0.30 meters with zero steady state error.

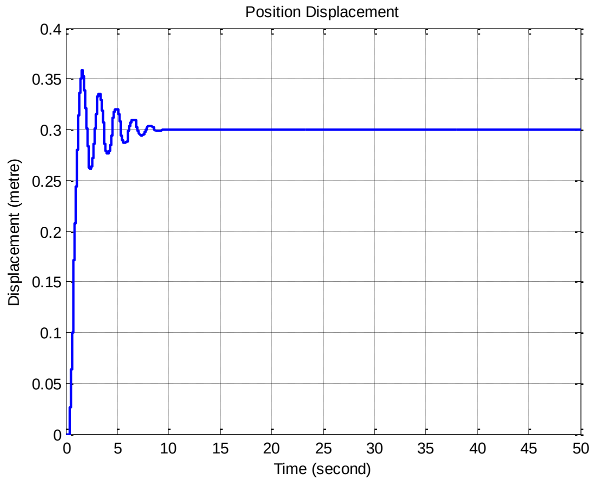

Figure 4 Response of trolley position.

4.2 Payload oscillation

Figure 5 shows the payload oscillation in the gantry crane system which controlled by the PD. It shows that the maximum payload oscillation is 1.1526 radian at 1.4 seconds. Then, the oscillation is slow down and reached the minimized oscillation of 0.0077 radian, which is approximate to zero radian.

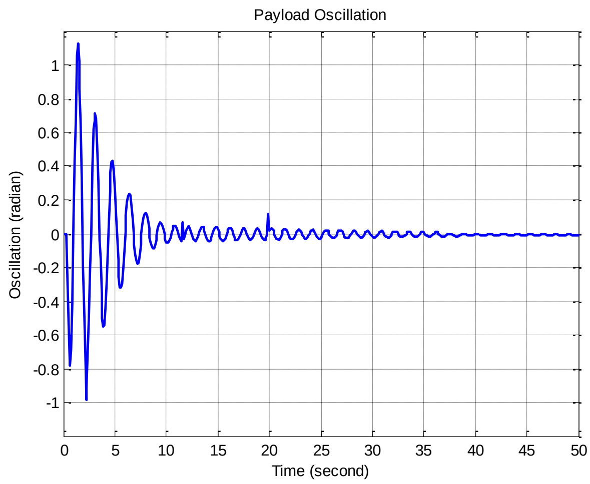

Figure 5 Response of payload oscillation

5. CONCLUSION

This paper is presented a control strategy of PID and PD controller which tuned by PSO in the 3D INTECO gantry crane. The controller is proposed to control the trolley movement with minimize oscillation. The results shown that with the implementation of the PSO, the system able to reach the desired position with low payload oscillation. Therefore, the controller works effectively in experimental platform.

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