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Tank Level Measurement using 3D Vision Systems

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Abstract

In this article, the development of a method to establish the liquid level of a tank is presented, through the use of 3D vision systems based on Kinect sensor. Given the location in the upper part of the level system, the operation of the depth measurement system and the characteristics of the tank, these factors are integrated so that once the 2d processing is done for the identification of the tank in the scene, a measurement as accurate as possible of the depth information of the sensor with respect to the variation of the level in the tank is obtained, which was reached with an average error of 0.5%.

Keywords. 3d vision, image processing, kinect, level measurement.

INTRODUCTION

The need to use automatic methods of measurement, whether level or similar, is present in many areas of industry and science, as reflected in [1] and [2]. Level measurement systems typically use a transducer that relates distance to a voltage or current, as is the case of ultrasonic sensors, among others, which have been used for this purpose for quite some time [3] [4]. Other common devices for level measurement are those based on radar [5] [6]. However, these transduction devices require systems capable of associating said electrical magnitude in a digital value easily read by man. Nowadays, with the advances of the techniques of image processing both in two dimensions (2D) and in three (3D), it is possible to use these techniques to perform the task of measuring distances and apply them to level measurement systems.

Among the most recent developments for 2D and 3D image processing is the Kinect sensor [7], which is capable, through a system of RGB and infrared cameras, plus a laser projection system, to obtain color information (RGB) of a scene, information in gray scale for nocturnal environments and depth for spatial relationships. Offering great versatility for a large number of applications in the field of engineering.

In this field, the applications with Kinect that are found are oriented to applications such as the 3D reconstruction of spaces for unmanned aircraft [8], the replication of movements in humanoid robots by recognition of human gestures [9], the detection of obstacles in the trajectory of movements of a robot [10] as well as the control of elevation of a quadrotor system [11]. But no reference to the use of the Kinect for level measurement has been found.

Given the capacity and low cost of this sensor in comparison with sensors of the ultrasonic type or similar and which in turn is capable of taking more than one storage tank given its angle of vision, the advantages of its use for this type of applications are appreciated. Given its recent incursion in the market (2010), its applications are still in development, so this article proposes the establishment of an equation that allows to relate the use of this sensor for a level measurement application.

The article is structured as follows: section II presents the general environment of the level measurement application, section III presents the deduction of the level equation in the tank, section IV presents an analysis of the results obtained and finally, in section V, the conclusions derived from the work carried out.

APPLICATION ENVIRONMENT

The level measurement system is referenced to a tank on a specific support, whose outline is shown in Figure 1. Since the measurement sensor is based on the capture of an image of the top view of the tank, this must be located at a distance such that its angle of vision covers the entire surface area of the tank and in the measuring range of the sensor.

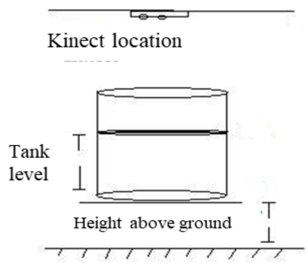

Figure 1. Scheme of the application.

The depth measurement system is based on the Microsoft Kinect, which uses a projection of an infrared beam, so it is necessary to use an intermediate element for the level reference, in the case of liquids. For this case, a float is used, whose upper face, that is, towards the sensor chamber, is painted red in order to be identified by image processing techniques, covering the whole surface area of the tank and where the detected pixels will be the search reference in the depth measurement.

The depth measurement task of the Kinect is limited to a range of operation of action distances, whose minimum and maximum values are illustrated in Table 1, for the two different operating modes of this sensor.

Table 1. Operation characteristics according to operating mode

Mode	Number of joints	Minimum distance	Maximum distance
Default	19	80 cm.	4 m.
Near	10(SDK 1.5)	40 cm.	3 m.

The depth information is obtained in a data array in a row byte type, where the depth value of each pixel of the image is represented by a data of two bytes (16 bits), in which the first 13 bits represent the depth and the remaining 3 bits contain information regarding the video game applications. The access to the information is given in a channel, for each coordinate pixel (m, n), with a three-bit shift to directly access the depth measurement, as it is related in equations 1 and 2.

$$index = (pixel.n - 1)image.width + pixel.m \qquad (1)$$

$$Depth = arrayDepth(index) \gg 3 \qquad (2)$$

The access to the pixel of interest is obtained through the use of a filter that allows to extract from the image (RGB), the red color referring to the float. The processing algorithm is based on a transformation of the RGB color space of the camera to the YCbCr space, in which the Cr component highlights all the red tones in the image by suppressing the others, in a more exclusive way than the R component of the RGB space. Equation 3 indicates the way to perform the space transformation.

$$Y(R, G, B) = 0.299R + 0.587G + 0.114B \qquad (3)$$

Where the component of interest is Cr = (R-Y).

A thresholding is applied to the Cr component, i.e. a threshold is established to demarcate the level of representation of the red that is of interest (250 for this example). In such a way that all the information of the image is excluded except the pixels of the float, figure 2 reflects the result of this action.

