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RESEARCH ARTICLE

Binding representational spaces of colors and emotions for creativity

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Abstract
To implement cognitive functions such as creativity, or the ability to create analogies and metaphors, it is important to have mechanisms binding different representational spaces. The paper discusses this issue in the broader context of having a ''artist'' robot, able to process his visual perception, to use his experience and skills as a painter, and to develop a creative digital artefact. In this context, two different spaces of color representation are respectively used to associate a linguistic label and an emotional value to color palettes. If the goal is to build an image that communicates a desired emotion, the robot can use a neural architecture to choose the most suitable palette. The experience concerning palette-emotion association is derived from the analysis of data enriched with textual description available on the web. The representation of colors and palettes is obtained by using neural networks and self association mechanisms with the aim of supporting the choice of the palette.

1. Introduction

The presented work takes place in the generic context of creativity and aims at investigating a basic mechanism that can be used for the construction of new representational spaces. A much-discussed theory was originated by the so-called model of *blending* (or conceptual integration) which identifies and connects mental spaces among them (Fauconnier & Turner, 1998). Considering cognitive mechanisms for creativity, three components generate a blend: the composition (or fusion) which pairs elements from the input spaces into *the blend*; the completion (or emergence) of a pattern in the blend, which is filled using long-term memory information; the process that simulate a cognitive work and its performance evaluation (Abdel-Fattah, Besold, & Khnberger, 2012; Pereira, 2007). In our opinion it is possible to have robust fusion algorithms and completion through the combination of various models of neural networks: an example of such an approach is described in Thagard and Stewart, 2011 that makes it possible to emphasize associations useful

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to generate creative ideas by simple vector convolution. The importance of associative mechanisms is also underlined by neurobiological models of creativity, many of which are based on the simultaneous activation and communication between brain regions that are generally not strongly connected (Heilman, Nadeau, & Beversdorf, 2003).

We propose an architecture that produces links between representational spaces originated from visual perception. In particular, we address two interesting cognitive aspects: the association between the name and the perception of color and the association between palette of colors and emotional labels. The two representation spaces are implemented by using neural networks, and from them new bindings in a ''creative'' space can arise. Extending a previous work (Infantino, Pilato, Rizzo, & Vella, 2013), we choose to put together a raw color representation with a link between emotion and color sets using some recent hypotheses that try to explain the mechanisms of creativity (Boden, 2009). Currently we have built a subsystem able to connect emotions and color palettes. This connection is aimed at obtaining a suitable palette if a specific emotion is required, in an image or a graphic artefact. This module is a part of a larger project that is focused on obtaining a robotic system able to paint and reproduce a portrait of a human subject. The project is aimed at combining an approach based on cognitive architectures (Goertzel, Lian, Arel, de Garis, & Chen, 2010; Langley, Laird, & Rogers, 2009) with mechanisms of computational creativity (Boden, 2009; Colton, Lopez de Mantaras, & Stock, 2009) trying to get an implementation that satisfies both software and hardware constraints, which are introduced when working with a real robotic platform.

All cognitive architectures presented in the literature do not explicitly provide mechanisms to achieve creativity, partly because only recent researches are addressing some important and closely related cognitive aspects such as emotions, intentions, awareness, consciousness. These aspects, and other high level functions of new cognitive architectures are reported in Samsonovich, 2012. Given the proposed models of creativity in literature, it is possible to identify some features that are likely to produce a *digital* portrait painter using a robot that is able to develop his artificial visual perception and to originate a *creative act* based on its experience, its expertise and also through interaction with the human (both during learning and in final evaluation).

The paper describes the first phase of our research project, and it aims at creating cognitive software infrastructure that provides creative skills mainly from visual perception. In a second phase, we plan to introduce the physicalness of the humanoid by including other sensory information such as auditory and tactile, to achieve perhaps the use of a real brush and a canvas. The paper is structured as follows: the first Section 2 gives a brief introduction to colors and emotion interaction as reported in relevant literature, the second Section 3 describes the proposed system, the third Section 4 illustrates the dataset used, the fourth Section 5 presents the results and finally some conclusions are drawn.

2. Colors and emotions

Choosing the right color set is an important issue for graphic professionals. A system focused on the creation of graphic artefacts has to emulate the same decisions that a graphic designer makes while developing her/his works. Picking the right color set is crucial because it plays a relevant contribution on a global emotional impact of artworks.

A study on relationship between color and emotions is reported in Ou, Luo, Woodcock, and Wright, 2004; this study assigns to each color a position in a space characterized by four dimensions like warm-cool, heavy-light, active-passive and hard-soft.

Color selection is an issue in many living environments: for example the right color set can influence the behavior of customers in a shop, as indicated in Bellizzi, Crowley, and Hasty, 1983.

Many studies were conducted on color harmonization, i.e. the way of selecting a group of colors aesthetically pleasing. There is not a consolidated formulation that defines a set of harmonic colors, but there are schemas or relations in color space that describe these sets: examples of harmonic color sets can be found in Cohen-Or, Sorkine, and Gal, 2006. Another use of color harmonization has been proposed in Wang and Mueller, 2008 were harmonic color palette were used in 3D rendering.

On these premises a system aimed at producing a digital image must select colors in a careful way. A wrong set of colors will not convey the ''right information'' and will not evoke the desired emotional response.

Color harmonization is also the subject of the study in O'Donovan, Agarwala, and Hertzmann, 2011; in this work the focus is on small color palettes called *color themes* that are collected in COLOUR Lovers web site,[1] a resource of tools for graphic designers.

A work on painting and emotion is presented in Shugrina, Betke, and Collomosse, 2006; in this work the colors and other parameters of a photograph are changed according to the mood of an user. The image is modified using a set of functions that shift color pixel according to the emotion in a pleasure-arousal space; for example arousal corresponds to color saturation and hue, while sadness and calm generate a shift to the blue spectrum.

Finally another relevant work is Csurka, Skaff, Marchesotti, and Saunders, 2011, which is focused on the association of color themes to abstract and emotional concepts (such as *classic, cool, and delicate*). This association is similar to the one presented in this work, but it is not related to an emotional space.

3. The proposed system

The proposed system is represented in Fig. 1; the system is composed of three interconnected neural systems: a neural gas (NG), an autoencoder network and a multi-layer perceptron (MLP).

The NG is a self organizing clustering network, described in Martinetz, Berkovich, and Schulten, 1993, used to represent and simplify the color input stimuli; the autoencoder is used to build a connection among palettes and emotion representations, while MLP labels the clustered color stimuli and creates the association between name and color perception (as presented in Infantino et al., 2013).

[1] *http://www.colourlovers.com.*