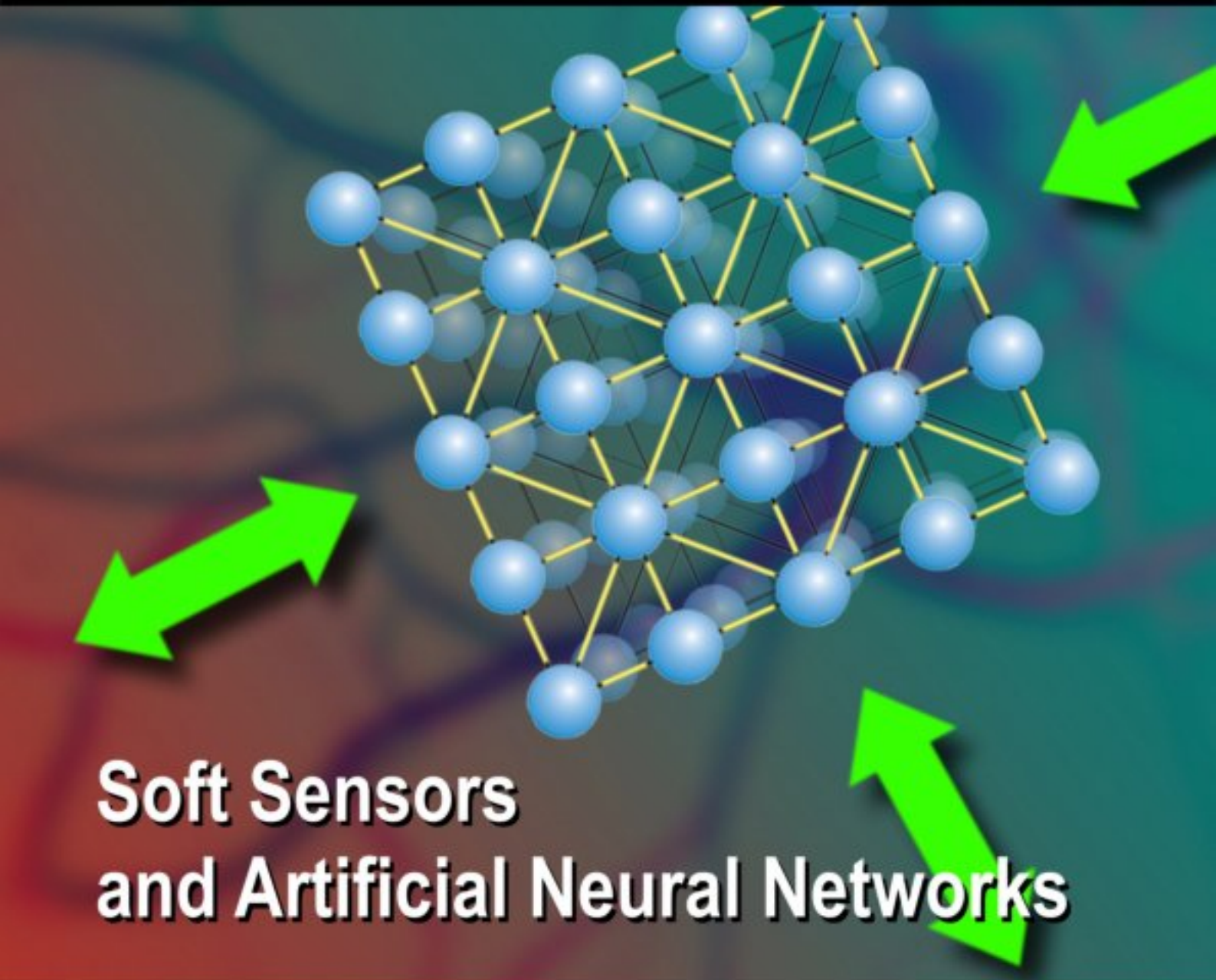
ISSN 1726-5479

SENSORS & TRANSDUCERS

vol. 145
10/12



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International Frequency Sensor Association Publishing

IFSA

Sensors & Transducers

Volume 145, Issue 10
October 2012

www.sensorsportal.com

ISSN 1726-5479

Sensors & Transducers Journal (ISSN 1726-5479) is a peer review international journal published monthly online by International Frequency Sensor Association (IFSA).
Available in electronic and on CD.

