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Conical Tank Level control using Vision Position PID controller

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ABSTRACT: The past few decades researchers much attention about the conical tank level control using various methods. Aim of the paper is to conical tank level control using vision position based PID controller, simulated and experimental results on the conical tank level control are presented. From the experimental results it is concluded that Vision Position PID controllers present the lowest energy consumption by the control signal.

KEYWORDS: Level control, conical tank, PID control, Vision Position PID control.

I. INTRODUCTION

In the control literature there exist works addressing the level control in conical tanks. This has been addressed from simulation and experimental viewpoints and several control techniques have been employed. Results ranging from basic PID control strategies [1] have been informed [3]. Advanced other controls such as model predictive control [4] passivity based control [5] has been reported. Even so, it is used as a model of the system based on a first order plus death time identification about operating points. Both in simulations and experiments consider for the parameters tuning a system linearization neglecting the plant nonlinear behaviour. Work on this level control in a conical tank is dealt from simulated and experimental points of prospect. To this point, a nonlinear model representing the plant behaviour is developed. A standard integer order PI control scheme is developed whose parameters are tuned using the root locus method and regarding a linearized models at three dissimilar operating points. This exploit is organized as follows: Section 2 admits general conception about vision position detection. Section 3 confronts the description of the Vision position conical tank system and the mathematical model of the plant based on physical considerations. Section 4 confronts the tuning operations for the controller parameters of the PID, VPPID controllers using the Root Locus and the Z&N methods. Sections 5 and 6 confront the simulation and experimental results of the aforesaid control method to the mathematical model of the plant. Particulars of the execution and comparisons amongst the control techniques studied are also discussed. In Section 7, the important conclusions of the work are depicted.

II.SYSTEM MODEL AND ASSUMPTIONS

2.1 Model of the conical tank system

The conical tank water is pumped from the recirculating tank to the conical tank using a pump driven by an induction motor driven by a variable frequency drive.

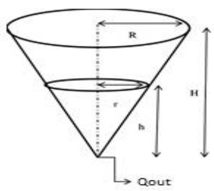

Figure 1 Conical Tank

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Mathematical model

$$\tan\theta = \frac{r}{h} = \frac{R}{H}$$

$$r = \frac{Rh}{H}$$

$$A = \pi r^2$$

$$A = \pi \frac{R^2 h^2}{H^2} \quad (1)$$

$$\frac{dA}{dt} = \pi \frac{R^2}{H^2} 2h \frac{dh}{dt}$$

$$V = \frac{1}{3}\pi r^2 h \quad (2)$$

$$\frac{dV}{dt} = \frac{1}{3}\left[A\frac{dh}{dt} + h\frac{dA}{dt}\right]$$

$$\frac{dV}{dt} = \frac{1}{3}\left[A\frac{dh}{dt} + h\frac{\pi R^2}{H^2} 2h \frac{dh}{dt}\right]$$

$$\frac{dV}{dt} = \frac{1}{3}\frac{dh}{dt}\left[A + h\frac{\pi R^2}{H^2} 2h\right]$$

$$\frac{dV}{dt} = \frac{1}{3}\frac{dh}{dt}[A + 2A]$$

$$\frac{dV}{dt} = A\frac{dh}{dt}$$

$$Q_{in} - Q_{out} = A\frac{dh}{dt} \quad (3)$$

$$Q_{out}(s) = \frac{h(s)}{K}$$

$$Q_{in}(s) - Q_{out}(s) = Ah(s)S$$

$$Q_{in}(s) - \frac{h(s)}{k} = Ah(s)S$$

$$Q_{in}(s) = \frac{h(s)}{k} + Ah(s)S$$

$$Q_{in}(s) = \frac{ksh(s)A + h(s)}{k} 2$$

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$$Q_{in}(s) = h(s)\left[\frac{ksA+1}{k}\right]$$

$$\frac{h(s)}{Q_{in(s)}} = \left[\frac{k}{kAs+1}\right]$$

$$\frac{h(s)}{Q_{in(s)}} = \left[\frac{k}{kAs+1}\right]$$

$$\frac{h(s)}{Q_{in(s)}} = \left[\frac{k}{k\frac{\pi R^2 h^2}{H^2}s+1}\right] \qquad (4)$$

III. SCOPE OF THE RESEARCH

3.1 Vision Position Detection

This section, presents the general concepts about the techniques used in this work. The basic definition of vision position is firstly introduced, succeeded by the structure of the classic PID controller and its extension to the vision position (VPPID). Root locus and Z&N tuning techniques are then briefly explained.

