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Visual Patterns Recognition in Robotic Platforms Through the Use of Neural Networks and Image Processing

Holman Montiel Ariza[1], Fredy H. Martínez[2] and Edwar Jacinto[3]

District University Francisco José de Caldas, Bogotá D.C., Colombia.
[1]ORCID ID: 0000-0002-6077-3510, [2]ORCID ID: 0000-0002-7258-3909
[3]ORCID ID: 0000-0003-4038-8137

Abstract

Current design trends with respect to the manufacture of human-like robotic platforms are constantly growing; day to day manufacturers generate new platforms in order to improve the integration of these technological tools into our daily activities. This paper proposes a methodology associated with pattern recognition by using Adaptive Resonance Theory (ART) Neural Networks and image processing techniques, allowing this way the NAO robotic platform to be easily used in experiments of human-robot interactions. It attempts to integrate an algorithm of geometric figures recognition so the robotic NAO can identify shape, color and size for the patterns in a fast and efficient way, to be associated with established activities or actions, such as: controlled displacements, extremities movement or played voice messages.

Keywords: ART, Pattern Recognition, Humanoid Robot, Artificial Vision.

INTRODUCTION

The development and implementation of artificial intelligence techniques associated with humanoid robotic platforms [1-2] such as the NAO, open a large amount of probability of use, these platforms could be used as guides at airports, receptionists, children care, children tutorship, among many other tasks[3]. But this implementation goes through a lot of challenges still to be developed, not only from the technical point of view but from one associated to the communication processes.[4]

This work is related to pattern recognition for geometric figures with action instructions associated to the NAO. It attempts to generate a didactic tool that allows the interaction between the human and the robot in a simple way[5]; also to generate a tool that allows exploring the communicative relations between the human and the machine[6], passing the barrier of communication that can be presented between them when performing basic tasks together.

The visual process of pattern recognition has presented a constant evolutionary process [7-10]. It uses a lot of techniques using low cost hardware with processor unit limitations, however, this visual function has a vital importance for the use of robotic mobile platforms, a fundamental part for navigation systems, mapping, localization, objects identification and of course the pillar process in the coordination processes.[14,15]

Considering the above, the present work establishes a proposal for the NAO robot to implement an algorithm for the recognition of patterns of geometric figures and the performing of a preset activity according to the type of image detected. This proposal is based on a neural network algorithm implementation for the learning of the geometric figures and the color detection through the use of RGB masks supporting the image processing.[11-13]

METHODOLOGY

The proposed development consists of two main operating blocks: image processing and pattern recognition in the ART neural network [13]. The process starts with the acquisition and the treatment of the image; this phase pretends to detect the specific color of the analyzed pattern. Once the color has been identified, the figure binarization is proceeded to be stored in a data vector, which will be added to the neural network for a later identification and classification. (See Figure 3)

Image processing:

The main function of the image processing focuses on the color detection of the geometric pattern the NAO presents. This task could be integrated to the learning process at the selected neural network since this allows the recognition of analogical signals, but for this case it was chosen to separate the activities in order to minimize the response times associated with the information processing by the electronic control unit of the NAO.

Figure 1: Color mask detection

The principle of detection used is based on the identification of color masks (see Figure 1), this identification process allows to detect a certain color based on the generic components of the RGB format [9,10], in this way the detection limits are defined for each particular color, this becomes the creation of a boundary table.

Table 1: Color detection range according to RGB format

RGB Range			*Color*
10	255	255	Low Red
0	58	78	High Red
28	255	212	Low Yellow
18	78	74	High Yellow
129	255	255	Low Blue
99	64	74	High Blue

Neural Network ART

An ART network (Adaptive Resonance Theory) basically consists of two layers in which forward and backward connections are established. Their operation is oriented to competitive environments in which is presented certain type of input information where only one of the output neurons will be activated after having competed with the others. This network seeks to categorize the data introduced in order to classify similar information into a single category, facilitating the process of learning new information without destroying the previously processed data [13]. In this type of network there is no distinction between learning steps and operation steps. The learning is "On Line" type or non-supervised competitive type, where the weights of the connections are adjusted according to the output layer neuron that has been winning or activated.