Sensors & Transducers Journal

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Volume 145
Issue 10
October 2012

www.sensorsportal.com

ISSN 1726-5479

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Sensors & Transducers Journal, Vol. 145, Issue 10, October 2012, pp. 33-40

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Sensors & Transducers

ISSN 1726-5479

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Design of Float-Image Level Transmitter for Level Measurement Using Image Processing Technique

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Received: 29 August 2012 /Accepted: 22 October 2012 /Published: 31 October 2012

Abstract: Level measurement was a vital parameter in process industries and it demands the need for cheap and non-contact measurement which was addressed in this paper. A fully automated computer based system of non-contact level measurement using image processing technique was proposed. The design consists of float allowed move freely in the vertical column when the liquid level changes. The image of the float is acquired and processed to extract its dimension and the extracted dimension is calibrated in terms of actual level. Various dimensions such as image pixel count, float area, side of a square float and radius of a circular float was considers for level measurement and their characteristics are analyzed. Finally, a GUI was developed to monitor and calibrated the instrument remotely.

Keywords: GUI, Image processing, Level transmitter, Float.

1. Introduction

Liquid level measurement is crucial in any process industries. A feed water level in a boiler should be maintained at certain rate for the effective and safe operation of a boiler. Level is defined as the filling height of a liquid in a tank or reservoir. The position of the surface is measured relative to a reference plane i.e. the bottom of the tank. If the tank's surface is not flat then the level is defined as the average height of a bounded area. Some of the parameters which affect the level measurement are foam, waves, turbulences and coarse-grained bulk materials. Various classic and modern methods exist to measure product level in storage and process tanks in the chemical, water, petrochemical and pharmaceutical industries, in static and mobile tanks. Typical tank heights are approximately between 0.5 m and 40 m [1]**.** Level transmitter is widely used in process industries to measure the liquid level.

The most commonly used liquid level measurement methods are radio frequency(RF) capacitance, conductance, hydrostatic head, radar and ultrasonic. Each and every method has its own benefits and complications. Mechanical, magnetic and other float level sensors works on the basis of opening or closing of a mechanical switch, either through direct contact with the switch, or magnetic operation of a reed. Magnetic and mechanical float level sensors are affected by chemical compatibility, temperature, specific gravity, density, buoyancy, and viscosity. Sensors such as pneumatic, conductive type, capacitance type and ultrasonic are affected by turbulence, form, and corrosion effects [2].

Image processing involves processing or altering an existing image in a desired manner. The image processing may either take place from any video or the image itself. Image processing is of two aspects, improving the visual appearance of images or preparing images for measurement of the features and structure present in it. Image processing technique has a wide range of application in noise filtering, content enhancement, medical imaging, remote sensing, astronomy [11], navigation [10] and autonomous machine applications [12].

The image processing technique involves different filters in which median filter is used to reduce the noise present in the image [7]. The median filter considers each pixel in the image in turn and checks at its nearby pixels to decide whether or not it is representative of its surroundings. In the median filtering technique the pixel value is replaced with the median of neighbouring pixel values. By sorting all the pixel values from the surrounding neighbourhood into numerical order, the median is calculated and then replacing the pixel being considered with the middle pixel value. Using the boundary trace function and filter the feature present in the float image is extracted.

The proposed system aims at the level measurement for various tank systems with various floating substance using image processing technique.

2. Design of Float-image Level Transmitter

2.1. Hardware Design

This system consists of a hollow pipe and a floating substance which is placed inside the pipe. A provision is there in the pipe such that when the level of the tank increases the liquid level inside the pipe also increases. A camera is mounted above the pipe to capture the image of the floating substance. Table 1 shows the specification of experimental setup.

Table 1. Specification of experimental setup.

