Playing a tic-tac-toe game against a robot manipulator using a vision system

JOGANDO O "JOGO DA VELHA" CONTRA UM MANIPULADOR ROBÓTICO AUXILIADO POR UM SIATENMA DE VISÃO

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ABSTRACT

This work deals with the integration of Robotics, Artificial Intelligence and Image Processing. To do that, a experimental setup was assembled at the Robotics Laboratory of the Mechanical Engineering Department of the Taubate's University, composed by a CCD black and white camera, a frame grabber with 8 bits resolution and a didactic robot kit Robix RCS-6. The main idea is to implement a tic-tac-toe game where the robot manipulator plays against a human opponent. The camera scene is composed by the tic-tac-toe board and the robot can "see" it using Image Processing techniques. The board's image is acquired repeatedly and an image subtraction between two simultaneous images is done. The threshold of the resultant image is calculated and a binary image is obtained. The centroid of the remain figure is calculated and used to allows the robot decides in which board cell it should play to block its opponent. Once this decision is taken, the robot, assembled in a two degree of freedom configuration, draws an X on the game board. Algorithms for threshold calculus and the robot inverse kinematics are discussed. The scene illumination and problems tha it address are also discussed. The program, developed in C++ language, works quite well and illustrate how those areas (Robotics, Image Processing and Artificial Intelligence) can work together.

KEYWORDS

Robotics, Image Processing, Artificial Intelligence.

RESUMO

Este trabalho tem o objetivo de integrar as áreas de Robótica, Inteligência Artificial e Processamento de Imagens. Para realizá-lo, um aparato experimental foi montado no Laboratório de Robótica do Departamento de Engenharia Mecânica da Universidade de Taubaté composto por uma câmera CCD monocromática, com 8 bits de resolução e um kit robótico didático Robix-RCS6. A idéia principal é programar um jogo da velha onde o manipulador robótico joga contra um oponente humano. A cena é composta por um tabuleiro de jogo da velha e o robô pode enxergá-lo utilizando Processamento de Imagens. A imagem do tabuleiro é adquirida repetidamente pelo Sistema de Visão e a subtração de duas imagens simultâneas é feita. A imagem resultante dessa subtração é binarizada. O centróide da imagem binarizada é calculado e usado para permitir que o robô decida em que célula do tabuleiro deverá ser feita a jogada para bloquear seu oponente. Uma vez que esta decisão é tomada, o manipulador robótico desenha um "X" no tabuleiro. Algoritmos para calculo do limiar e cinemática inversa e direta do manipulador robótico são discutidos. A iluminação da cena e problemas gerados por esta iluminação são também discutidos. Um programa desenvolvido na linguagem C++ funcionou muito bem e ilustra como essas áreas distintas podem ser integradas.

PALAVRAS-CHAVE

Robótica, Processamento de Imagens, Inteligência Artificial.

INTRODUCTION

The image process is a field that grown fast in the last years. Images are used in several areas such as geography where most images used comes from satellites and airplanes and study urban problems related to human occupation, in robotics with pattern recognition, and welder robots, archeology, treating bright and contrast of images to improve old images. In the literature Kabayama, A. M. and Trabasso L. G. (1999), describe three different techniques of three-dimensional computer vision where MATLAB was used to implement the computer vision algorithms. Rillo, A. H. R. C. at al (1996) address the reconstructive versus purposive dichotomy in computer vision, using a system that includes visual perception and a robotic manipulator. Stemmer, M. R. and Neto, C. A. M. (1998) shown an image recognition system that use Fourier Descriptors and neural networks to classify the objects. Brown at al (1998) shown the control of a puddle geometry where the puddle geometry is measured with a CCD camera.

This work uses a experimental setup composed by a CCD black and white camera, a frame grabber board with 256 256 spatial resolution and 256 gray levels. Also a didactic robot manipulator kit Robix RCS-6, is used. Its purpose is to implement a tic-tac-toe game where the robot manipulator plays against a human opponent. The camera scene is composed by the tic-tac-toe board and the robot can "see" it using Image Processing techniques. The board's image is acquired repeatedly and a image subtraction between two simultaneous images is done. The threshold of the resultant image is calculated and a binary image is obtained. The centroid of the remain figure is calculated and used to allows the robot decided in which board cell it should play to blocked its opponent. Once this decision is taken, the robot, assembled in a two degree of freedom configuration, draws an X on the board game. Algorithms for threshold calculus and the robotinverse kinematics are discussed. The scene illumination and problems caused by this illumination are also discussed. The program, developed in C++ language, works quite well and illustrate how the areas (Robotics, Image Processing and Artificial Intelligence) can work together.

