Automated Water Tap Controlling System Using Machine Vision

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Summary
Water is essential for everybody in the earth. As we know only 2.5 percent of fresh water is available on the earth and only less than 1% of water is available for drinking purpose. All the available fresh water is ground water, that acts as a reservoir that can also be tapped to various uses. This system makes use of image processing techniques and tries to minimize the wastage of water from the taps. The main focus towards the system design was to ensure that the taps should be able recognize objects placed below it and able to fill the container with desired level of water automatically. The designed system detects the object as hand or bottle, if the detected object is bottle then the water level will be indicated, the accuracy obtained for the detection of hand is 85.71% and for the bottle is 77.77%. The proposed system is to provide an automated method to conserve water efficiently.[1,5,6].

Key words:
Image processing, Machine Vision, object detection, feature extraction, Hough Transform.

1. Introduction

As we know the available fresh water on Earth is only 3% and finding efficient methods to prevent water from further wastage is more efficient task[16]. The water is majorly wasted through taps., hence the main focus towards the system design was to ensure that the taps should be able recognize objects placed below it and able to fill the container with desired level of water automatically [6]. This proposed work focuses on detection of object for which, this system makes use of image processing and try to minimize wastage of water from the tap. Whenever the object is placed under the tap it must detect the object through camera fixed on it.
The different camera features have important consequences on quality of images.
Further, use of computer vision techniques referring to object classification and identification have been used to implement autonomous system to control and monitor the flow of water from the taps[19]. This proposed work consists of three important steps:

a. Detection of water containers: Using deep learning methods new objects have been detected, analyzed and recognized. For estimating the shape and size of the bottle, this proposed work shall use geometrical features.
b. Detection of Human Hands: Using Skin color-based techniques hand portion will be segmented and detected.
c. Estimation of water capacity: Using simple algorithm like Edge Detection water filling capacity of the containers will be estimated and monitored continuously.

2. Literature Survey

2.1 Background

As we know Image Processing is an increasing area of research now a days. The primary objective for selecting intelligent taps using image processing was to minimize the wastage of water. use of computer vision techniques referring to object classification and identification have been used to implement autonomous system to control and monitor the flow of water from the taps anything else with pixels involved[14].
The very purpose of using Python programming language was to express concepts in fewer lines of code [13].
As per the experimental results shown in [1], the intelligent system that was developed was accurate enough to detect moving object and acquire the image with an accuracy of 94.26% .
An approach referring to hand segmentation integrating involving color and motion is taken into consideration by the approach as experimented by Lim Wei Howe et.al[2].
The color segmentation method is used to determine the skin color and background information around the hand [3].
In [4], Sobel's algorithm is used for the edge detection and it is improved in to the horizontal and the vertical edge direction.
A feature extraction algorithm [5], for bottle inspection that considers status of caps followed by level of the liquid in the bottles.
In [6], use of fuzzy logic helped the researchers to develop a water saving tool to take care of water wastage.
In[7], a system for water level measurement using PIC16F707 microcontroller is described. Selected

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method uses capacitance to measure the dielectric permittivity of a surrounding medium. Microcontroller used here requires minimal number of external components which ensures low cost of sensor hardware implementation.

2.2 Functional Requirements

2.1.1 Hand Detection

Input: Capture the video frames from webcam.
Process: The hand portion will be segmented and detected by using skin color-based techniques.
Output: slide view the original frame along with the skin detected frame [2,3,9,10].

2.1.2 Bottle Detection

Input: Capture the video frames from webcam.
Process: objects have been detected, analyzed and recognized along with level of the water by using deep learning methods.
Output: The bottle is detected, and the bounding box is computed[4,7,8].

3. Methodology

In this section the algorithms that are part of implementation process are being explained., the proposed architecture is as shown in fig 3.1, defines the high-level design of the system.