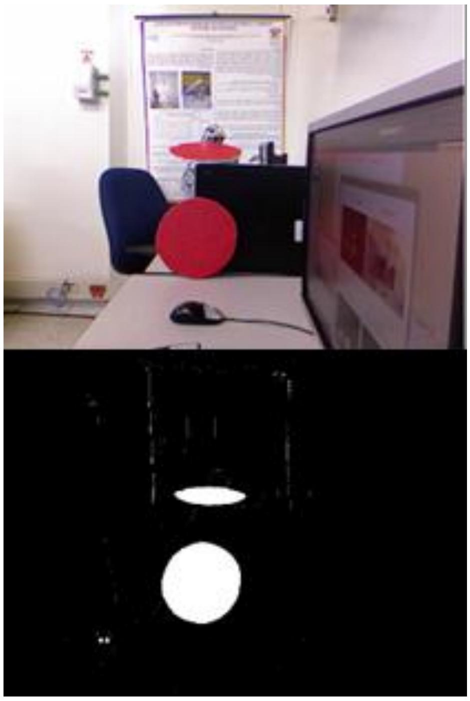

Figure 2. Thresholding of the Cr component.

Level equation

Once the pixels corresponding to the surface area of the float have been identified, they allow identifying, from the depth information of the kinect, the distance at which the sensor float is located. Therefore, to establish the filling level of the tank, the known fixed distances must be related, which depend on the structure of the filling system. Said distances are related in figure 3 and correspond to the height at which the sensor is located above ground level (*Dt*), the distance of the tank above ground level (*C*), the thickness of the float (*A*), the thickness of the base of the tank or the support on which it is located (*B*) and a variable distance that corresponds to the distance from the sensor to the float (*dPi*).

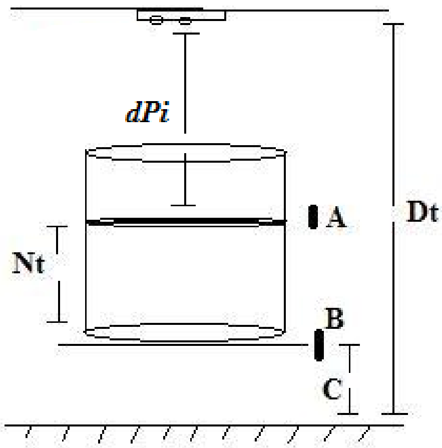

Figure 3. Related distances.

The fixed distances, in this case *A*, *B* and *C*, must be subtracted from the distance of the sensor to the ground, obtaining a constant that for the case is called dk and is represented by equation 4.

$$dk = Dt - (A + B + C) \tag{4}$$

The distance dPi corresponding to the value measured by the kinect in the pixel i, of coordinates (x,y) in the depth information, must be subtracted from the constant distance dk thus obtaining the level relation of the tank with respect to the pixel i (*Nt (i)*), represented by equation 5.

$$Nt(i) = dk - dPi(x, y) \tag{5}$$

Given that there is a ratio of pixels that correspond to the entire surface area of the float, it is possible to find an average value more representative of the general level of the liquid in the tank by adding the value of the level corresponding to each pixel and dividing it by the number of considered pixels. Finally, the equation that represents the general level of the tank is described by equation 6.

$$Nt = \frac{1}{n}\sum_{i=1}^{n}(dk - dPi(x, y)) \tag{6}$$

ANALYSIS OF RESULTS

The developed algorithm was executed in a computer of 1.7 GHz of processing speed, with 1.5 GB of RAM memory, under the C# programming environment and Emgu CV machine vision library, corresponding to the variant of the OpenCV library of INTEL applied to the .NET programming environment. Under this platform, the processing speed of the algorithm is lower than that of Kinect image capture, allowing to process video images at 30 frames per second.

When applying the equation to the system of measurement of level implemented, it was sought to corroborate manually the level of filling of the tank, by means of a conventional metric system. The results obtained are shown in table 2.

Table 2. Error for different levels of filling.

Meter	Eq. 6	% Error
20	19.6	2
30	29.7	1
40	39.8	0.5
50	49.8	0.4
60	59.9	0.17
70	69.9	0.14
80	79.9	0.12
90	90	0
100	100	0

It can be observed in table 2, how for low values of filling, the error tends to be higher, not exceeding 2.4% for the exposed case, while for high values of filling it is close to zero. This is due to the fact that, with the distance, the Kinect presents an incremental error up to its maximum measurement value, which corresponds in the case of level measurement, to the low filling values, i.e. when the float is farther from the sensor.

CONCLUSIONS

Based on the characteristics of the system under consideration, an equation that satisfactorily represented the level of the tank level was obtained by obtaining the depth information through a 3D vision system.

The efficiency of the sensor in the depth measurement was checked, by comparing the level measurement manually against the value obtained by means of the developed equation. It is observed that the error obtained is less than 0.5%, which implies a highly reliable measurement system.

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