Parameter	Value
Pipe height	50 cm
Tank height	26 cm
Camera resolution	340 x 280
Light intensity	75-625 lux
Pipe diameter	4.5 cm
Float white space diameter	2.5 cm
Float diameter	4.2 cm

The height of the pipe and the light intensity of the camera have to be maintained at a particular range. The light intensity of the camera should not get affected by the ambient light which could be done by blackening the inner walls of the hollow pipe. The height of the hollow pipe may affect the clearness

of the captured image. So the height of the hollow pipe should be double the height of the tank so that the captured image won't get dilated or blurred. The light intensity should be good enough to capture the float image at the minimum level as well as at the maximum level. Since the liquid flows to the hollow pipe through the provision at the bottom, obtained output level will be free from turbulence and foam.

Figs. 1 and 2 shows the schematic diagram of float- image level transmitter and hardware setup of the float -image level transmitter

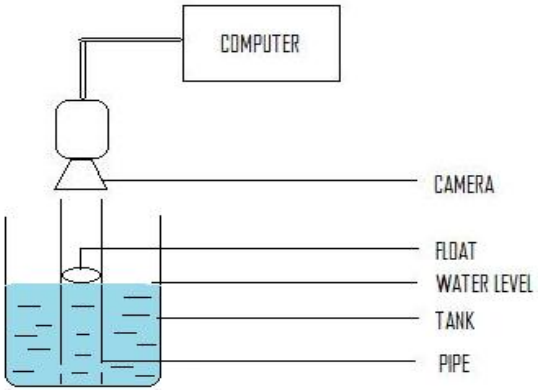


Fig. 1. Float-image level transmitter.

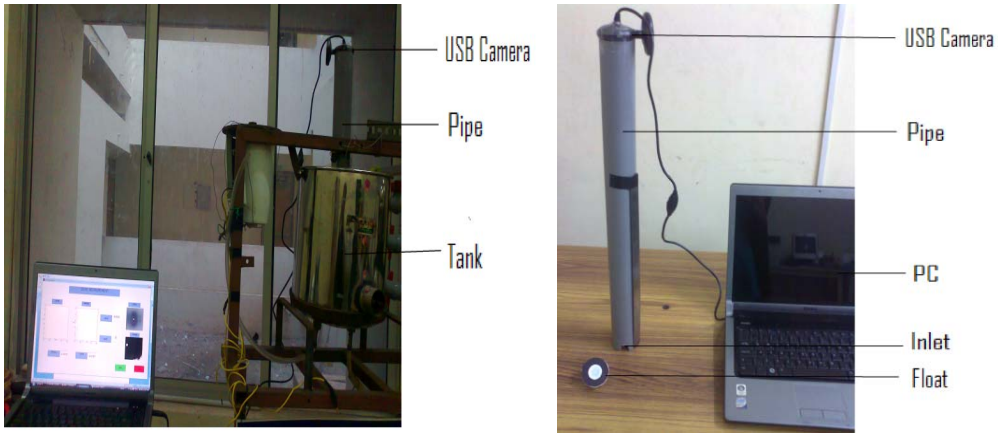


Fig. 2. Hardware setup.

2.2. Software Design

The program is developed in MATLAB software and interfaced with the tank using a graphic user interface (GUI). GUI has a video from which the image is captured and processed using image processing technique. Image processing involves many pre-processing techniques, following pre-processing techniques are used for the extraction of features present in the image.

2.2.1. Median Filter and Boundary Tracing

The captured image is pre-processed using median filter and boundary tracing techniques. Median filtering is similar to an averaging filter, in that each output pixel is set to an average of the pixel

values in the neighborhood of the corresponding input pixel. Then the value of an output pixel is determined by the median of the neighborhood pixels. For this proposed system median filter is used to remove the outline boundaries without reducing the sharpness of the image.

Next, Black and White boundary trace algorithm is used to trace the exterior boundary of objects and boundaries of holes inside these objects. In a binary image, a non-zero pixel (i.e.) White pixel corresponds to a fore ground and a zero pixel (i.e.) Black pixel corresponds to the back ground of the image. Then the trace algorithm starts trace in clockwise directions all the edges of the image and forms a boundary of the foreground image. Thus, the image size of the float was determined using the boundary obtained.

