Hybrid Adaptive Precise Position Control of Three Degrees Freedom Platform

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Abstract-This paper describes the implementation of a hybrid self-tuning regulator for the positioning of motors in 3-degree of freedom table in image stabilizer. This system has three motors in yaw, pitch, and roll axis for control of table. The servo motors are permanent-magnet dc motors in which no speed reducer is used. Experimental results obtained with three dc motors in yaw, pitch and roll axial.

There are two innovative aspects of this work. First, parameter estimation is used to adapt the feed forward compensation terms instead of the gains of the feedback controller, as usually is the case in conventional indirect self-tuning regulators. Second, the complete adaptive controller has been implemented with matlab and c program and pcl812 card and encoder card and motor driver for command the motors.

In result one method with hybrid increase accuracy system, specially when input error signal is large and need to maximum speed control system.

I. INTRODUCTION

The use of a direct-drive actuator in motion control applications allows obviation of the problems associated with mechanical gearing. In the direct drive scheme, backlash and the high mechanical stiffness of the direct-drive actuator make it very attractive for high-accuracy positioning systems such as digital control machines.

When the load is gear driven, the variable inertia effect of the load is attenuated by the square of the gear reduction ratio when reflected to the motor shaft. Therefore, the varying inertia as well as the effects of friction are more prominent for the direct-drive actuator, where the gear ratio is equal to 1 and can no longer be neglected. State-of-the-art controllers designed for accurate positioning of servo drives combine the feed forward control with the feedback control. In this scheme, the feed forward control provides immediate torque to lead the load with no delay, and the feedback control takes care of the fine error detection. Feed forward compensation gives excellent results, as long as it relies on a precise model of the load. Previous publications report the use of feed forward control for the positioning of a gear-driven constant load [1]. This work was In direct-drive applications, the varying load effect, which is not attenuated by a gear reducer, makes it difficult to accurately tune the feed forward controller. Self-tuning is a convenient way to incorporate automatic modeling of a varying load. Because the self-tuning regulator has the ability to tune its own parameters, it is well suited for feed forward control, which depends critically on good models. The self-tuning regulator, which is an adaptive controller, can be thought of as being composed of two loops. The inner loop consists of the process and a regulator such as the one described earlier. The parameters of the regulator are adjusted by the outer loop, which is composed of an on-line parameter estimator. The regulator parameters may be calculated by any suitable control design method such as pole placement, deadbeat response, etc. The real-time on-line parameter estimation is usually based on a recursive least-squares (RLS) algorithm.

In adaptive control system change controller parameters while system is controlled and corrected if variant dynamic process trough outbreak turbulences .Then remain performance of system in desirable level.

Keyword: Adaptive control, DC motor , picture stabilizer , three degrees freedom table.

II. SYSTEM ANALYSIS

A. Motor Model

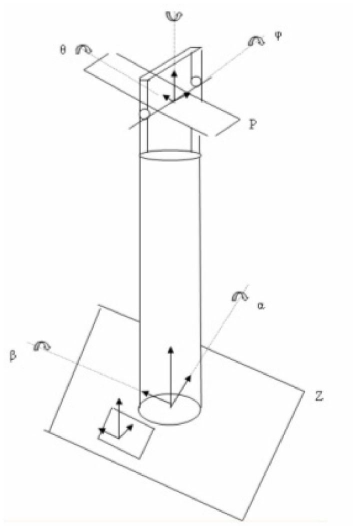


Fig 1: system structure

First, describe the dc servo-motor model In the discrete time domain, the z transfer function between the position Θ(z) and the motor terminal voltage $V_t(z)$ is :[]

$$\frac{\theta(z)}{v_t(z)} = \frac{b_1 z^{-1} + b_2 z^{-2}}{1 + a1 z^{-1} + b_2 z^{-2}}$$

Because of use gearbox in three axis for take real position, encoders

To have really Θ in three axis motor the position of encoder must be multiplied in transform coefficient.

Considering: $e(k) = \theta(k) - \theta(k-1)$ thus $e(k) = a_2 e(k-1) + b_1 v(k-1) + b_2 v(k-2)$

The RLS equation is, therefore:

$$\underset{-}{\hat{\theta}}(k) = \underset{-}{\hat{\theta}}(k-1) + \underset{-}{K}(k-1)\left[y(k) - \phi^t(k)\underset{-}{\hat{\theta}}(K-1) \right]$$

$\underset{-}{\hat{\theta}}(k) = [a_2(k), b_1(k), b_2(k)]$ is parameter vector , y(y)=e(k) is the output scalar

$$\underset{-}{\phi}(k) = \begin{bmatrix} e(k-1) \\ v(k-1) \\ v(k-2) \end{bmatrix}$$ is input-output measurement vector

$$\underset{-}{K}(k-1) = \frac{P(k-1)\underset{-}{\phi}(k)}{\left[\lambda + \underset{-}{\phi}^t(k) P(k-1) \underset{-}{\phi}(k) \right]}$$

$$P(k) = \frac{\left[I - \underset{-}{K}(k-1)\underset{-}{\phi}^t(k) \right] P(k-1)}{\lambda}$$

