A cognitive approach for a humanoid painter

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***Abstract*— In this work we propose a system which exploits a cognitive architecture in order to implement a creative painting mechanism in a humanoid robot such as the Aldebaran NAO®. The system is capable of autonomously assessing its own work during the portrait creation process, which is simultaneously influenced by the perceptions of the robot. In particular it takes into account the perception of the visual appearance of the portrait which is being realized. The system output is ready to be converted in a set of NAO arm gestures. This would let the NAO robot capable of drawing a portrait by waving some sort of virtual pen in the air. The NAO gestures will be captured through an infrared acquisition system and interpreted as being movements of a brush on a canvas. The results will be continuously evaluated and compared with the internal model of portrait in order to decide how to complete the painting. This approach will realize an autonomous dynamic improvement process, and not a mere planning painting procedure.**

I. Introduction

Creativity plays a crucial role in human beings. Since this feature characterizes mankind, it would be interesting to provide creative capabilities to an humanoid robot.

In this work we try to combine an approach based on cognitive architectures [1], [2] with some mechanisms of computational creativity [3], [4] and an embodiment provided by a NAO® humanoid.

Given the proposed models of creativity in literature, we have identified some features that are likely to produce a *digital* painter by using a robot that is able to generate a *creative act* triggered by its artificial visual perception, according to its experience and expertise [5], [6], [7]. Our first approach was aimed at developing a cognitive software infrastructure that provided creative skills mainly coming from visual perception. In a second phase, we have considered to use the physicalness of the humanoid to create the final artwork through the gestures of the robot. The present work is a first step in this direction.

II. A cognitive architecture for a humanoid painter

Cognitive architectures represent the infrastructure of an intelligent system that manages, through appropriate knowledge representation, the process of perception, the processes of recognition, categorization, reasoning, planning and decision-making [2].

In order to make the cognitive architecture capable of generating behaviors which resemble to those of humans - and especially in the case of creativity - it is important to consider the role of perceived emotions. As a matter of fact, reasoning and planning may be influenced by emotional processes and their representations as it happens in human beings.

This statement is in agreement with the hypothesis that human creativity only makes sense when placed in the context of rich social interactions [8], [9], [10]. An interesting architecture for the purposes of our work is the Psi model [11], [12] and its architecture that involves explicitly the concepts of emotion and motivation in cognitive processes. MicroPsi [12] is an integrative architecture based on the Psi model which has been tested on some practical control applications. It has also been used on simulated artificial agents in a simple virtual world. Similarly to other architectures, MicroPsi currently focuses on the lower level aspects of cognitive process. It does not directly handle advanced capabilities like language and abstraction.

The Psi Model offers an effective framework to develop a creative system since it manages two important urges like Certainty and Competence. These two urges are fundamental for creativity evaluation [13].

During a training phase the creative system proposed in [5] constantly produces a set of image processing procedures, called SketchString in fig. 1 and 3, by selecting the ones that produces the “desired output”. What a “desired output” is, is decided a priori using the metaphor of the “painting style”.

In a painting a style is a set of recognizable characteristics that makes two paintings of the same object looking completely different. We used a Self Organizing Map (SOM) [14] to obtain a map of some painting styles and used the placement of the image obtained from a SketchString Processing, as a measure of the “desired output”.

A. Painting Style Development and Evaluation

During the Production Phase the humanoid creates a portrait of a subject by using a snapshot and a set of image filters obtained from some predefined painting styles. The choice and the use of the painting style in a portrait processing is driven by the motivations (or Urges in the figure) of the system. We found that these *Urges* can be implemented by using the cognitive model Psi [11] that also takes into account concepts related to Certainty and Competence. The agent that has enough competence to go beyond the common ground is much more creative than the others.

