TWO APPROACHES FOR A SERVOMECHANISM CONTROL SYSTEM USING COMPUTER VISION

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Abstract: In this paper a servomechanism vision control system, based on hand language, is presented. The control images are acquired by a generic *webcam* and processed, in the working phase, in quasi real time. For this processing, two approaches were considered: in the first one, we used the object control moments to identify the desired order; in the second approach, we used image control orientation histograms. In both approaches, the preset orders images to be considered are acquired in the learning phase. The used servomechanism and the two approaches used for the vision control system are described and some advantages and weakness of each one are indicated. An example of an images control order set, which works satisfactory, is also presented and some conclusions and future work are also addressed.

1 INTRODUCTION

The main objective of the present work was the developing of a vision control system for a servomechanism, equipped with two linear motion axes, based on hand language. With that goal, we decided to use a generic *webcam*, for the image acquisition, and by the following control philosophy: the system should in the learning phase associate control orders to certain images, and in the working phase recognize the desired order.

In the first approach for the vision control system, we identified the command orders by the calculation of the object control moments, (Jain, 1995). This approach, although simple, did not allow the distinction of a high number of control orders. We then started using a different approach (Freeman, 1995, 1996, 1998, 1999), based on image orientation histograms. This one, although more complex than the previous, is also very easy to implement, little demanding in computational resources (necessary condition for quick processing) and allows a reasonable number of working orders. These two approaches will be succinctly described in this paper.

We have divided this paper in the following way: In the next section, the used servomechanism is presented; In the third, we describe the interface developed to control it through a personal computer; We then describe both approaches considered for the vision control system and, by the end of this section, we present a set of images control orders which work satisfactorily; In the forth, and last section, are indicated some conclusions and possible future work.

2 SERVOMECHANISM DESCRIPTION

The servomechanism considered it is compose by a structural static base and a dynamic one, the working table, Figure 1. Two hydraulic cylinders, one vertical and one horizontal, of 600 and 350 mm respectively, manipulate the referred working part.

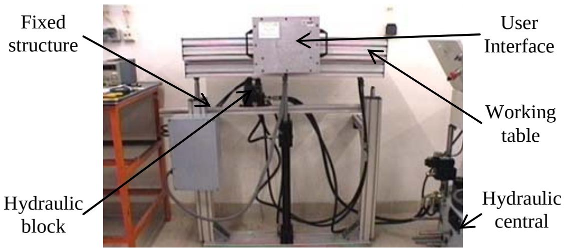

Figure 1: Servomechanism used in this work.

The servomechanism is also equipped with four sensors that are used to check the limit positioning of each cylinder.

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To enable the interface between the control personal computer's board and the electric command system, an AX757 board was used which has eight digital signal inputs and eight relays. In this work, the digital signal inputs were used to monitor the four sensors referred above, and two of the relays in the servomechanism command. To send the command signals from the computer, we had the AX5411 from which we only used the digital capabilities (because there was no speed variations involved but only movement in the imposed ways).

As we can see in Figure 1, the used servomechanism was already equipped with a user interface element that allows its manual command. The main objective of this work was the developing of another control system based on hand language.

3 SERVOMECHANISM CONTROL

The first step of this work, was the development of a friendly user interface that allows, through a personal computer, the totally servomechanism control and monitoring. This interface was built on a *Microsoft Windows* (Richter, 1998) platform, using the *Microsoft Visual* C^{++} (Young, 1998) programming environment, and integrated in an already existing generic system for image processing (Tavares, 2000, 2002).

In Figure 2 we present the developed interface for the servomechanism's computer control. Through this interface, we can check the sensors state, turn on/off the hydraulic central motor, control the loading valve, move each cylinder, with two different speeds, and execute an emergency stop.

The next step was the development of the vision control system based on hand gesture.

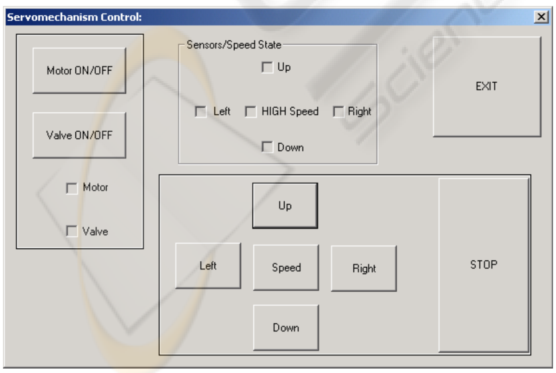


Figure 2: Developed interface for the servomechanism's personal computer control.