THE EXPERIMENTAL SETUP

The experimental setup, shown in Fig.1, is composed by a CCD black and white camera, a frame grabber board with 256 256 pixels spatial resolution and 256 gray levels. Also a didactic robot manipulator kit Robix RCS-6, is used. The robot is assembled with two degree of freedom, and has movement in the x-y plan only. The frame grabber uses a ISA slot and is in 233MHz PC compatible microcomputer. It can acquire up to fifty frames per second. In the CCD camera scene lies a tic-tac-toe board, and its image is continuously sampled by the frame grabber. When a move happens on the board, using image subtraction, the program detects the change in the scene and calculate in which position this move was done. This calculus is possible, doing the binarization of the remaining image and calculating its gravity center.

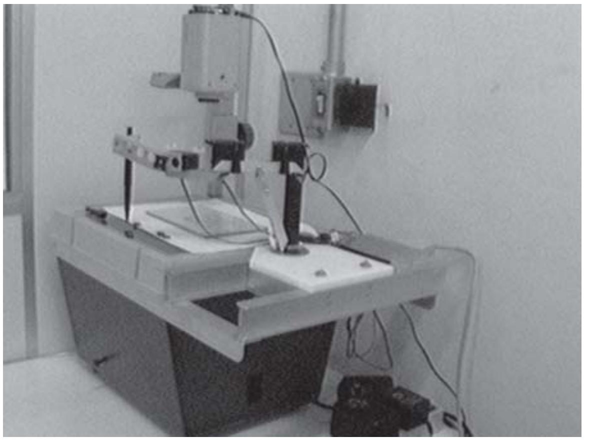


Figure 1 - The Experimental Setup

THE KIT ROBIX RCS-6

The didactic kit Robix® RCS-6, can be assembled with up to 6 servo motors and its configuration can be chosen by the user. In this work, was chosen a configuration with two degrees of freedom, Fig. 2, that allows the robot to move only in the x-y plane. The third servo motor illustrated in Fig.2 was used just to move the pen up and down.

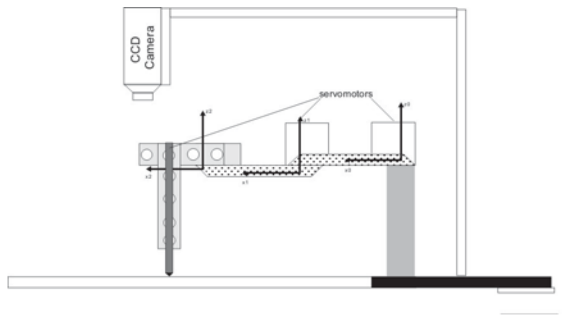


Figure 2. Scheme of the robot and CCD camera assembly

The configuration chosen is very simple one and have the Denavit-Hartenberg parameter described in Table 1. The parameter in Table 1 are related to the frames described in Fig. 2, with L1 = 10mm and L2 = 10mm.

Table 1 - Denavit-Hartenberg for the chosen configuration

Link	θ_1	α_2	a_i	d_i
1	θ_1	0	L_1	0
2	θ_2	0	L_2	0

With this parameters, the robot workspace in the x-y have the spectrum shown in Fig. 3.