A simplified diagram of the Psi architecture is shown in the Production Phase part of Fig. 1. An agent that implements this architecture has a Long Term Memory (from now on LTM) storing the plans and all the knowledge about the environment. This knowledge is used by the Planning block that also processes the sensory inputs. The Urges block

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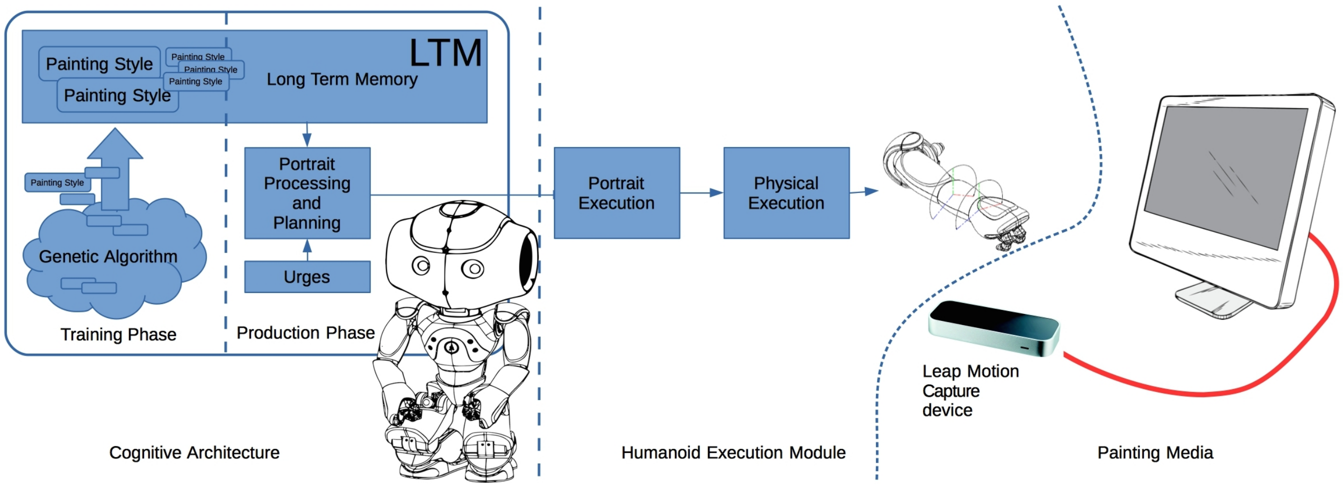

Fig. 1: The overall diagram of the proposed system.

(a) Output of the creative process

(b) Output of edge extractor

Fig. 2: Examples of the painting model and physical execution model.

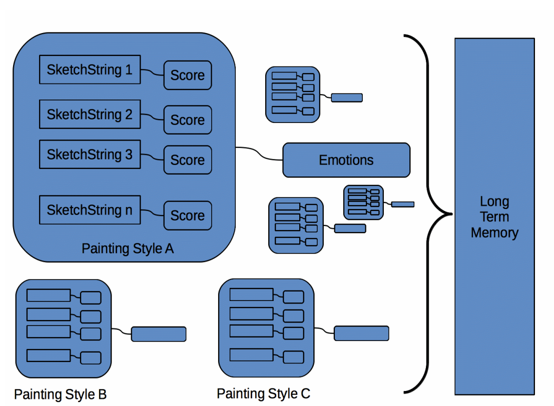

Fig. 3: The set of styles that constitutes the a priori knowledge of the program.

manages the motivations that justify the actions of the agent (together with the sensory inputs) and modulates the response of the agent. Motivations are one of the most important characteristics of the model for our application. The Urges not only modulate the reactions of the agent but they also push the agent to find new solutions to the problems and change the importance of the sensory inputs.

The proposed system generates a portrait using a snapshot of the subject during the Production Phase. It basically processes the subject image by using a set of filters with different parameters that are generated during the Training Phase.

The following subsections will explain how the painting styles are generated during the Training Phase and how the Production Phase is connected to the cognitive capabilities and influenced by emotions.

B. Painting Style

The sequence and the parameters of the applied filters are coded using a character sequence string that is called SketchString.

The filter sequence in a SketchString is obtained in a Training Phase using a Genetic Algorithm. Ideally each filters sequence should transform a random face snapshot to a portrait from a set of famous pictures.