It is worthwhile noticing that the convergence of the estimator depends on the vector K and the covariance matrix P and is independent of the parameter vector $\underline{\theta}$ Therefore the initial knowledge of the parameter vector is unimportant whereas the initial value of the matrix P should be set as large as possible. With the forgetting factor λ, about $1/(1 - \lambda)$ numbers of *old* data are used to estimate θ . Therefore, the initial knowledge of the parameter vector is unimportant, and $\theta\underline{(0)}$ can be set to zero.

Typical values of the forgetting factor are $0.95< \lambda<0.99$.

2.3 Load inertia and friction

Once the parameters a_2, b_1 and b_2 are estimated, the static gain K and the time constant τ of equation (3) are easily determined knowing the sampling period T.

$$k = \frac{k_t}{(k_t^{\ 2} + FR)}$$

$$\tau = \frac{JR}{(k_t^{\ 2} + FR)}$$

From above equation :

$$\frac{FR}{k_t} = k^{-1} - k_t$$

$$\frac{JR}{k_t} = k^{-1}\tau$$

$$\tau = \frac{JR}{k_t/k}$$

In this equation that is tested for yaw axis $k_t = 0.0587\frac{Nm}{A}, R = 2^{\Omega}$ and T=1ms and parameters of motor is obtained as below figures,

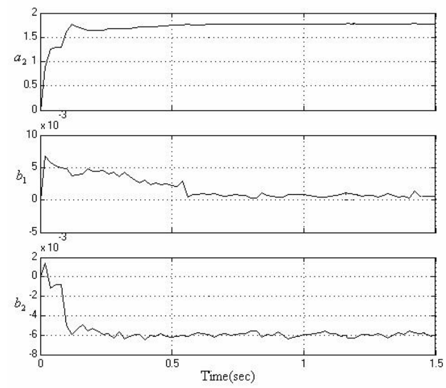


Fig2:estimation of motor's coefficients for T=1ms, P0=10e8.

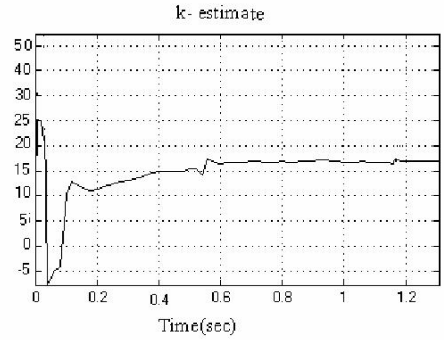


Fig3. estimation of motor's constant of motor(k)

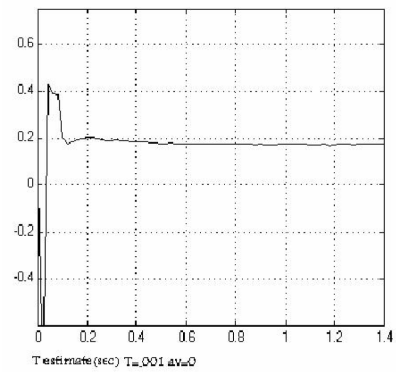
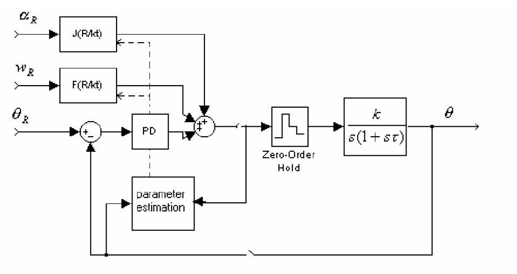


Fig 4. estimation of motor's time constant(τ).

3.4 Feedforward motion control

In order to increase the response time and to impose acceleration and speed profiles during servo mode, feed forward terms are added to the feedback controller output. One feed forward term is proportional to the speed and the other is proportional to the acceleration. The speed and acceleration references are obtained by differentiation of the displacement trajectory. The feed forward terms provide the voltage reference part

that is necessary to follow the desired position trajectory. In this scheme, the feed forward control provides immediate torque to lead the load with no delay and the feedback control takes care of the fine error detection.
Online estimation of motor's obtained parameters with recursive algorithm (RLS) and $\alpha_R = w_R^{\circ}, w_R = \theta_R^{\circ}$
Block diagram of closed loop system is:



The feed forward controller is based on an approximate model of the load torque T_l, that is

$$T_l = J\alpha + Fw \qquad (23)$$

Since there is no constant term, the feed forward terms will intervene only in the servo mode and will reduce to zero during the regulation mode.