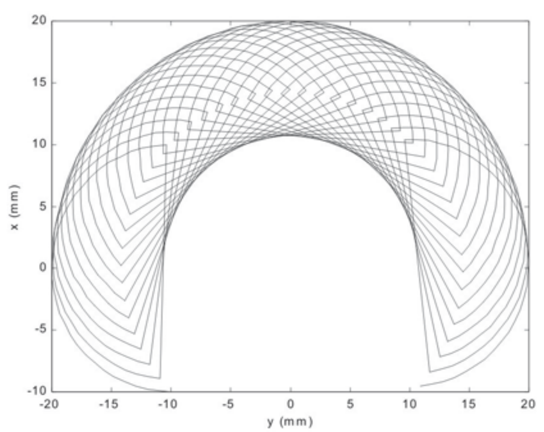


Figure 3. - Robot workspace

Those parameter also led us to the to the following equation for the robot inverse kinematics, Ribeiro and Yamaguchi, (1999)

$$\theta_1 = 2\arctan\left(\frac{-2L_2 sin(\theta_2) \pm 2\sqrt{L_2{}^2 sin(\theta_2)^2 - y^2 + L_1{}^2 + 2L_1L_2\cos(\theta_2) + L_2{}^2\cos(\theta_2)^2}}{2(y + L_1 + L_2\cos(\theta_2))}\right)$$

$$\theta_2 = \arccos\left(\frac{x^2 + y^2 - L_1{}^2 - L_2{}^2}{2L_1L_2}\right)$$

The Program Developed

The computer program developed in this work manages the image acquisition system and the robot manipulator as well. It is responsible for process the data that comes from the frame grabber, check if a movement was done on the scene, calculates the position where the human opponent played and move the robot to draw an X in the best position to blocked the opponent. The algorithm implemented by the program is shown in Figure 4.

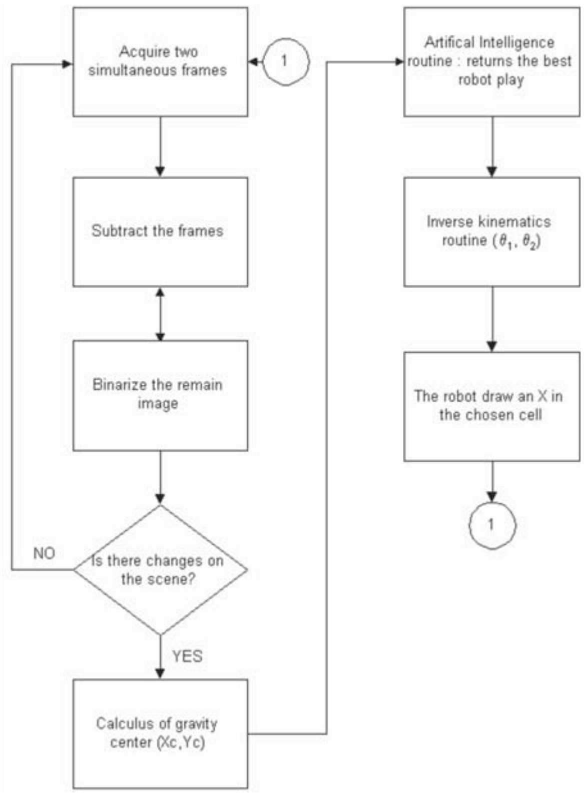
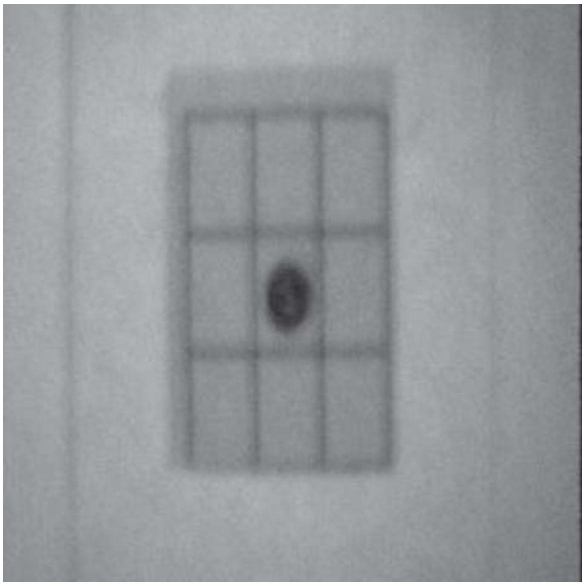
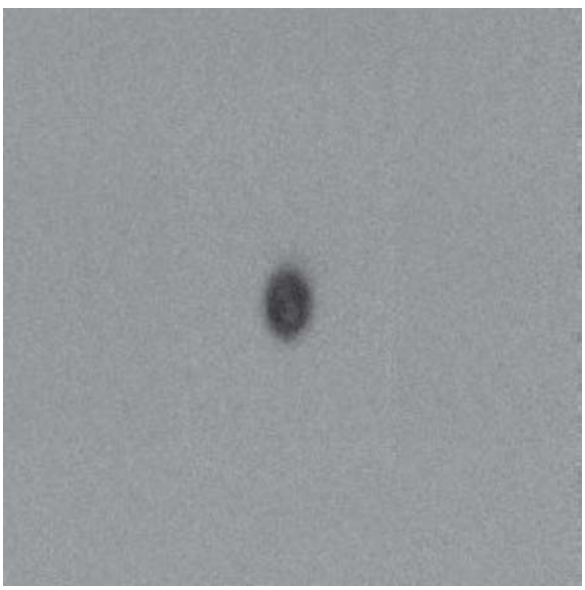