2.2.2. Object Detection, Dilation and Smoothening

The captured image can also be pre-processed using object detection, dilation and smoothening of the image. Other word for object detection is segmentation. The object to be segmented differs greatly in contrast from the background image. This change in contrast between the object and background can be detected by operators that calculate the gradient of an image. The gradient of an image is calculated and a threshold is applied to create a binary mask containing the segmented object. The threshold values are calculated using various edge detection algorithms. Then the threshold value was tuned and edge operator is again used to obtain a new binary mask that contains the segmented object of our interest. Then, the image is dilated using linear structuring element, which is created as a square matrix with all binary ones. Other objects that were not interest but connected to the border of the image can be removed using the structural element created. Finally, in order to make the segmented object look natural and smooth, the object is smoothened by eroding the image twice with a diamond shaped structuring element. This method of pre-processing is more accurate than the boundary tracing method but it is a time consuming process. Since, level is a slow vary process in order to have accurate level measurement this type pre-processing can be used.

2.2.3. Graphical User Interface (GUI)

A human machine interface (HMI) was designed in order to monitor and calibrate the instrument when ever required as shown in Fig. 3.

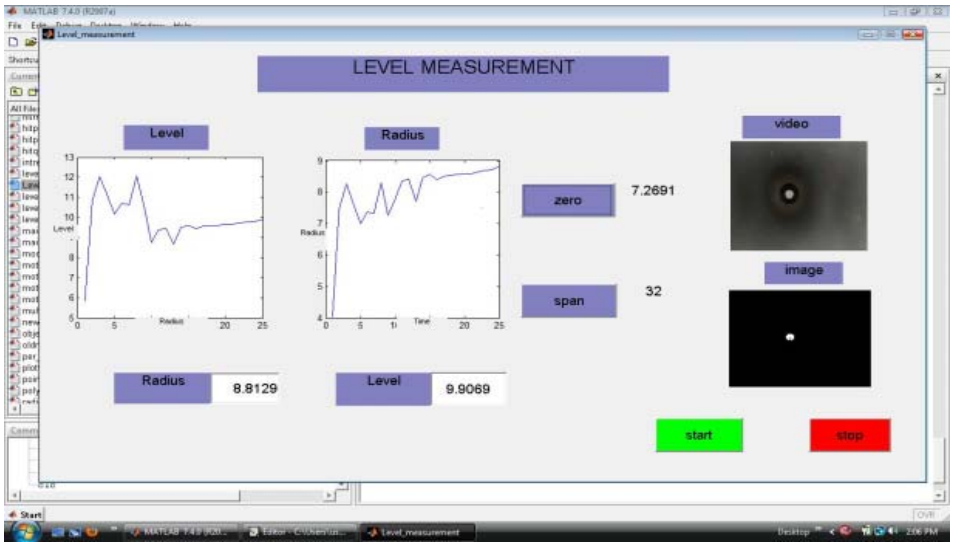


Fig. 3. Float-image level transmitter GUI.

The GUI has a video, pre-processed image and the graph showing the variation of radius and level with respect to time. The live stream video and prep-processed image was displayed which enables the operator to understand the efficiency of the algorithm used in extracting the processed image from a raw video. Two graph/trend charts was developed. One of the trend charts is to display the extracted feature such as area, radius and pixel count. The other is to display the level in cm with respect to time. Thus, the operator can simultaneous view the extracted feature and the level and have a clear understanding of their relations in terms of linearity, bias etc. The data flow diagram shows that the captured image is pre-processed using image processing technique from which the features such as area, radius, side and pixel count are extracted. Finally using the transformation algorithm, level of the tank is measured.

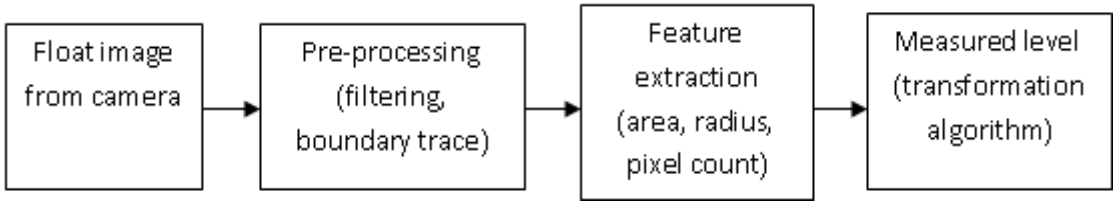


Fig. 4. Data flow diagram.