3.1 Object's Moments

In image analysis domain, the use of moments associated with represented objects, (Jain, 1995), to characterize them (position, size and orientation) and therefore recognize them, is very common. As our problem is indeed a recognition problem and, just referred, due to this common use, we elected this method to the first approach for our vision control system.

To compute the object's shape area A - the zero order moment, object's centroid coordinates $(\bar{x}, \bar{y})$ - the first order moments, and the object's elongation axis orientation θ - the second order moment axis, we can use the moment's method:

$$A = \sum_{i=1}^{n}\sum_{j=1}^{m} B[i,j], \quad \bar{x} = \frac{\sum_{i=1}^{n}\sum_{j=1}^{m} jB[i,j]}{A},$$

$$\bar{y} = \frac{\sum_{i=1}^{n}\sum_{j=1}^{m} iB[i,j]}{A}, \text{ and } \tan(2\theta) = \pm\frac{b}{a-c},$$

where: (n,m) are the image's dimensions, (i,j) are the pixel's coordinates, and a, b and c are, the second object's moments, defined as:

$$a = \sum_{i=1}^{n}\sum_{j=1}^{m} \left(x'_{ij}\right)^2 B[i,j], \quad b = \sum_{i=1}^{n}\sum_{j=1}^{m} x'_{ij} y'_{ij} B[i,j],$$

and $c = \sum_{i=1}^{n}\sum_{j=1}^{m} \left(y'_{ij}\right)^2 B[i,j]$,

with $x' = x - \bar{x}$, $y' = y - \bar{y}$ and $B[i,j]$ set to 1 (one) if the pixel belongs to the object or set to 0 (zero) if not.

In Figure 3 we present an example of getting the geometric properties of an object using the above formulated method. The results are, as can been seen, satisfactory.

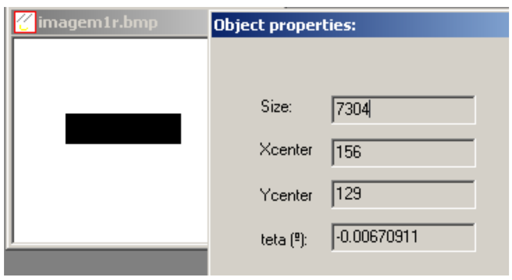


Figure 3: Determination of area, centroid coordinates and orientation of an object using the moment's method.

However, although simple, this method presents some disadvantages: the control object has to be represented by a single region, with shape preferably rectangular, the image binary and the number of possible control orders has to be reduced because the obtained orientation angle is always between 0º and 180º. To overcome these problems, we implemented a methodology based on image orientation histograms that will be described in the next section.

3.2 Image's Orientation Histograms

To overcome the problems associated with the moments method, previously described, was implemented a methodology based on orientation histograms (Freeman, 1995, 1996, 1998, 1999).

Basically, this methodology consists on calculating the orientation histogram of each acquired image, and compares it with the histograms stored in the learning phase (determined from the images corresponding to the desired orders). Therefore, it is calculated the orientation histogram for each 256 grey levels control image and stored in a 16-component vector. This vector is then smoothed in order to even its components. The comparison of the current order image, with the ones considered along the learning stage, is obtained by the difference between histograms' vectors.

In this method, the pixel's orientation is calculated as:

$$\theta[i,j] = \arctan(di, dj),$$

with:

$$di = B[i,j] - B[i-1,j], \quad dj = B[i,j] - B[i,j-1],$$

and $B[i,j]$ equals the pixel's intensity level.

In the orientation histograms calculations, we only consider pixels which have, on one hand, an intensity level above a predetermined value, thus neglecting the noise pixels, and, on the other hand, a contrast value $\sqrt{di^2 + dj^2}$ superior to a certain threshold, thus neglecting pixels from areas with reduced meaning.

In Figures 4 and 5 we can see the implemented interfaces for the vision control system, in its learning and working phases. The considered control orders were the following: left, right, up, down, speed change (fast/slow) and stop; in Figure 6, is presented a working example images set for this six control orders.

In the implementation done, the control system, when in automatic working mode, is constantly acquiring images and cyclically, in predetermined time intervals, does the active image interpretation and processes the associated working order, Figure 7. When there is a considerably difference between the active image's histogram vector and the ones stored in the learning phase, the system rejects the order. The four sensors are also monitored cyclically which inhibit, or not, the movement in the respective way.