Figure 4 - Algorithm to manage the image system and the robot manipulator

Initially, two frames are acquired simultaneously from the scene. The computer holds the frame grabber, and the images are subtracted and threshold value is



(b) board with a play;



(c) subtraction of (b) minus (a);

(d) image (c) binarized

The algorithm used to get a threshold value is quite simple to implement and worked very well. It's based in the image histogram, Parker, J. R., (1997) and consists in to chose the two main regions in a image using its histogram. It can be summarized in the following steps

1. Calculus of the image histogram (vector h)
2. Choose the largest value of h (h[hmax])
3. Calculus of the vector y as : y[k]=(k-hmax)^2*h[k]
4. Choose the largest value of y (y[ymax])
5. Choose the threshold value as the minimum value between h[hmax] and h[ymax]

Results and conclusions

This work proposes a experimental setup to do the automation of tic-tac-toe game. The experiment involves a CCD black and white camera, a frame grabber with 256 256 spatial resolution and 256 gray levels. The experiment also includes a didactic robotic manipulator kit Robix RCS-6 assembled with two degrees of freedom which motion is limited to the x-y plane. A computer program that manages all this hardware was developed and implements routines to acquire and treat the scene image, to move the robot into its workspace and decide where the robot should play to blocked its opponent. The experimental setup was assembled in the Robotics Laboratory of the Mechanical Engineering Department of Taubate's University and achieved its objective, with the automation of the tic-tac-toe game.

The first thing that we should be concerned when dealing with image processing is the scene illumination. In this work was used a back light illumination board to improve the scene contrast and avoid noise. The CCD camera used can also becomes a noise source if the number of lux (luminance) needed by the camera was high (bigger than 0.1 lux). To show the importance of the illumination, Fig. 6 and 7 compares two images acquire with two different cameras.

calculated using the subtraction result. The remaining image is binarized and the number of black pixels in the binarized image will allow the computer to decide if there is changes on the scene.

If there are changes on the scene, the computer executes an Artificial Intelligence routine that returns the best play the robot should do to blocked its opponent. So the robot draws an X on the cell suggested by the Artificial Intelligence routine. If there is no changes on the scene, the computer releases the frame grabber to acquire two more consecutive frames.

Figure 5, show a sequence of two images acquired by the frame grabber, subtracted and binarized to discover in which cell the human opponent played.

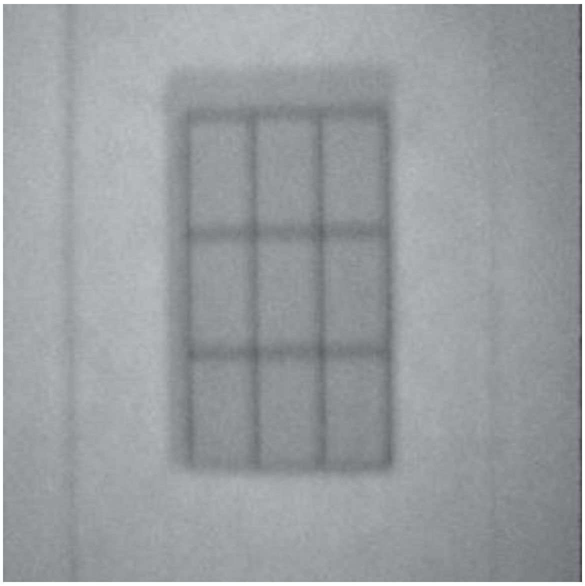


Figure 5. (a) empty board;

