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# Estimator and Controller Design for a Didactic Liquid Level System by System Identification Approach

## INVENTOR


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## ABSTRACT


This poster is a piece of report on the identification of Didactic Liquid Level Systems. The term didactic is used as to enlighten the purpose of proto-typing liquid level system for educational use. A liquid level system with unknown mathematical characteristic is identified using ARX (Auto-Regressive with Exogenous Input) model. The estimator is designed. Literal analysis of the experimental data is conducted to obtain the discrete transfer function as well as state space representation of it.

The identification process which exploits the advantage of linear parametric ARX gives beneficial information such as correlation, best fit and poles-zeros location. The Linear Quadratic Regulator (LQR) is tested for such liquid level system before the estimator is designed. Literal analysis of the estimator performance is conducted as a preliminary insight to the next investigation on the self tuning Proportional – Integral – derivative (PID) algorithm.

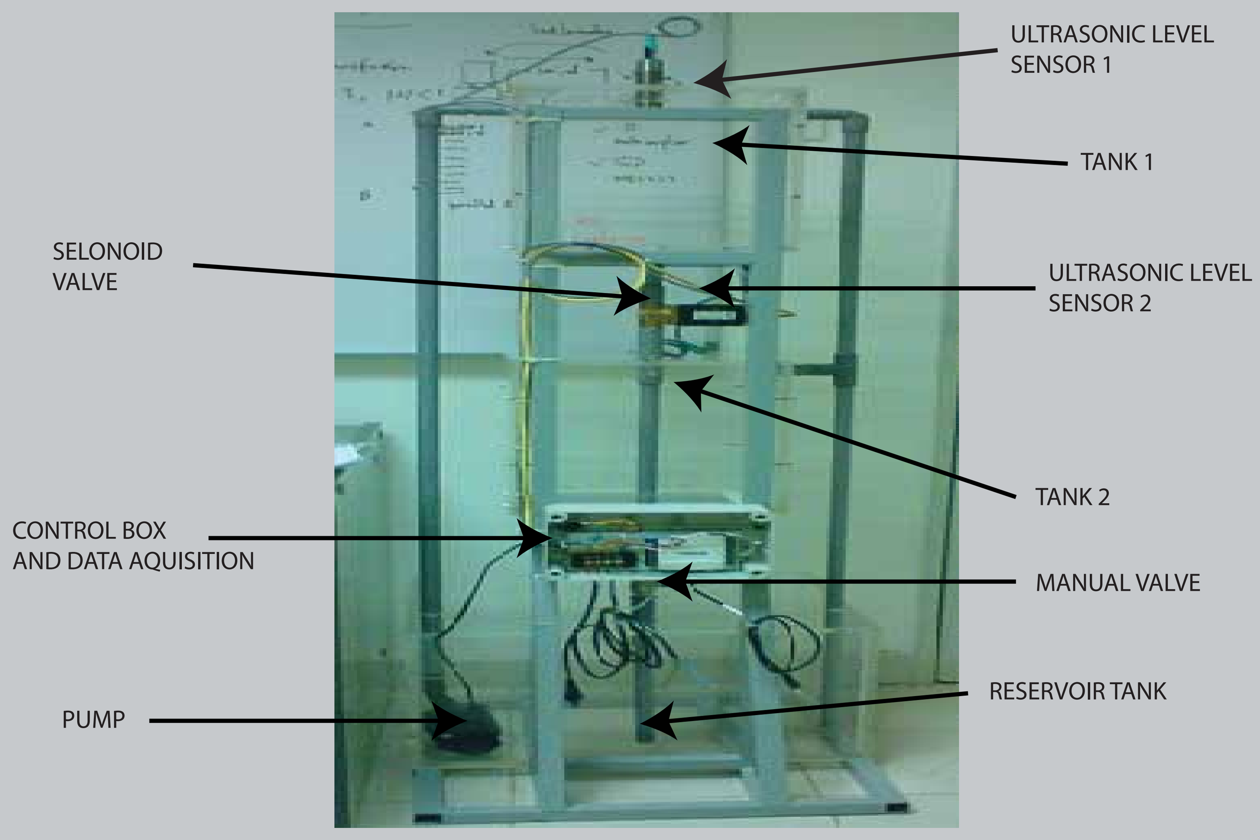
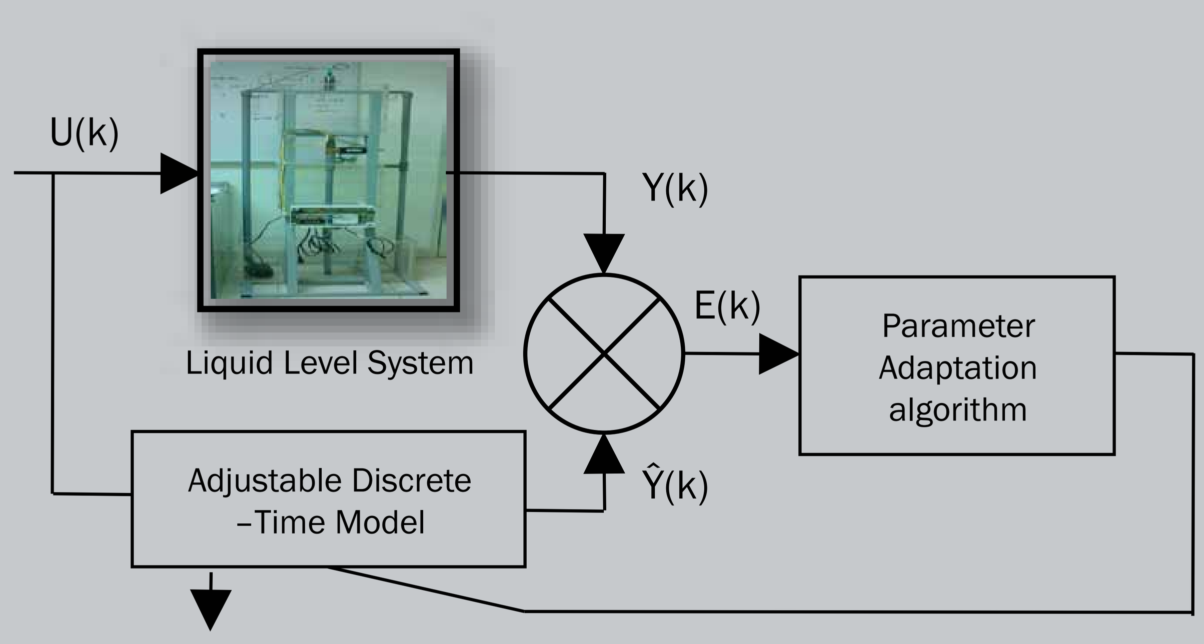