Experimental results were obtained using a standard permanent magnet DC motor to show the effect of feedforward compensation. Fig. 4 shows the response obtained with a PD controller. It can be seen that the position curve does not follow precisely the desired trajectory. Fig. 5 shows the response obtained with the same PD controller to which feed forward terms as described by equation (23) were added.

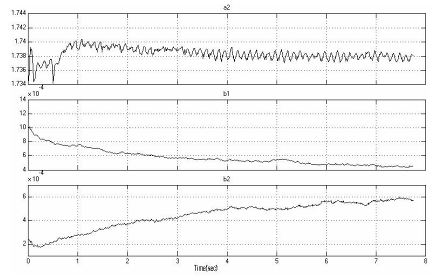


Fig 6:estimate of coefficient in adaptive control.

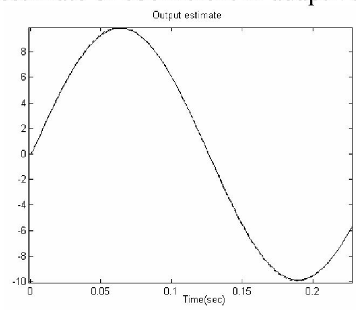


Fig7: compression of input an output in adaptive control and estimation of torque.

Optimization response system with use of hybrid controller

In this section used proposed method and optimized response system. in this method use of open loop response and on/off controller. If error was positive and high -Vmax and when error was negative and low +Vmax applied to system. If error was between $-e_{\max}$, $e_{\max}$ adaptive controller is on and variants voltage continuate and its value is 24 to -24 volt .
One simple method is use of on/off switch with hysterics and better method is use of control switch on/off with attention to error value and variation output signal slope. For this purpose used from variation of voltage, speed and position curve. If reduction speed slope would be constant in every point speed curve calculated time required by this equation:

$$p_g = p_t + w_t \times \Delta t$$

$$\frac{w_t - w_g}{\Delta t} = \alpha \quad , \quad w_g \approx 0 \quad \Rightarrow \Delta t = \frac{w_g}{\alpha} \quad , \quad p_g = p_t + \frac{w_t^{\,2}}{\alpha}$$

p_t : motor present position

p_g : motor position after stop

w_t : motor present speed

w_g : motor speed after stop

α : sloop of rate

Δt : time of decrease

Because purpose that stopped motor then $w_g \approx 0$

This controller contains windup circuit that control of position in motor is best. In fig.9 position control system in motor for different positions was illustrated. For small position speed is slow and huge position speed is high.

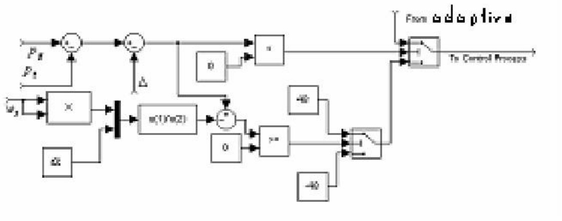


Fig8: block diagram of hybrid control for improve of system response

Rule of controller are:

1) $p_g - p_t - \Delta < 0 \quad \Rightarrow PID \quad Controller$

2) $p_g - p_t - \dfrac{w_t^{\,2}}{\alpha} - \Delta > 0 \quad \Rightarrow V = 24\,v$

3) $p_g - p_t - \dfrac{w_t^{\,2}}{\alpha} - \Delta < 0 \quad \Rightarrow v = -24\,v$

Block diagram for this controller illustrated in fig.8 (values of α , Δ are constant). with adjust this values for different positions and pass one equation trough points get a good content for this values.

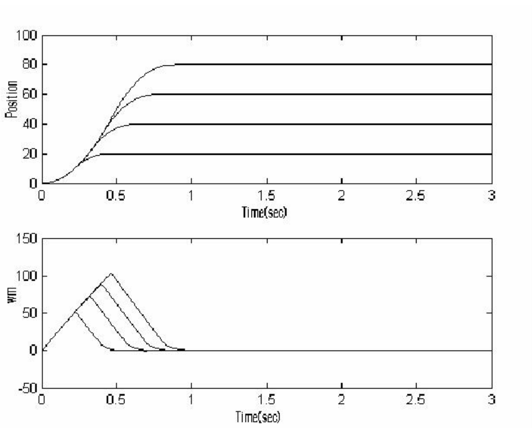
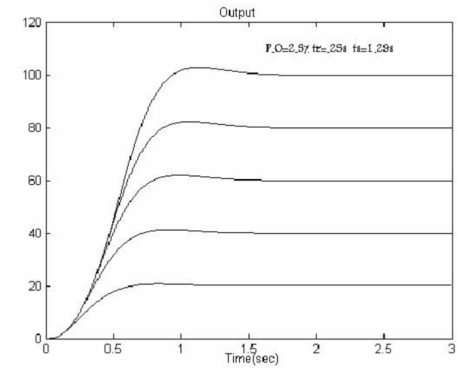
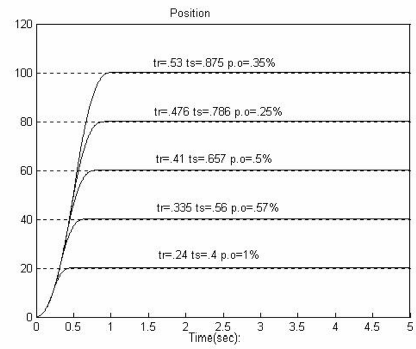


Fig9: speed and position of yaw in hybid control for different positions.



