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# Elimination of error due to barrel distortion using visual servoing technique

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**Abstract**
Normally, when an object is imaged using a camera, the region of interest within the object, away from the image center, tend to have variation in geometry from the original. This is due to the Barrel distortion caused by the lens, where the centre of the image is much magnified than the perimeter. This causes error in the measurement in the regions which are away from the image center. To avoid such error the central axis of the camera should align with the centre of the region of interest. The proposed system uses Visual servoing technique to move the XY table in desired direction. Visual servoing helps to locate the area of interest within the object, exactly in the imaging axis of the camera, so that the error due to barrel distortion can be eliminated.

**Keywords:** visual servoing, barrel distortion, XY table movement, camera axis, image centre.

## 1. Introduction

One of the most challenging ambitions of human kind has been the realization of machines mimicking the human capability to gather and elaborate complex information on the environment so as to interact with it in an autonomous manner. During this endeavor humans have supplied such machines with a large sensorial and elaboration capacity, and have designed their structure so as to replicate human limbs like arms and hands. The two most important human senses providing sufficient information on an unknown environment for the execution of generic interaction tasks are the tactile sense and the visual sense. Devices able to partially imitate these human senses are the force sensors and the visual sensors, respectively. In fact, tasks like parts mating or localization and grasping of moving objects may appear to be very simple for humans thanks to their capacity of interaction provided from such senses.

The visual sense, that is probably the most powerful among the human senses, is often lacking in many human-made devices. In fact, without visual information, manipulating devices can operate only in well-structured environments, where every object is known and can be found in a well-known pose (position and orientation).Thanks to the use of visual sensors, these devices could be used for applications where the geometry and the pose of the objects to be manipulated or avoided cannot be known in advance. The integration of different types of interaction and field sensors has today become an indispensable step to increment the versatility and the application domain of modern automation devices. Until a few years ago, the cost of many kinds of these sensors was actually too high. Only recently, the integration of a visual system into the sensorial equipment has become affordable for many kinds of applications.

A visual system is a passive, remote and distributed sensor that captures information from a large region of the workspace in a non-invasive manner. Nowadays, it provides a partial imitation of the visual human sense in a relatively economical way. In fact, the cost of a CCD camera and of the relative image processing hardware has become quite competitive, with respect to the quality and the wealth of the provided information. With the increasing of real-time capabilities of such systems, vision is beginning to be utilized in the automatic control community as a powerful and versatile sensor to measure the geometric characteristics of the workspace. Moreover, the use of efficient real-time algorithms for visual applications, running on powerful and economic hardware, make it possible the use of visual information directly in the control loop, giving origin to what is known as visual servoing.

Visual servoing is a control strategy based on various kinds of information extracted from a sequence of images provided by a visual system. In general, this system may be composed by one or more cameras, computational system, and specific image processing algorithms. Like human sense during the execution of a specific task, the visual system may be specialized for measuring a specific feature of interest, e.g. the presence of objects and obstacles, the presence of a target object, etc. This information, once available, may be used by a specific control unit to perform the assigned task. Probably, the main difficulty in the study and application of this technique resides in its intrinsic multidisciplinary from image processing and sensor fusion, to real-time computation and control theory.

## 2. Background

Due to barrel distortion caused by the lens, the region of interest away from the image centre tends to have variation in its geometry. To avoid such geometrical errors a special technique called Visual Servoing technique is implemented here in this project. In this technique the central axis of the camera should align with the camera. This helps to locate the area of interest within the object exactly in the imaging axis of the camera.

### A. Workflow of the project

The flow diagram shown below explains about the procedural method of the project. The image is acquired by using the Samsung SDC-310 camera. The acquired image is processed using MATLAB library. The size parameters are extracted from the image which is compared with the boundary value and from the compared value the motor control signals drives the motor. The system keeps on processing the image and drives the motor until the exact position is reached. The process flow is as shown in Fig. 1.