Figure 1: Liquid Level System

## THE STATEMENT

Liquid level systems in figure 1 is rich with non-linearities and disturbances. As such, building the dynamic model of such system is tedious without any known parameters presented. The used of system identification methods are worthwhile for the parameter estimation of such systems.




## THINGS TO PONDER

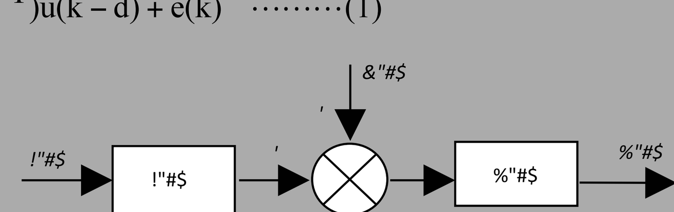
Apart from nonlinearities, there may be unknown parameters which hinders the objective to obtain a complete model of the system. Those parameters may not be estimated accurately if reliable experimental data is absent. These factors abstained us as researchers to use conventional control theory.

## IDENTIFICATION PROCESS

Through system identification process, all important information such as best fit, residual analysis, correlation, and pole-zero location are obtained. As such, the mathematical model of Liquid Level System is acquired. As the system suffer from chaotic behavior and bifurcation phenomena which come from the dynamics of the motor pump, solenoid valve and sensors, the use of identification tool in MATLAB is beneficial. A few structures of parametric model such as ARX model, ARMAX model, OE model and BJ model can be used as liquid level model structure. ARX model serves the basic structure as this structure ignores the moving average or the error dynamics of the system. As such, ARX model is used and the general model with appearance of error dynamics e(k) is represented by the difference equation (1). Lowercase 'd' is time delay which represent the difference between u(k) and y(k).