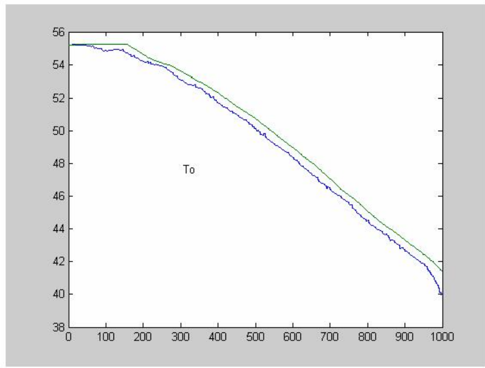
a)



(b

Fig10: system output for different positions. A) adaptive control b) hybrid control.

4-practical results:



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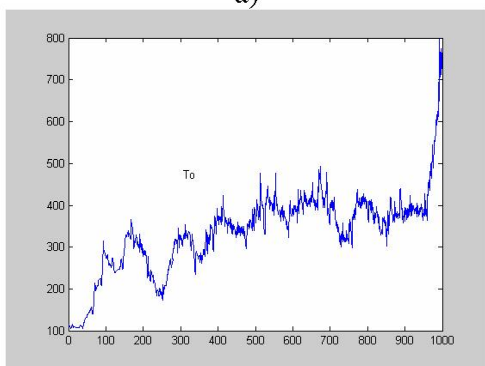
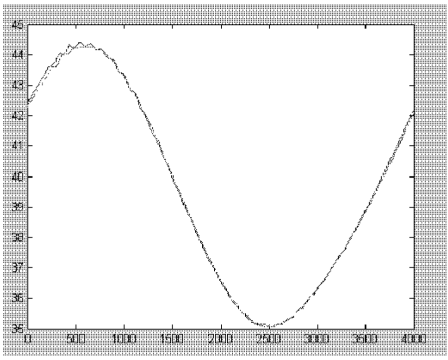
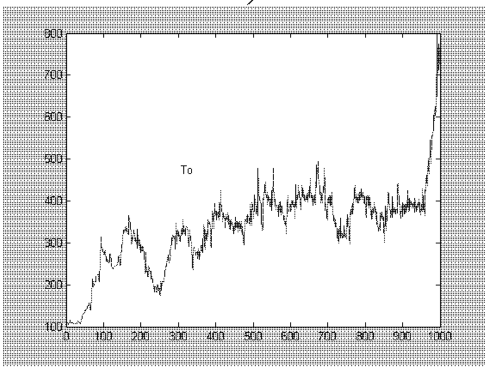


b)

Fig11: a) input and output position b) pwm output to motor (from d/a) in adaptive control and stabilizer is on



a)



b)

Fig12: a) input and output position b) pwm output to motor (from d/a) in hybrid adaptive control and stabilizer is on

Conclusion

From simulation and results we obtain that with use of hybrid method results is better related to adaptive and PID methods. We can estimate parameters of motor with use adaptive method and applied these parameters for accuracy control system. We can obtain values α , Δ with intelligence methods.

Refrences:

[1] Asghar taheri , MSC degree thesis " design and simulation of electro optical tracker system with adaptive controllers" , 2001.

[2] Jianxin Tang , " Real-Time DC Motor Control Using the MATLAB Interfaced TMS320C31 Digital Signal Processing Starter Kit (DSK) " , International Conference on Power Electronics And Drive Sytems ,1999.

[3] A. Scottedward Hodel , Charles E. Hall ," Variable Structure PID Control to Prevent Integrator Windup " , IEEE 2001 .

[4] Louis A. Dessiant , Bernard Hebert , Hoang Le. Huy , " An Adaptive Controler for a Smooth Positioning System " , IEEE 1989.

[5] Liaw, C.M., Shue, R.Y., Chen, H.C., Chen, S.C. ," development of a Linear brushless DC motor drive with robust position control, " Electric Power Applications, IEE Proceedings , March 2001

[6] Kasa, N, Watanabe, H., "A Sensorless Position Control System by Salient-pole brushless Dc Motor,",Industrial Electronics, Control and Instrumentation, 1997 IEEE transaction .