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Automated Human Following Trolley Using Image and Video Processing

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Abstract: In today's world, the trolleys are used in most places like a shopping mall, hospitals, colleges, etc., and everything is manually operated using their physical strength. This paper proposes an automated human following trolley using the image and video processing. The HSV value of the image taken from the camera will be calculated. If it matches the valid sticker's value, then the trolley will follow that person who has a specific sticker by maintaining a constant distance from that person. The distance estimation technique is used to calculate the distance between the user and the trolley. Background subtraction algorithm is used for recognition and detection purposes. The basic model of the following human trolley was designed, and it was tested under various lighting conditions and verified the correctness of background subtraction by keeping invalid stickers. The designed model was confined with a boundary like hospitals and shopping malls. The same approach with some improvements could be used in other fields like schools and colleges, libraries, agricultural fields, war fields, etc.

Keywords: Video processing, HSV, background subtraction, distance estimation.

1. Introduction

Based on today's technology, we have manually pushing trolleys in malls, hospitals, colleges, etc. It is difficult for humans to both push and shop; the nurse to push and treat the patients as pushing the trolley requires much energy. If the weight is less, there will be no issue, but it should be pushed with a lot of energy if the weight is more. Many types of research were made to solve this problem, and some new technology has been implemented on the trolley to follow the human automatically. However, these systems used sensors and other hardware, which was costlier, and its performance were not so well.

It is considering the existing system and its disadvantages, the proposed work aimed to automate the trolley to follow the human by using image and video processing technology. Each trolley has a unique sticker that is provided to the user. A webcam is attached to the trolley, which takes the user's images, and by applying a background subtraction algorithm on these images, the sticker could be detected and recognized. A distance estimation algorithm is used to maintain a constant distance between the user and the trolley, thus avoiding a collision.

Objectives:

- To design a following human trolley using the image and video processing.
- Detection of the sticker from the input image and video by eliminating background and noise.
- Recognition of the detected sticker to be followed.
- Maintain constant distance between the user and the trolley by avoiding a collision.

The paper consists of, Section I, which contains the introduction to the proposed approach, Section II related work is briefly presented; section III contains methods and various steps performed to solve with flow chart. In Section IV, test cases and test results are described, and Section V gives a conclusion for the researched work and future scope for improvement.

2. Related Work

S N Joshi et al. [1] proposed a following human trolley using raspberry-pi. Unique identification tags were used to detect and recognize the user. Raspberry-pi, ultrasonic sensors are used for obstacle detection and avoidance. Motor drivers and IoT technology were used to build the trolley. D Iravan et al., [2] have proposed a designed human follower trolley robot based on object tracking (color detection) method. The main objective is to build a robot that can transport goods from one place to another by following the user based on his clothes' color. To implement this, they have used web-cameras; ultrasonic sensors were used to avoid a collision. The trolley recognized and followed the user using kinetic sensors and analyzing depth and skeletal data [3]. It used hip-joint skeletal data to determine the direction of the user's motion. The kinetic sensor was used for maintaining a constant distance between the user and the trolley. Their skeletal data will recognize each user, and each data is given a skeletal id. This system used RFID tags and corresponding readers to automate the billing system. It displayed the items list using LCD monitors installed on the trolley [4]. This system provides automation for the billing process in the shopping mall. Using RFID tags and readers, the items are scanned, and its availability will be displayed in the LCD monitor fixed on the top of the trolley. L S Y Dehigaspege et al., have described a comprehensive model with features such as guided traveling, tracking, and billing. Technologies such as automatic human-guided traveling with the use of Arduino Mega were used. Billing was also automated using a barcode reader and scanner. An android tablet with a great UI is present on the trolley. The guidance system of the trolley was implemented using the traditional line following technique [6]. It also displayed item locations using a database to improve the user's experience. Arduino mega is used as a microcontroller, Bluetooth module is used to transfer data. The entire map of the mall is fed to the system to make easy navigation for the user. S Patil et al., [7] proposed a unique approach within the trolley by making the billing process faster and easier. All the individual trolleys are connected to the central server. Wireless sensor networks were used which consists of small sensor modes. Zig-bee protocol is used to automate the billing system. Each customer processes their billing process locally at their trolley. Once the shopping is completed, the bill could be generated and paid using the UI provided in the screen, which is placed at the top of the trolley. B Ilias et al, [8] designed a following human trolley. The designed system aims to decrease the physical burden on medics through motorized, human following trolleys. The trolleys are implemented using ultrasonic sensor and sonar techniques.