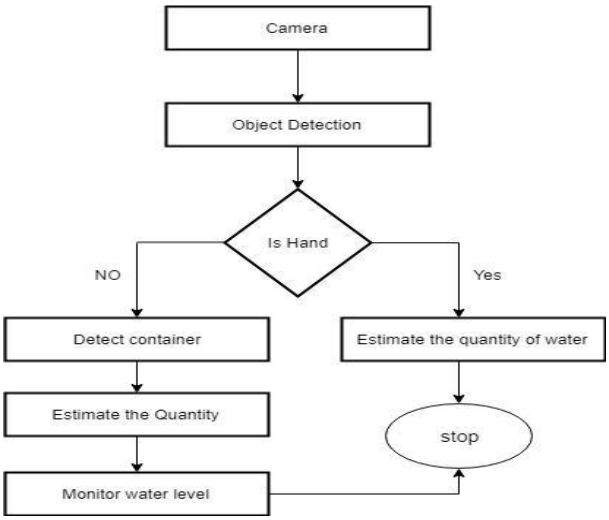

Fig. 3.1 The Proposed Methodology

The methodology used in developing the systems is as described below:
Step 1: Detect the object by using a camera.
Step 2: If the detected object is hand,

then

sprinkle the amount of water required for the hand.

a. If the detected object is not hand
then
it may be a bottle / container,
calculate the amount of water required to fill the bottle / container.
b. Monitor the amount of water level in the container/bottle.
c. Stop.

The next section discusses the algorithms used for skin segmentation and bottle detection while developing the system[2,3].

3.1 Algorithm for Skin Segmentation

Input: capture the video from webcam
Output: slide view the original frame along with the skin detected frame.
Step 1: Repeat Loop over for every frame
Step 2: If Frame is not read, encounter end video
Else
Go to step 3
Step 3: Resize the frame and convert it into HSV color space
Step 4: Verify the HSV pixel intensities (upper and lower boundaries)
Step 5: If Lower boundaries = [0, 50, 90] &
Upper boundaries = [25,255,255],
Then pixel indicates a skin color tone
Else
Pixel Indicates no skin color tone
Step 6: the mask is subjected to a series of erosions and dilations using elliptical kernel.
Step 7: Blur the mask to remove noise- use Gaussian blur method.
Step 8 apply the skin mask to the desired frame.

3.2 Algorithm for Bottle Detection

Input: Capture the video from webcam and wait for min of 2 seconds to warm-up the camera
Output: Display the contents of the bottle (colored bounding box, line that indicates the depth of the liquid).
Step 1: Repeat Loop over for every frame
Step 2: If Frame is not read, encounter end of the video

Else

Go to step 3

Step 3: Resize the frame to a maximum width of 600 pixels

Step 4: acquire frame dimension and convert into a blob

Step 5: Permit the blob through the network to get the detection and prediction values.

Step 6: Perform probability check

Loop over the detection and check for the confidence

Step 7: If (Confidence value < minimum confidence)

The object(bottle) is not detected

Else

The object(bottle) is detected and compute the bounding box

Step 8: Verify the depth of the bottle using Hough transformation[17,18].

4. Experimental Consideration

Since the color tone of human skin varies, it is quite difficult to design a segmentation or detection method. Hence forth RGB colour space is not preferred for colour-based detection and for its non-uniform characteristics, in this context the HSV colour approach is ideal and preferred[2,3].

a. Skin Color Segmentation:

1. Apply Skin Segmentation to detect the hand.
2. Change the image from RGB to HSV color space.
3. Set threshold values for the HSV color Space.
4. White Pixels (255) represent areas as skin. Black Pixels (0) Pixels represent areas that are not skin.
5. Use Erosions and dilations and repeat the process to detect small false-positive skin regions in the image.

b. Hand Detection:

Hand detection is done by using skin color segmentation, in which the hand region is segmented, and the non- skin pixels will be excluded, the corresponding output is as illustrated in the figure as shown below[9,10].