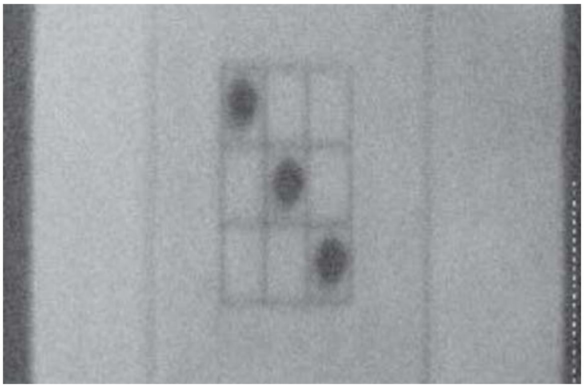


Figure6 - Image acquired with a 1.0 lux camera

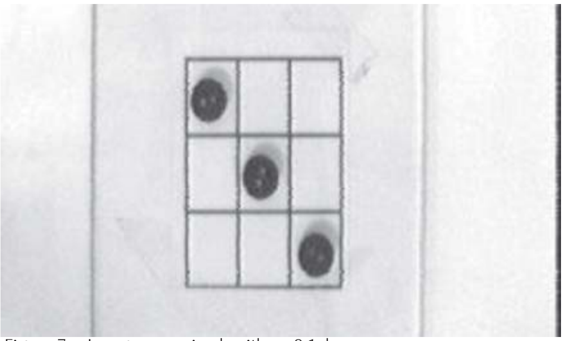


Figure7 - Image acquired with a 0.1 lux camera

The first image was acquired with the CCD camera used during the development of this work and the second with a CCD camera that unfortunately was acquired after we finish the work. The first camera requires at least 1.0 lux to work well and the second one requires at least 0.1 lux. A better way to compare the images is to analyze its histogram, shown in Fig. 8 and 9.

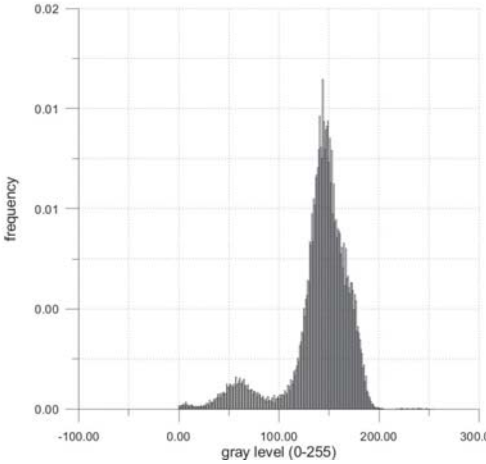


Figure 8. Histogram - image with poor contrast

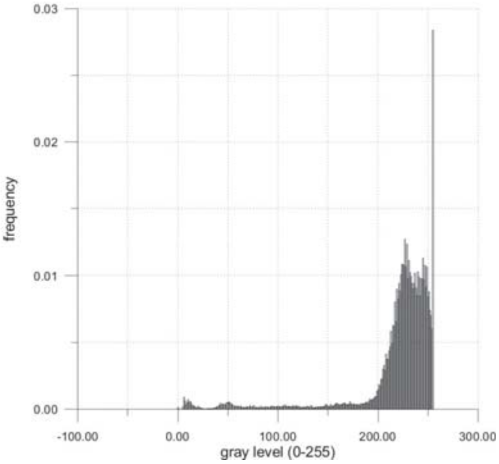


Figure 9. Histogram - image with good contrast

The Robix RCS-6 didactic kit is quite good to work. The user can assemble it in many different configurations and control it using C language. The kit has a very good repeatability but poor precision. To illustrate these characteristics, Fig. 10 shown the result of a program that commands the robot to draw a star on a piece of paper thirty times.

Figure 10. Robix RCS-6 repeatability and precision

This work is still on progress and the next steps are to improve the system of image acquisition with a better camera and use those ideas to develop a work that implements the feedback control of an industrial robot using the image acquisition system as a vision sensor.

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