The nurse following robot with obstacle avoidance, which could carry a load of 10kg, was designed, and a mobile platform using sensor integration was made. M Kumar et al. [9] proposed work to solve the billing process problem in a shopping mall. They called it "smart trolley with instant billing." They used ARM 7 microcontroller and RFID scanner and a wireless technology called ZIGBEE. When the user picks a product and drops it into the trolley, the RFID scanner scans the product's unique code, and its price, displayed on the LCD screen fixed on the trolley. C Akshay et al. [10] describe building a robotic cart that can track and follow the target in unstructured environments. This paper attempted to reduce human efforts for domestic and industrial applications. A robot is implemented using various sensors like R/F, laser, cameras. K Akhila et al., [11] developed a system that could control an automatic ARM utilizing an application built in the android platform. Android phones and raspberry pi boards are connected through wi-fi. An indication is produced in the android application that will be received through the raspberry pi board, and the automatic ARM works according to the predefined program.

Looking at the above-mentioned research works, it is clear that many types of research were made to automate the shopping trolley. Most of them concentrated on automating the billing system and a good user interface. Only some researches were made to automate the trolley to follow humans, using sensors, IoT, line-following, and other techniques. Instead of using more hardware components if we use image and video processing to detect, recognize, and maintain constant distance, it would be much effective. Considering all these things, our proposed work uses a single camera to replace different sensors and other hardware.

3. Methodology

Once the system starts, there is a camera that will be continuously capturing the image or video. Each trolley will be provided with its specific sticker, which will be given to the user who wants to use that trolley. The output of the camera that is the video frame will be sent to the background subtraction process. If the input frame consists of the sticker provided earlier, then the rest of the things present in-front of the input video frame are considered background and subtracted. The foreground that is the detected sticker is masked and utilized for further processes.

The system calculates the area of the masked region and its location. If the masked area and the distance from the trolley is present within the range specified, then the trolley follows the user (sticker). While following, there will be a constant distance maintained between the trolley and the user. If the masked area is out of range, then the system will stop. Figure 1 explains the overview of the system set of processes, sub-processes involved in the system.

3.1 Algorithm Used

- . **Background Subtraction**

Background subtraction is a technique/algorithm used in image processing and computer vision where the foreground part of the image is extracted and used for further processing. The main aim of this technique is to detect and recognize the object from the given sequence of images. There will be a reference frame with which the current frame will be compared. Initially, the current frame will be pre-processed and sent to the background model. There only the sticker is considered as foreground, and rest other things has the background and subtracted from the frame. Only the foreground is masked and used for further processing. Figure 2 shows the process of the background subtraction algorithm.

Steps involved in Background subtraction:

- Background Estimation: Background estimation is the process of distinguishing foreground (novel) from background (non-novel) elements, from a scene of a video sequence. This method consists of two steps: First, the input video is converted into frames. Second, the background is estimated from the successive frames. A-frame difference algorithm is used to estimate the background.

$$D(x, y) = | I_{n+1}(x, y) - I_n(x, y) | \ \forall\ (x, y) \in [1, N] \times [1, M]$$

Where,

I_n, I_{n+1} with the value of two different frames of two different time t_n, t_{n+1}. NXM is the image frame dimension. Applying suitable threshold 'T' on D(x, y) results in a binary image that classifies unchanged background and moving object.