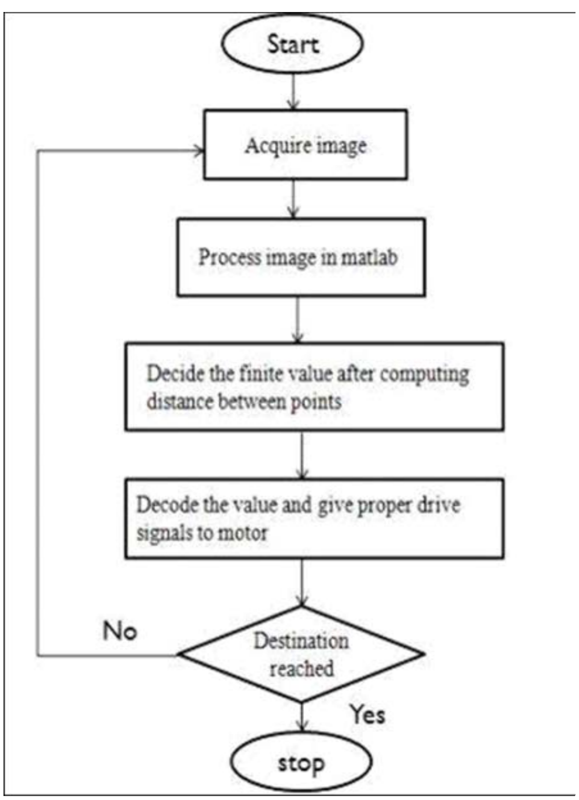


**Fig 1:** Visual servoing process flow

## 3. Experimental setup

The camera acquires the image and sends the image to PC. A set of algorithms in MATLAB will recognize the area of interest in the object and find the center of the area of interest.

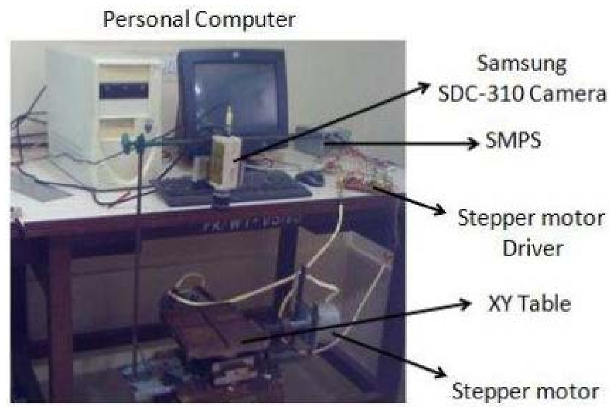


**Fig 2:** Experimental Setup

After computing the distance between the center of the region of interest and the centre of the image and the angle between the line joining the centers with reference to any of the two axes, it will compute the number of pulses to be given to the motor so that the desired position is reached. The computed result will have the information of how much should the X and Y independently or simultaneously rotate, to place center of the area of interest exactly on the image center. The decision of the angle of rotation of the X & Y motors will be given by the PC to the motor driver through Parallel port.

### A. Camera Specification

The camera used for the visual servoing system is Samsung SDC-310 and it is as shown in Fig. 3. It is an analog camera and a frame grabber is used to interface this camera with the PC. The other parameters of the camera are given in Table I.


**Fig 3:** Samsung SDC-310 Camera

**Table I:** Specification of Camera

| Camera Sensor Resolution | VGA(640*480) |
|---|---|
| Frame Rate | 14.7 |
| Working Distance | 52cm |
| Lens Focal Length | 25mm |
| Primary Magnification: | 0.00435 |
| CCD/CMOS | CCD |

### B. XY Table

XY tables are flat surfaces mounted on ball bearing slides or roller slides with multiple linear bases and are composed of forcers and platens.

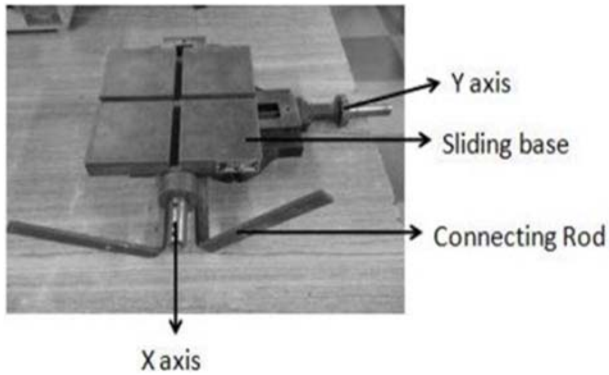


**Fig 4:** XY Table

The forcer glides over the platen on frictionless air bearings and moves continuously in a linear motion across the platen. To create multiple axis, linear bases are often stacked on top of one another, with the top "Y" axis acting both as a carriage to the bottom base and as the base which holds the table. Adjustable gibes can be attached on both axes. These types of XY tables, used frequently for the movement of robotic, are often called "positioning tables". Fig. 4 shows the picture of the XY table used for Visual Servoing.