Fig. 4.1 Hand Detection

c. Bottle Detection:

When the bottle is given as an input, the bottle will be detected along with the bounding box with an accuracy. When multiple bottles are placed the system can detect the multiple bottles[8,11] as shown in the figure below:

Fig. 4.2 Bottle Detection

d. Hough Transform:

An algorithm for detecting water level in bottle is as discussed below using Hough Transform [17,18].

a. By using any suitable edge detection scheme, determine all the edge points in the captured frame.
b. Quantize (a, b) space into a 2-dimensional matrix (HT) with appropriate quantization levels.
c. Initialize HT =0.
d. Increment by 1, the element from matrix H (ai ,bi) if it is found to correspond to an edge point resulting in a histogram or a vote matrix showing the frequency of edge points corresponding to certain (a, b) points lying on a common line.
e. Finally, the histogram HT is thresholded where only the large valued elements are taken, that correspond to lines in the Frame.

5. Results & Analysis

5.1 Performance Evaluation

The results obtained in the experimentation are tested for the mapping efficiency, four criteria of class C1 are used for performance evaluation[19]:

Table 5.1: Evaluation Criteria

Category	Instance_type	Terminology_used
False Positive	classified as C1	fp
False Negative	not classified as C1	fn
True Positive	classified as C1	tp
True Negative	not classified as C1	tn

5.1.1 Measures for Evaluation:

$$\text{Recall} = (tp) / (tp + fn) \quad (1)$$

$$\text{Precision} = (tp) / (tp + fp) \quad (2)$$

$$\text{Accuracy} = (tp + fn) / (tp + tn + fp + fn) \quad (3)$$

a. Different test inputs were given for hand detection, the corresponding values were generated for accuracy, precision and recall are as shown below in fig 5.1.
Accuracy=85.71%
Precision=91.66
Recall=91.66

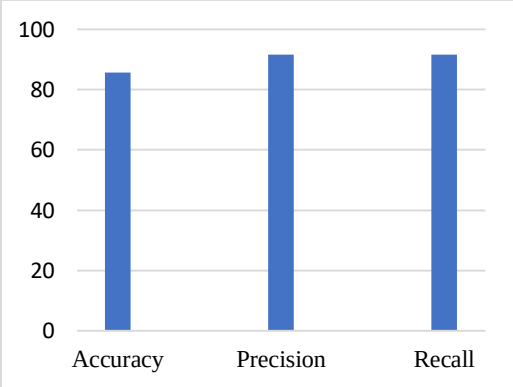

Fig. 5.1 Evaluation of Hand Detection

b. b. Different test input were given for bottle detection, , the corresponding values were generated accuracy, precision and recall as shown below in fig 5.2.
Accuracy=77.77%
Precision=85.71
Recall=85.71

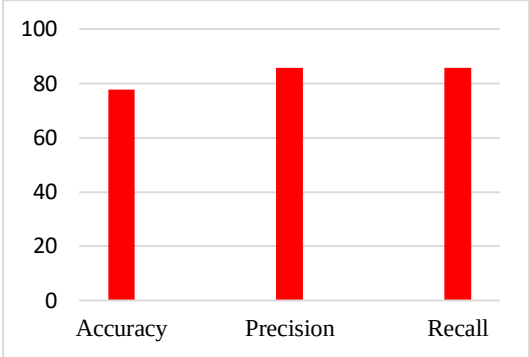

Fig. 5.2 Evaluation of Bottle Detection

6. Future Scope & Conclusion

The designed system just detects the level of water in the bottle , which can be further enhanced by displaying its volume to be filled in terms of ml/ltrs and design the taps to respond to human voice by performing speech recognition operations.
It has been observed that there is no perfect technology, and each technology has specific features that work in well-defined problem specific situations.
This system makes use of image processing techniques and tries to minimize the wastage of water from the taps. It is designed in such a way that taps should be able recognize the objects placed below it and should be able to fill the container with desired level of water automatically. Further results show that the accuracy obtained for the detection of hand is 85.71% and for the bottle is 77.77%.

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