- Background Subtraction: Some approaches achieve detection using background subtraction and predicting the background through the next update interval. In these approaches, the background is not estimated but detected. This algorithm is based on an image differencing technique which is mathematically represented as follows:

$$D(t) = (1/N) \sum |I(t_i) - I(t_j)|$$

Where,

N is the number of pixels in the image, $I(t_i)$ is the image I at the time i, $I(t_j)$ is the image I at the time j and D(t) is the normalized sum of absolute difference (SAD) for that time.

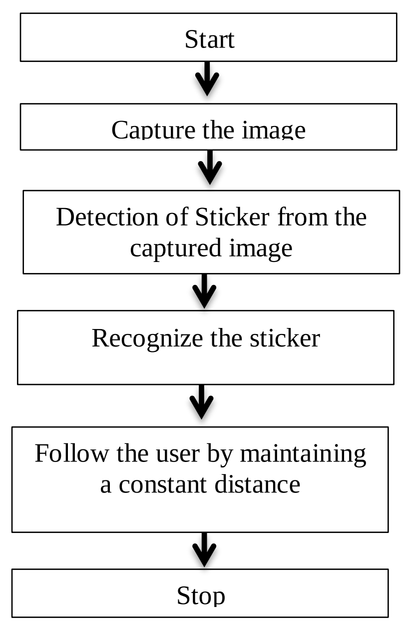

Figure 1: Overview of the system.

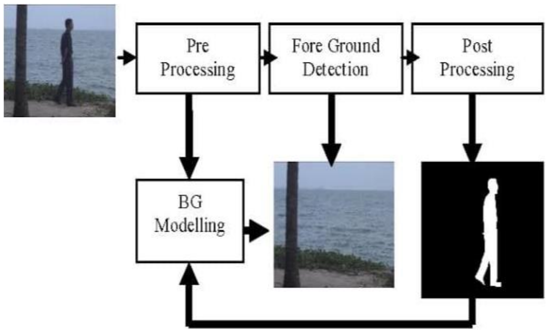

Figure 2: *Background subtraction.*

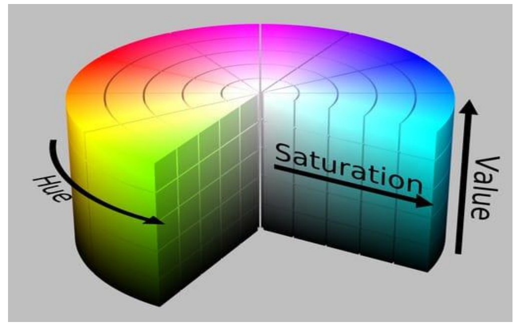

Figure 3: HSV Table

- **HSV color model**

There are various color models like RGB, CMY, etc. The HSV is also one of the color-model, which is widely used in graphic software, which symbolizes various colors combined to get the various range of colors. In RGB and CMY color models, only primary colors like red, green, blue, and cyan, magenta, yellow were used, but HSV is very close to how the human eye perceives color. HSV color model consists of 3 main components hue, saturation, and value. This color range describes hue (colors) in-terms of their saturation (shade) and their values.

Hue: Hue describes the various color portions of the model, expressed as a number range from 0-360 degrees.

- The red color comes in the range of 0 to 60 degrees.
- The yellow color comes in the range of 61 to 120 degrees.
- The green color comes in the range of 121 to 180 degrees.
- Cyan color comes in the range of 181 to 240 degrees.
- The blue color comes in the range of 241 to 300 degrees.
- Magenta color comes in the range of 301 to 360 degrees.

Saturation: Saturation depicts the gray color's availability in a particular color image from 0 to 100%. Reducing the saturation towards 0 adds more gray color and provides a faded effect. In some cases, saturation appears to be in the range of 0 to 1, where 0 gives gray, 1 gives its primary color.