For example, we can have a set of sequences that produce images similar to Andy Warhol pictures, other ones producing an effect similar to the Rubens portraits, and so on. The different sets of sequences with similar effects are called *Styles*. We collected a set of well known portraits as a reference. Each Style is also related to a set of emotion labels that are obtained labeling the images of the reference set with emotions that they cause in an observer as explained in the next sections. These emotion labels will be used to choose the Style during the Production Phase in order to obtain a result that expresses what the artificial artist feels and perceives from the subject.

C. Humanoid Execution Module

Beyond the selection of the style there is the creation of the portrait through the physical movements of the robot to draw the portrait. This activity can be implemented through

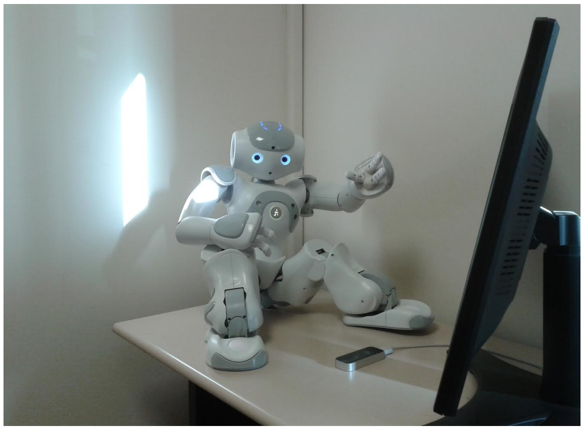

Fig. 4: Setup with NAO® and Leap Motion device

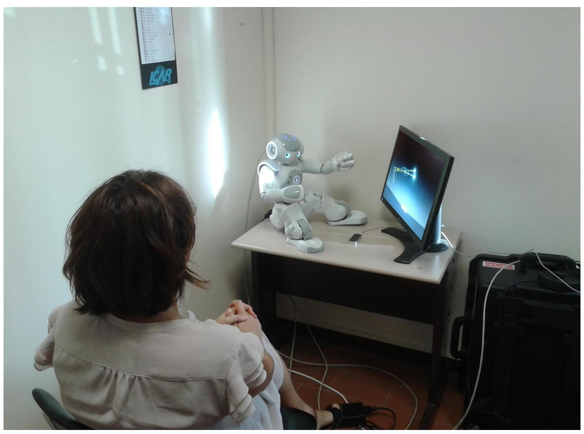

Fig. 5: Portrait execution.

the analysis of the movements through infrared mouse that captures the movements of the arm of the humanoid and convert them in sign in an image.

The cognitive architecture as previously discussed can be used for different robots that perform with theirs own capabilities the final work of art. In our case, the robotic platform used is the Aldebaran NAO® V4 H25. We have planned the following mode of execution: the robot observes the user's face to be painted, and through the cognitive architecture it has in its memory a model of the portrait to realize; the painting will be done by moving the hand in the free space in front of the robot as if there was a virtual canvas; spatial coordinates of the movements are captured using a Leap Motion® device, and they are used to perform virtual strokes displayed on the monitor.

The movements are guided by an elaboration derived from the output of the creative process (Fig. 2(a)) and the output of an edge extractor (Fig. 2(b)). During execution, the robot observes the result of what he has produced so far, and he compares this partial product with the model in its memory; this approach allows to modify the execution of the portrait while the whole process is running.

III. Conclusion

We have presented a first step towards the implementation and the embedding of a creative painting mechanism in a humanoid robot. We have chosen to use the Aldebran NAO® as implementation platform thanks to the advanced programming facilities which are provided. The creative process have been implemented according to the well-known PSI cognitive architecture and its core is given by a genetic algorithm approach which provides a set of styles which are chosen according to both internal and external evaluation. This system can help on understanding how the errors and misalignment between the model and the results of a physical execution influence creativity and creative processes. In particular when an error in execution can be accepted, when it is refused and when (or if) it is considered a seed for a new creative process.

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