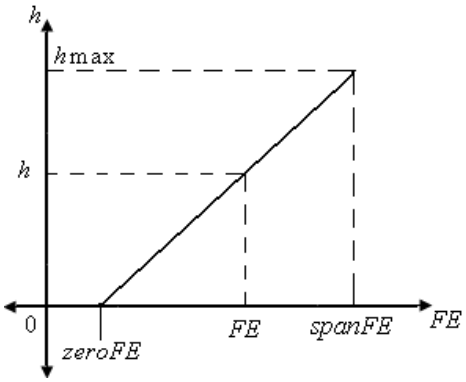
3. Working

The float-image level transmitter is placed inside the tank vertically whose level has to be measured. The float was allowed to float freely inside the pipeline above the liquid level. Make sure the length of the pipe should be double the size of the maximum level to be measure. This ensures a uniform distribution of light intensity, since the LED light was fitted on the top of the pipeline. However, other techniques such as using light distributors can also be employed to distribute the light intensity uniformly in the pipeline.

The image of the floating substance is captured using a camera interfaced to the PC and the captured images are processed in a PC using MATLAB software. The image is then pre-processed using filters and boundary trace function. The features present in the image can be obtained by such pre-processing techniques, from the obtained image the radius, area and pixel count can be calculated. As the level increases the floating substance rises up and gets zoomed in. So whenever the level increases the feature extracted (radius, area, pixel count) of the floating substance in the captured image increases. The feature extracted of the floating substance increases linearly with the liquid level of the tank.

3.1. Zeros and Span Calibration

The HMI designed also provides the calibration feature also. This enables the operator to calibrate the instrument remotely. For Zero Calibration, the actual level of the tank was set to zero and the values of the extracted features was recorded as the bias value which have to subtracted from each and every measurements. The recoding of this bias value will happen when the operator clicks the ‘zero’ button. For Span Calibration, the actual level of the tank was set to its maximum limit and the values of the extracted features were recorded using the ‘span’ button. Using these values the measured level was calculated using standard formula.



$$h = \frac{(FE - zeroFE)}{(spanFE - zeroFE)} \times h\max$$

Fig. 5. Zero and span calibration.

4. Result and Discussion

The proposed system provides a level measurement without any physical contact with the liquid level and the sensing unit. The proposed system has minimal hardware requirement such that the data transmission could be effectively done and free from data loss problems. The resultant is free from hardware noises and other signal interferences which makes it ideal for underground level measurement and hazardous chemicals level measurement. Results shows that the proposed system has a satisfactory level of linearity as shown in Fig. 6 and accuracy as shown in Fig. 7. Fig. 6 shows that the normalized float radius normalized float side and normalized pixel count of the floating substance vary linearly with the normalized level of the tank.

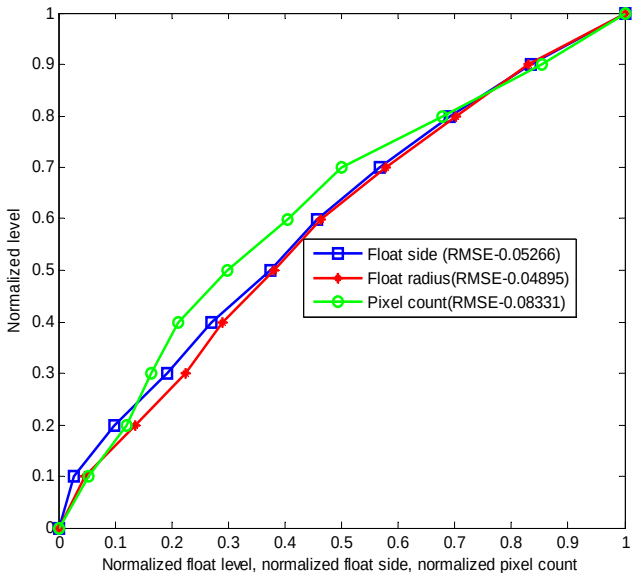


Fig. 6. Normalized level of tank vs normalized radius, side, pixel of float.