Value (Brightness): Value/Brightness works in coordination with saturation and describes the brightness/intensity of the color from 0 to 100%, where 0 is completely dark, and 1 is completely white. Figure 3 shows HSV table (cylinder).

In our project, the sticker's HSV value will be provided for the trolley, which will be unique for each trolley. Only this value will be detected, and the rest other color is treated as background. This technique helps us differentiate the background and foreground, and these values will be processed further using a background subtraction algorithm.

- **Distance Estimation Technique**

The distance estimation is given relative to the distance between location 1 and location 2. The Euclidean distance between point x and y is the length of the line connecting (x, y). The formula for Euclidean distance is given by-

$$\boldsymbol{d(x,y) = \sqrt{\sum_{i=1}^{n}}(xi - yi)^2}$$

To find the user's distance from the camera of (trolley), we are using this technique. Here, the position of the camera is considered as (x1, y1) and the position of the user (sticker) is considered as the (x2, y2). We have to find the distance between these two points. To find the position of the sticker we will be using the value of the masked area whose center will be calculated. The center of the sticker is considered as the second point (x2, y2), the distance between this point and the camera will be calculated using the above formula.

This distance will be maintained constant while the trolley follows the user, thus avoiding the collision. Figure 4 illustrates the distance estimation technique.

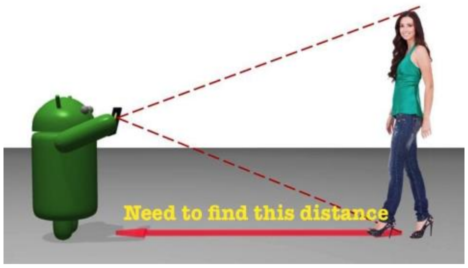

Figure 4: Distance Estimation

4. Results and Discussion

Our work aimed to develop an automated trolley that follows the using human image and video processing technique. The trolley we have built is only a basic model, and we had set our boundaries for hospitals and shopping malls with a flat surface. A camera is mounted in front of the trolley, which continuously captures the user's image or any other things present in-front of it. Each trolley will be provided with a unique sticker, which will be given to the user who wants to use that trolley. The trolley is programmed to follow the user who is having a valid sticker, by recognizing it. If the user moves forward, left, right, backward, and stop the trolley will do the same by maintaining a constant distance from the user.

Compared to existing solutions, which we're using different sensors like a kinetic sensor, motion sensor, an ultrasonic sensor for following the human, our project has a single camera that is programmed to perform all the operations performed by those sensors, using the image and video processing. This makes our project more efficient in space allotment, consumption of power. Our project is comparatively low cost those existing hardware solutions.

The basic model of the trolley was designed which consists of:

- Pi-camera, which is fixed in front of the trolley.
- Carrier, which can fit around 500-580cc of volume into it, is placed at the backward position of the trolley.
- Two BO wheels with one caster wheel are used for the movement and DC motors are used to rotate these wheels.
- Raspberry-pi 4 is used as a microcontroller.

Figure 5 shows the design of our trolley.

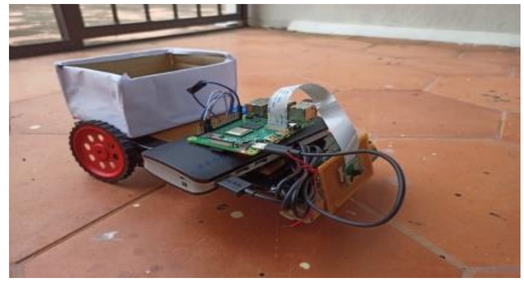

Figure 5: Design of the trolley.

- **Detection process:**

The unique sticker is placed in-front of the camera and it is detected, rest of the object in the image is treated as background and eliminated. Figure 6 shows output of the detection process.