### *ARX Model Structure*

$$A(Z^{-1})y(k) = B(Z^{-1})u(k-d) + e(k) \quad \cdots\cdots\cdots(1)$$



### *Input Signal*

$$u(k) = V_{dc} + \sum_{i=1}^{p} a_i \cos \omega_i t_s k \quad \cdots\cdots\cdots(2)$$

### *Plant Model*

$$A(Z^{-1})y(k) = B(Z^{-1})u(k) + e(k) \quad \cdots\cdots\cdots\cdots(3)$$

$$\therefore A(Z^{-1}) = 1 - 1.418Z^{-1} + 0.4948Z^{-2}$$

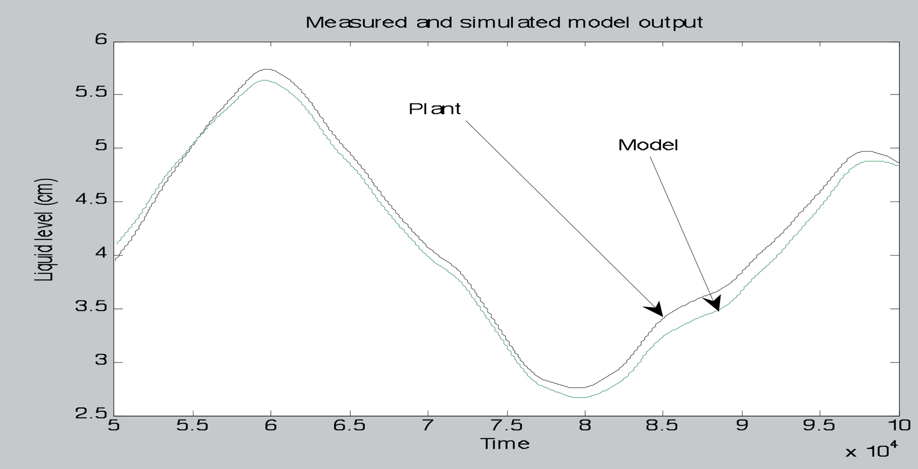
$$\therefore B(Z^{-1}) = 0.07887Z^{-1} + 0.03591Z^{-2}$$

$$G(Z^{-1}) = \frac{B(Z^{-1})}{A(Z^{-1})}$$

$$G(Z^{-1}) = \frac{0.07887Z^{-1} + 0.03591Z^{-2}}{1 - 1.418Z^{-1} + 0.4948Z^{-2}}$$

$$G(Z) = \frac{0.07887\ Z + 0.03591\ Z}{Z^2 - 1.418\ Z + 0.4948} \quad \cdots\cdots\cdots(4)$$

$$G(S) = \frac{104.8S + 4.032\text{x}10^{6}}{S^2 + 3518S + 2.698\text{x}10^{6}} \quad \cdots\cdots\cdots(5)$$