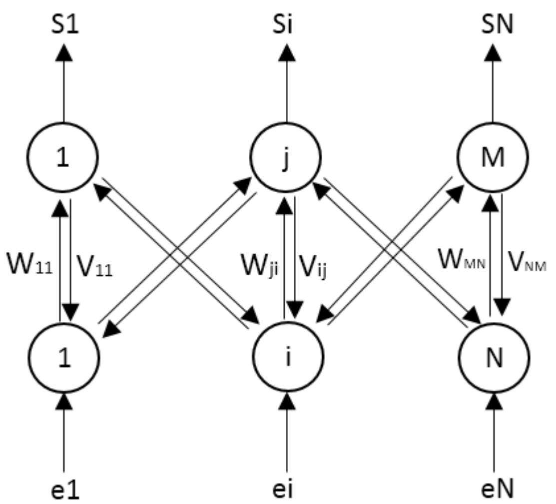

Figure 2: ART network architecture

IMPLEMENTATION

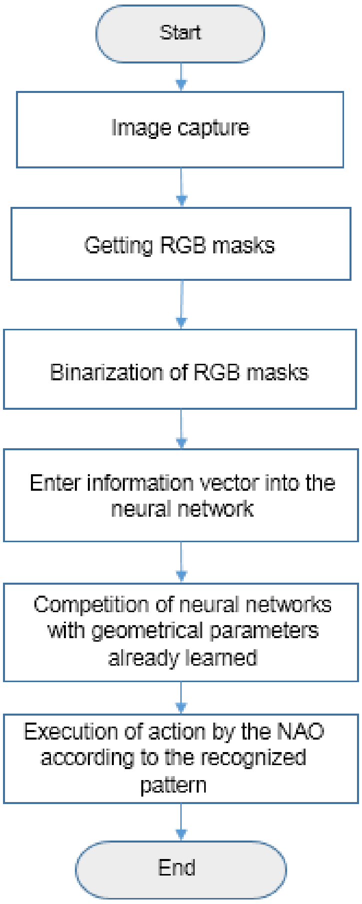

Figure 3: Flow diagram

After knowing the two functional blocks on which the development was implemented, it is necessary to identify the flow of the process for the geometric patterns identification. Figure 3 describes step by step the diverse activities developed in the image analysis presented to the NAO platform. Must be taken into account that it seeks to identify basic patterns that can be easily used by children at the time of interacting with the platform, as shown in figure 4, 6 patterns (A-F) are created associated with 6 activities that will be executed at the moment of showing the figure to the robot.

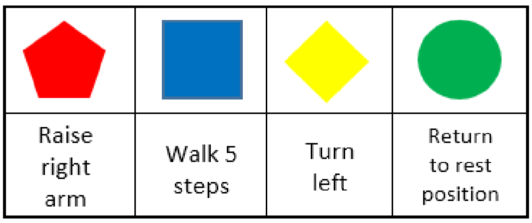

Figure 4: Association of patterns with NAO response activities

In the first instance, the identification of the color masks is performed to recognize which group belongs to the activity to be executed, this means that once the color is detected the image is reverse binarized. As the color mask used to detect the pattern is white, it is necessary to generate its inverse, since the black pixels are represented by the binary value 1 and the white ones with the value 0. See Figure 5.

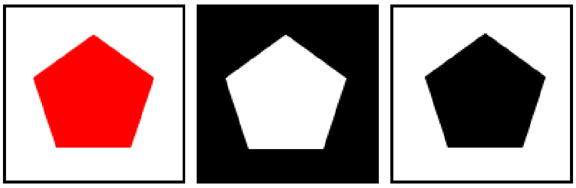

Figure 5: Pattern to detect binarization

Once the image is binarized, a N-elements data vector is created with the values of the pixels, in this case the network would have N neurons in the input layer where each of them will receive the value of a pixel and the output layer is formed by 6 neurons, where each output neuron is associated with a particular pattern type.

The operation of the network starts once the input vector is shown. $E_k = (e_1^{(k)}, \ldots\ldots e_N^{(k)})$, this is where each input layer neuron receives the respective pixel value $e_i^{(k)}$ and sends the neurons to the output layer through the connections W_{ji}.