**Table II:** Specification of XY Table

| Parameter | Specification |
|---|---|
| Type | Base table |
| X-axis span | 15cm |
| Y-axis span | 20cm |

### C. Stepper Motor and its Drive
Four TIP-122 power transistors are used to drive the stepper motors. Two such drivers are used to drive the two stepper motors. The specification of the two stepper motors is as shown in the Table III. A SMPS is used as the power source to drive the motors. The communication between the PC and motor driver is done through parallel port.

**Table III:** Specification of Stepper Motor

| Specification | X Motor | Y Motor |
|---|---|---|
| Type | DC Stepping motor | DC stepping motor |
| Weight | 7kg | 10kg |
| Step angle | 1.8 | 1.8 |
| Input voltage | 12V | 12V |

## 4. Methodology
### A. XY Table Motion Control
XY Table motion control is done by using motor driver. The direction and the amount of distance to be moved is decided by the image position with respect to the axis of the camera. A numerical value which is rational to the shift of the image with the axis of camera is sent to the driver. The motor driver drives the motor. The feedback is obtained by continuous imaging which in turn regulates motion of the XY table.

### B. Thresholding
- The simplest segmentation method.
- Application example: Separate out regions of an image corresponding to objects to analyze. This separation is based on the variation of intensity between the object pixels and the background pixels.
- To differentiate the pixels interested in from the rest (which will eventually be rejected), perform a comparison of each pixel intensity value with respect to a threshold (determined according to the problem to solve).Once separated properly the important pixels, set them with a determined value to identify them (i.e. value of 0 (black), 255 (white) or any value that suits your needs).

### C. Direct Visual Servoing
The Direct Visual Servoing techniques don't use any feedback from the actuators but the only feedback is through the camera. Depending upon the image, the actual position of the system is known and to move to the desired position, comparing the actual and desired positions an error signal will be generated. This error signal is the actual signal generated by the algorithm and it will be modified suitably to feed the motors. The feedback control of the Direct Visual Servoing system is shown in Fig. 5.

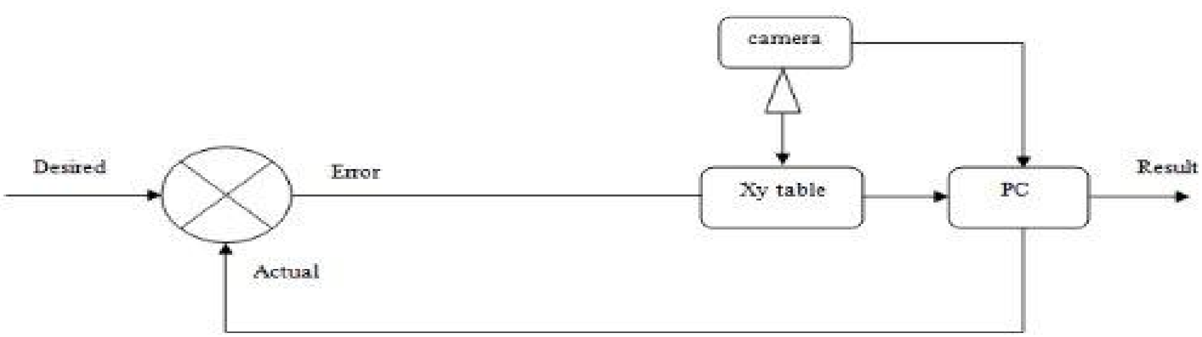


**Fig 5:** Direct Visual Servoing

### D. Servoing Based on Image
Servoing based on image purely controlled by the position of the image of the object in the field of view. There should not be any sort of mechanical or electronic feedback to the system. Object that to be tested is kept over the base table. Thresholding of this image segments interested image that is holes out of overall image. From these segmented holes a single hole that to be tested is selected and its centre point is

identified. The present centre point of the entire image is then identified. From this information the angle between the centre of the image and selected hole is calculated. The coordinates with respect to the reference axis is then calculated. The coordinate values and direction information reveals the timing for switching the motors of XY table. Using the driver circuit the XY table is driven and aligned with the coordinates of the present object with the image centre.

## 5. Conclusion

In some industrial scenario where some parts are to be inspected using multiple cameras as the size is too large. For such large parts or components having multiple cameras is expensive and also having single camera to cover the entire part in the field of view will create a loss in information in the part. Hence an objective comes here to use a single camera to inspect the part not by covering the entire part in the field of view but by limiting the field of view to a particular region and moving the part/camera in X and Y directions so that the entire part is covered. This paper demonstrates such an objective and this can be used in industries. A multiple drilled chasis is used as the part of inspection and the XY table is moved so that the centre of each drilled hole coincides with the camera axis. Thereby ensuring accurate measurement of dimensions.

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