In vision position control system camera plays an important role. The camera continuously captures the images x frames per second. The set point is of the system is nothing but the reference point of the system. The output signal is calculated from reference image. The feedback signal is getting from output point. The camera image is act as a feedback path. This image value is compared with set point of the system, nothing but the reference image.
Instantaneous output will be,
output = reference image – actual image

Error = output;

The minimum error is zero. It means that the system desired set point has been reached. If non-Zero errors developed, it can be carried out by corresponding proportional integral and derivative signals to bring the system stable.

3.2 Vision Position PID controllers

Vision position (VPPID) controllers are combination of image processing and proportional integral and derivative control. The image of the system coordinates are calculated to find out error.
The PID controller is defined as,

$$C(s) = k_p + \frac{k_i}{s} + k_d s \qquad (5)$$

The VPPID controller can be written as

$$C(s) = (k_p + \frac{k_i}{s} + k_d s) * position(x, y) \qquad (6)$$

VPPID controllers are free from sensor noises and easy to get feedback information.

3.3 Root locus method

The tuning PID controllers fits to the root locus technique, which considers a closed-loop control of its overall transfer function (TF) has the form

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$$\frac{Y(S)}{R(S)}=\frac{G(S)}{1+G(S)H(S)} \qquad (7)$$

where*Y is output* and *R is input of* the reference system signals, respectively. *G*(*s*) is considered as the transfer function formed by the controller and the process plant, *H*(*s*) is the transfer function of the measuring device. Tuning method tries to find out the poles, zeros and a high frequency gain of the controller, via the satisfying of two conditions on the system. Unity gain is the open-loop trnasferfunction:

Magnitude condition

$$|G(S)H(S)|=1,-\infty<K<\infty \qquad \textbf{(8)}$$

The angle of open-loop transfer function is an odd multiple of π:

Angle condition

$$\angle G(s)H(s)=(2i+1)\pi, k\geq 0, i\in Z \qquad \textbf{(9)}$$

3.4 Ziegler-Nichols method

The tuning parameters of PID controllers are done with the Ziegler and Nichols tuning method. It is used for tuning of VPPID controllers. There are two methods, which are based on a particular dynamic characteristics of the plant under confined conditions. These values can be done either from the mathematical model and/or experimentally.

IV. PROPOSED METHODOLOGY AND DISCUSSION

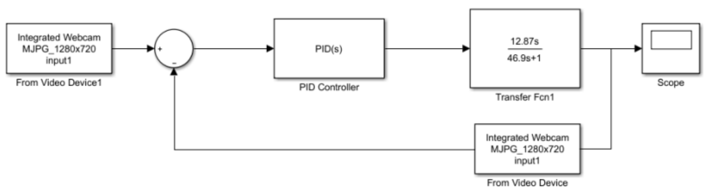

Figure 2 Proposed VPPID Conical Tank system

4.1 **Vision Position**

The reference image r(x,y) is compared with actual image a(x,y) and yields luminance, contrast and structure in each image respectively. The luminance is compared with luminance, contrast is compared with contrast this processing is done for each and every frame of the actual image. Vision feedback done by an optical tracking system. Calculation of the control system accuracy was performed using SSIM.

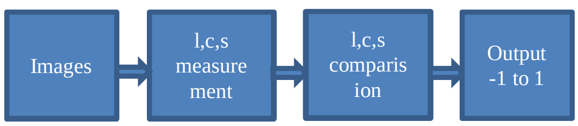

Figure 3 SSIM Vision Position

$$SSIM(x,y)=l(x,y)*c(x,y) \qquad (10)$$

The images are showing the different stages of a level in the tank. Three stages are considered for experiments. Low, medium and high.

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Case 1:
The actual image frame n shows the quarter level and it is compared with set point level reference image. Now it gives instantaneous

n[th] frame for quarter level $l(x,y)$ and $c(x,y)$

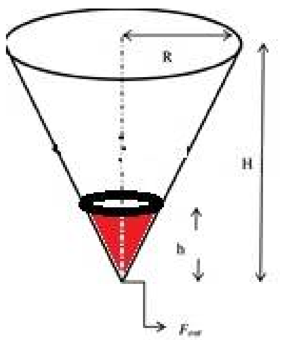

Figure 4Conical Tabk with LOW level

Case 2:
n[th] frame for medium level $l(x,y)$ and $c(x,y)$

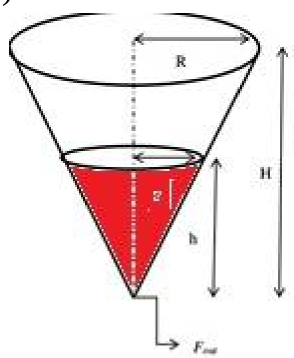

Figure 5Conical Tabk with Medium level

The mean square error value is half of the value; and for structure it is 0.

$$SSIM_n(x,y) = l_n(x,y) * c_n(x,y) \quad (11)$$

Case 3:
n[th] frame for HIGH level $l(x,y)$ and $c(x,y)$;