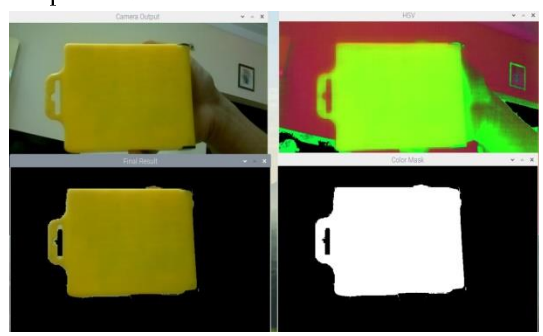

Figure 6: Detection process

When the user with valid sticker comes in-front of the trolley, the sticker's image is captured by the camera and the sticker's HSV value is determined. The first window of the Figure 6 shows the input image captured by the camera. Second window shows the HSV converted image of the input. If the input image's HSV value is equal to the HSV value of the valid sticker, then it is considered foreground, and the unmatched rest region of the input image is considered to be the background. The background will be subtracted, and the third window shows the image of the detected part. Only the foreground is masked as shown in the fourth window of Figure 6.

- **Recognition process:**

Only the unique sticker which is detected will be recognized and followed. The other stickers present in-front of the trolley will not be recognized. While the recognition process, the HSV value of the sticker present in the input image will be compared with the HSV value of the detected sticker, that is, if the detected sticker is yellow. Its HSV value is 64, then the present sticker in-front of the trolley should also have HSV value between 60-70 then recognized and used to follow.

The system was tested under various light conditions. Here are the following test cases and their results, which are as shown in table 1.

Table 1: Sample test cases

TC#	Description	Expected Result	Actual Result	Status of Execution
TC01	We are working on a camera.	It should continuously capture the things present in-front of it.	It is continuously capturing the things present in-front of it.	**Pass**
TC02	Detection of the sticker in a clear environment.	Only the yellow-colored sticker has to be detected.	Only the yellow-colored sticker is detected.	**Pass**
TC03	Detection of the sticker in a clumsy environment.	Only the yellow-colored sticker has to be detected and rest others to be ignored.	Only the yellow-colored sticker is detected, and rest others are ignored.	**Pass**
TC04	They are showing other color stickers for the camera.	The system should not detect the sticker.	The system is not detecting that sticker.	**Pass**
TC05	We are moving the sticker forward.	The trolley should move forward.	The trolley is moving forward.	**Pass**
TC06	We are moving the sticker in the left direction.	The trolley should move left.	The trolley is moving left.	**Pass**
TC07	We are moving the sticker in the right direction.	The trolley should move right.	The trolley is moving right.	**Pass**
TC08	They are stopping the sticker suddenly while moving.	The trolley should stop immediately.	The trolley is stopping immediately.	**Pass**
TC09	We are moving the sticker backward.	The trolley should move backward.	The trolley is moving backward.	**Pass**
TC10	Avoiding collision.	The trolley should maintain a constant distance from the user.	The trolley is maintaining a constant distance from the user.	**Pass**

5. Conclusion and Future Scope

In the present world, image and video processing are used in various domains for solving many problems. Likewise, our proposed work is also solving manually pushing trolleys, using the image and video processing. The usage of background subtraction algorithm for detection and recognition has increased the system's performance, using HSV color model for the detection and recognition of the sticker rather than RGB and CMY color model added more unique colors for identification of the sticker. The distance estimation technique, which is embedded with background subtraction, helps to maintain a constant distance from the user. Thus, avoiding collision, and it also replaced the usage of multiple sensors which in turn decreases the cost of our project. The model we have designed is a basic one that can work efficiently in shopping malls and hospitals with a flat surface.

The system's efficiency and effectiveness can be further increased by using high-resolution cameras, good microcontrollers, and effective design. It could be implemented in other fields like schools and colleges, airports, and other areas where there is a flat surface using the required design.

Further, it can be used in agricultural fields, war fields, etc.,Where there is an uneven surface, by keeping this programming part for detection and recognition constant and adding some more efficient mechanisms as per the demand of the environment that is, using big and rough wheels, good power source, etc.

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