Since the level measurement with round floating substance has very less root mean square error (RMSE-0.04895) compared with the square floating substance and pixel count. It is evident that level measurement calibrated against the radius of round floating substance is more linear and accurate.

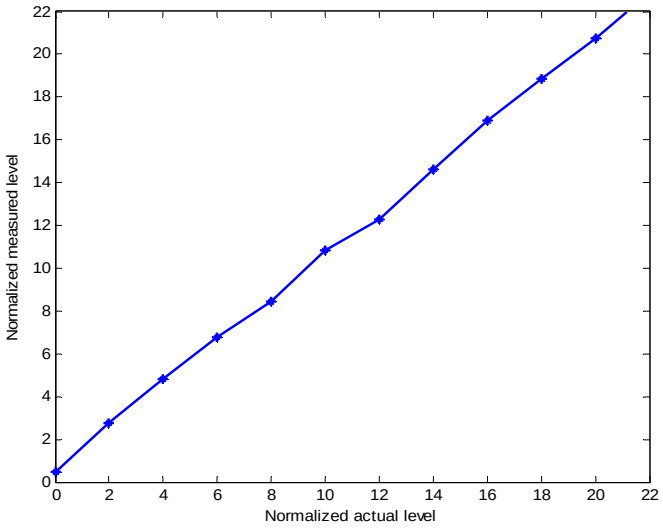


Fig. 7. Normalized actual level vs. normalized measured level.

Fig. 7 shows the relation between the normalized actual level and the normalized measured level. From the obtained results it is evident that using the float-image level transmitter the level variation up to a minimum level of 1mm can be determined.

5. Conclusion

A method for measuring the level of various tank systems with various floating substance is developed using image processing technique. With this better performance, acceptable accuracy and reliability, the proposed system could have fast response, simple and cost effective for substitution of the conventional level measurement systems. It is evident that the proposed system is not affected by turbulence, form and corrosion. It could be further calibrated for various ranges by just altering the pipe size and float size.

The proposed system could be further developed as an embedded product. It can also be developed using 'open CV' as a stand-alone module which focuses mainly on real time image processing. Since the output is digitalized output, the proposed system could be compatible with the standard industrial network architecture. As the proposed system has acceptable accuracy and easy interface with the PC, it could be developed as a smart transmitter with the built-in level measurement and control.

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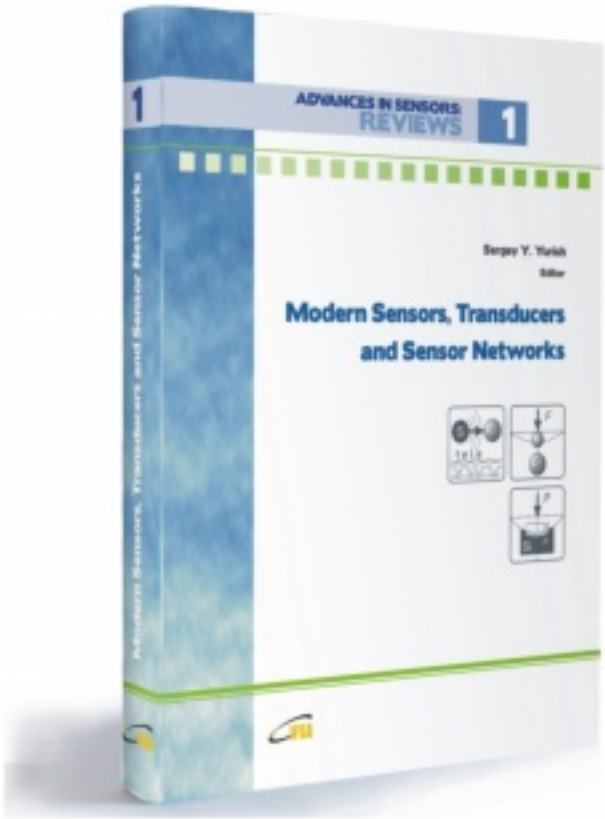

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