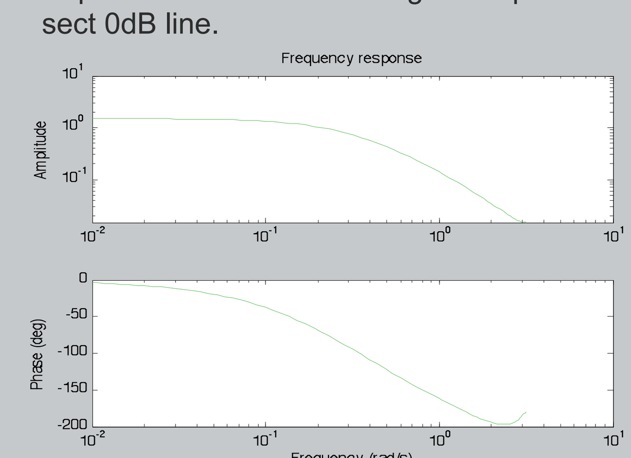

*Measured and simulated model output yields best fit of 86.93*

### *Matrix Form*

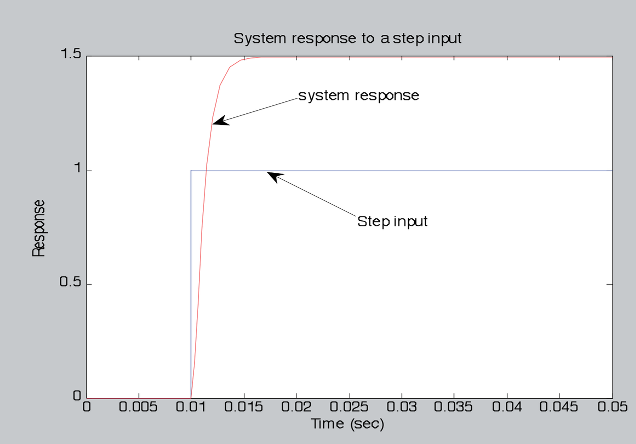
$$A = \begin{bmatrix} -3518 & -2.698e+006 \\ 1 & 0 \end{bmatrix} \quad B = \begin{bmatrix} 1 \\ 0 \end{bmatrix} \quad C = \begin{bmatrix} 104.8 & 4.032e+006 \end{bmatrix}$$

## PRELIMINARY TESTING

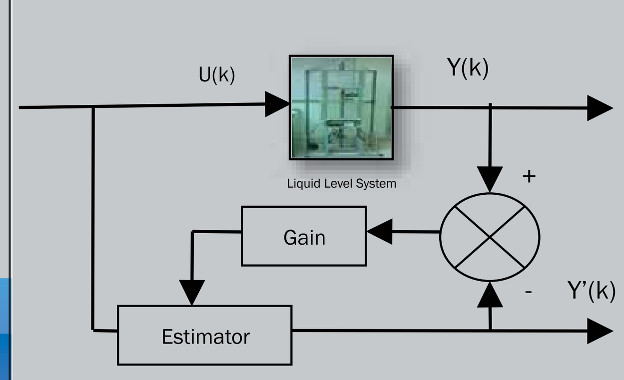
The plot shows that the stability need to be improved as the phase plot has not meet the required -180° when the magnitude plot intersect 0dB line.

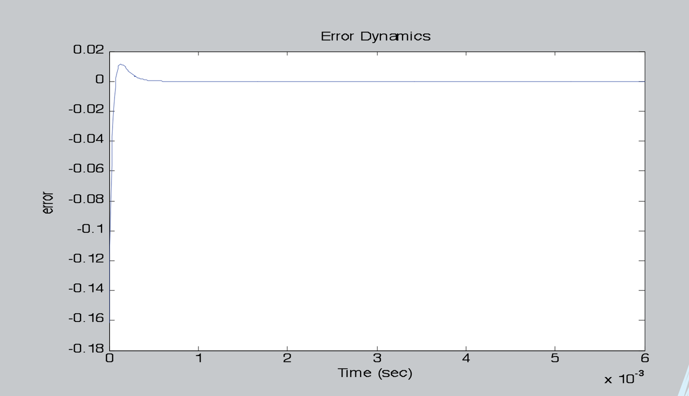


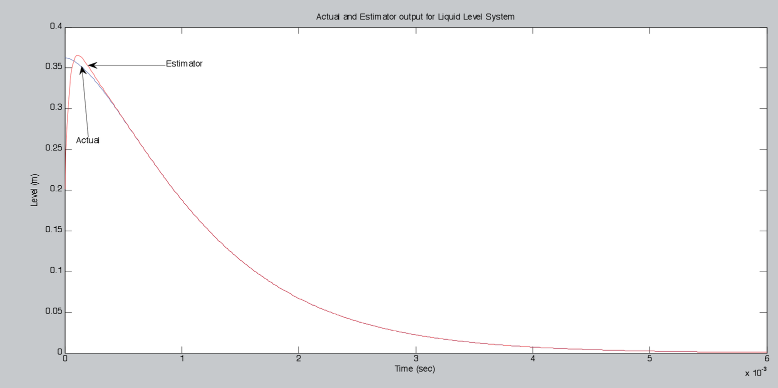

Step response in confirms that the system suffers around 50% steady state error due to the step change.




## ESTIMATOR RESULT




## PID COMPENSATOR RESULT

| Type | Location | Damping | Frequency |
|---|---|---|---|
| Real Zero | -14809 | 1 | 14809 |
| Real Zero | -547 | 1 | 547 |
| Integrator | 0 | -1 | 0 |

$$C(S) = 4200.8\text{x}\frac{(1 + 6.8\text{x}10^{-5}S)(1 + 0.0018S)}{S}$$