It should be initialized the weights V_{ij} with value 1 and W_{ji} with 1 / (1 + N) values where N refers to the number of neurons of the input layer.

At the implementation process the neural network must initially store the patterns to be identified, the information of the first pattern that is entered will be stored as the weights of the first output neuron, then, by entering the following vectors will occur the competition process between the neurons of the output layer by implementing the following equation:

$$\sum_{i=1}^{N} w_{ji*e_i^{(k)}}$$

The winning neuron will perform the variation of the weights of the feedback V_{ij} connections by the equation:

$$V_{ij}(t+1) = V_{ij} * (t) e_i^{(k)}$$

Where $e_i^{(k)}$ is the value of each pixel for the input data.

The weight of the feedforward W_{ji} connections will also have to be modified using the equation:

$$W_{ji}(t+1) = \frac{V_{ij} * (t) e_i^{(k)}}{\gamma + \sum_{i=1}^{N} v_{ij*(t)e_i^{(k)}}}$$

Where γ has a value of 0.5 and N is the number of neurons at the input layer.

As previously mentioned, the network learning is unsupervised and depends heavily on the influence of the monitoring parameter (ρ), this value is set in a range between 0 and 1, in the case of this development it was set to 0.85 indicating this way that a pattern similarity of more than 85% must be found between the input information vector and the data stored in each of the output neural networks. This indicates that each time an information vector $E_k = (e_1^{(k)}, \ldots\ldots e_N^{(k)})$ is entered, the competition process between the neurons at the output layer will be performed. The winning neuron will calculate the similarity ratio given by:

$$\frac{|E_k \cdot V_{j*}|}{|E_k|}$$

Where $|E_k \cdot V_{j*}|$ is equivalent to:

$$\sum_{i=1}^{N} e_i^{(k)} V_{j*}$$

And $|E_k|$ is equivalent to:

$$\sum_{i=1}^{N} e_i^{(k)}$$

If this similarity ratio is greater than the monitoring parameter (ρ), a combination of patterns is performed by adjusting the weights V_{ij} by an AND operator, indicating that the information entered belongs to the pattern stored in the respective output neuron; Otherwise the algorithm will ignore that information and it will be rejected, generating a voice message at the NAO indicating that it does not know the figure that is being shown.

RESULTS

The behavior of image processing associated with color detection is susceptible to variation in light conditions. This reflected a margin of error of 6.66% for the 30 color samples used in the detection of the three colors used during the test (green, red and blue). It is important to perform a calibration process regarding the limit levels for the range of color to identify; for validation tests at the step of image processing a development interface was installed on PHYTON, this platform runs on Windows 7 - 32 Bits operating system, with an Intel Core I5-4200U CPU 2.3 GHz processor and 6 Gb RAM; In this environment the color ranges established for detection levels were validated, these values are defined in Table 1.

Respect to the neural network used, a performance validation was performed on a total of 50 samples for each pattern to be recognized, this test allowed the identification of the level of effectiveness for the neural network learning, see Table 2. In order to validate the tolerance of the network against the variation and displacement of the input samples, tests were performed with variations of size and slight rotations of the geometric figures, identifying that the type of neural network used (ART) is sensitive to such modifications due to the information degradation for the prototype corresponding to the adaptation of the values of the weights, all this is caused by the Boolean operator AND executed between the data prototype of the output neurons and the data of the input vector.

Table 2: Level of effectiveness of ART network

Patterns	*Number of samples*	*Effectiveness*
A	42	84 %
B	40	80 %
C	41	82 %
D	43	86 %
E	47	94 %
F	45	90 %

The effectiveness levels obtained were achieved by making variations in size of no more than 10% and with a rotation degree not greater than 15 degrees, as previously mentioned, the control parameter (ρ) used was 0.85, with levels of variation used in size and rotation obtaining acceptable levels for the similarity ratio, identifying that the results obtained highly depend on the established monitoring parameter.

CONCLUSIONS

It was presented an effective learning mechanism on simple geometric patterns based on neural networks for the robotic platform NAO, although it does not support drastic modifications for the learned patterns, it becomes a useful tool to incorporate, validate and experiment with the NAO in processes of human-robot interaction, since even a small child who knows the geometric figures and colors can interact in a simple way with this robot.

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