The mean square error value is zero; because the set point has reached. For structure it is one 1.

$$SSIM_n(x,y) = l_n(x,y) * c_n(x,y) \quad (12)$$

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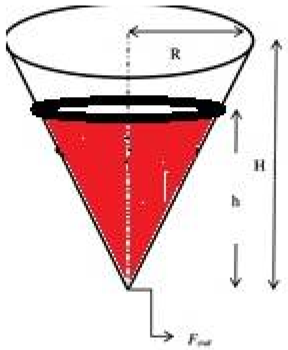

Figure 6Conical Tabk with HIGH level

V. RESULT AND DISCUSSION

5.1 Matlab Simulation

The simulation is done using Matlab coding and the reference image is stored and compared with actual image frames continuously.

```
% video. This loop uses the System objects you instantiated above.
reference_image1 = step(vidDevice);
imshow(reference_image1);
imwrite(reference_image1,'Deena_ref.png');
reference_image=rgb2gray(reference_image1);
imshow(reference_image);
nFrames = 0;
%while (nFrames<100)     % Process for the first 100 frames.
while (nFrames<100)     % Process for the first 100 frames.
% Acquire single frame from imaging device.
rgbData = step(vidDevice);
refe=rgb2gray(rgbData);
%'immse' Mean-Squared Error
[ssimval, ssimmap] = ssim(reference_image,refe);
immse(reference_image,ssimmap);
error = 1-ssimval;
pTerm = Kp * error;
integrated_error = integrated_error + error;
iTerm = Ki * integrated_error;
dTerm = Kd * (error - last_error);
last_error = error;
pid_image = (K*(pTerm + iTerm + dTerm));
OverallG = pid_image *H;
fprintf('\n The mean-squared error is %0.4f', err);
% Increment frame count
nFrames = nFrames + 1;
end
```

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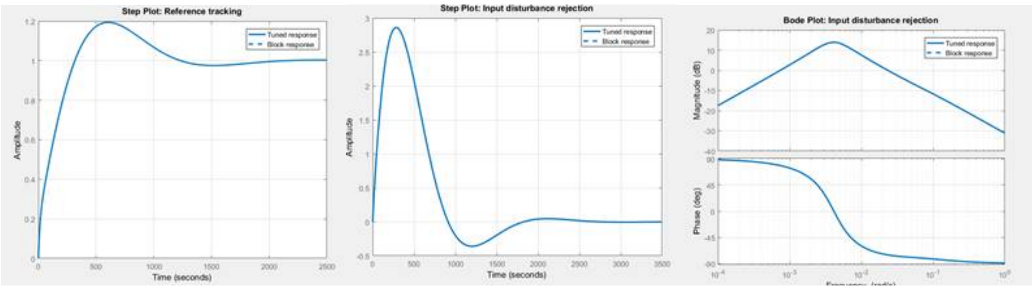
Table 1 PID Tuning Parameters

	Tuned	Block
P	0	200
I	34.7608	55.0921
D	0	0



(a) (b) (c)

Figure 7 Plant responses without VPPID a. Reference Tracking b. Input disturbance rejection c. Bode plot

```
t = 0:0.01:10;
L1 = feedback(OverallG,1)
figure; step(L1,t)
grid
```

5.2 **Experimental results**

The existing conical tank is shown in the figure 8.

Figure8 Conical tank system.

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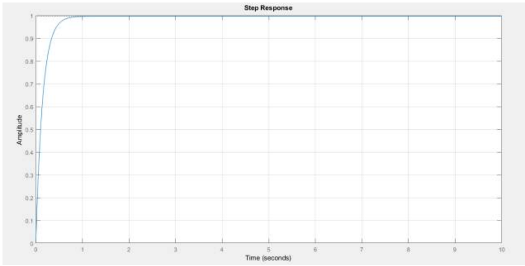

Figure 9 System output with VPPID

Table 2 Performance and Robustness

	Tuned	**Block**
Rise Time	0.23 seconds	8.11Seconds
Settling Time	0.409 seconds	14.4 seconds
Overshoot	0%	0%
Peak	0.998	0.999
Gain Margin	Inf dB @ NaN rad/s	Inf dB @ NaN rad/s
Phase Margin	90.1 deg @ 9.54 rad/s	Infdeg @ NaN rad/s
Closed-loop stability	Stable	stable

VI.CONCLUSION

The VPPID simulated for three different position and the experimental results for the same level control have been obtained. Plant nonlinear model of the system the parameters of PID and VPPID controllers were tuned which are summarized in Table 2. The proposed vision position PID system was effective and suitable for conical tank level control. The working of VPPID controllers with PID controllers is fair. A working onVPPID plus PSO tuned using is called for and will be part of the future research to be performed. This is the subject for future research andnatural extension of this work.

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