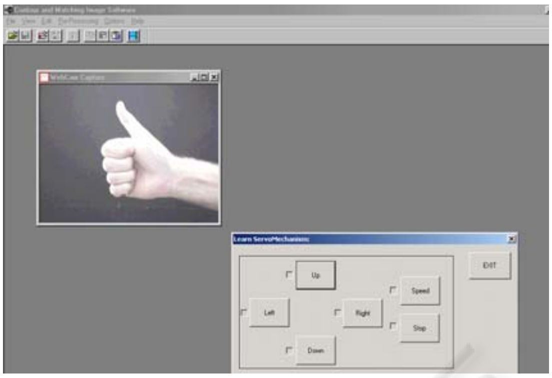


Figure 4: Vision control system interface for the learning phase. (To the visible image will be associated a command order by choosing the corresponding button.)

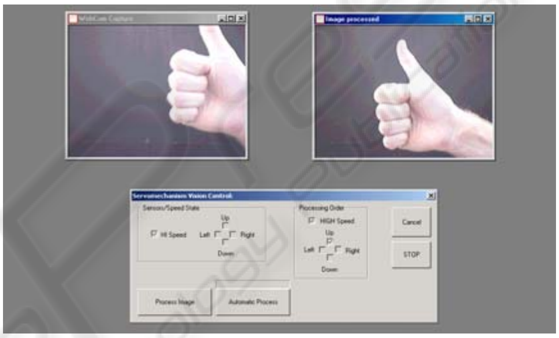
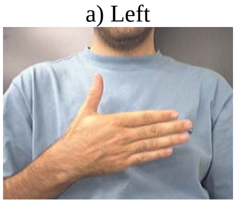


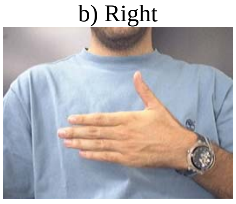
Figure 5: Vision control system interface for the working phase in manual processing mode. (In the left window is visible the actual capture image, and in the right one the last processed image.)

a) Left

b) Right



c) Up



d) Down.

e) Speed change

f) Stop

Figure 6: An example of a satisfactory working orders image set for the vision control system based on the orientation histograms methodology.

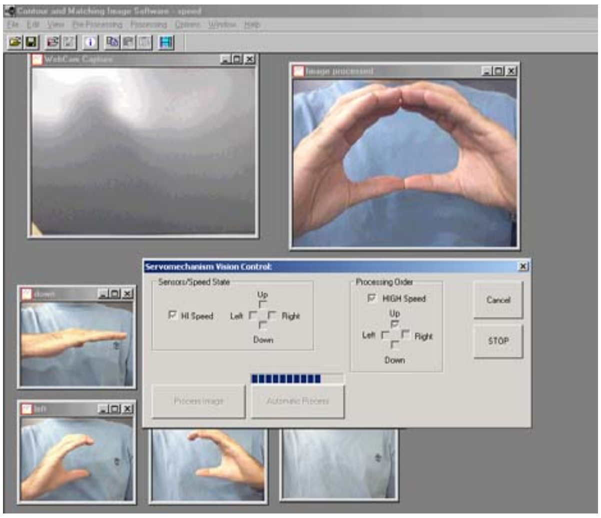


Figure 7: Servomechanism's vision control system based on the orientation histograms methodology in the automatic working mode.

4 CONCLUSIONS AND FUTURE WORK PERSPECTIVES

In this paper, was presented a servomechanism's vision control system based on hand gesture. The used servomechanism was described, presented the developed interface to its personal computer control, and presented both approaches considered to the control system. The first one, based in the command object's moments, is of simple and quick implementation. However presents some disadvantages, mainly the reduced number of possible control orders. The second one is based on image orientation histograms, and easily overcomes this problem with a reduced computation cost increment.

During the several experimental tests done, we concluded that the methodology based on orientation histograms presented two great advantages: implementation simplicity and execution quickness. The referred approach, works in satisfying manner controlling the used servomechanism, and could be considered in other kinds of friendly interfaces: games, computerized applications, home appliances, robotic systems, remote controls, etc.. However, we also found that this approach presents some limitations as well: As the used *webcam* does not compensate lighting changes, the vision control system does not react the same way if those variations are significant. Another problem with the actual version of the vision control system, relates with the control object's size and how it domain each control image. This last problem is augmented by the lack of an *Auto-Focus* system in the used *webcam*.

For future work, to turn the vision control system more robust to the problems previously referred, we can suggest: a) The tracking of the control object through images sequence using, for example, *Kalman* filters, (Tavares, 1995), with active contours (Blake, 1998; Tavares, 2000, 2002), as indicated in (Blake, 1993). b) The employ of a more sophisticated camera, which, by itself, can improve the robustness of the adopted vision control methodology.

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