Lessening stress and anxiety-related behaviors by means of AI-driven drones for aromatherapy

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Abstract. Stress and anxiety are part of the human mental process which is often unavoidably yield by circumstances and situations such as waiting for a flight at the airport gate, hanging around before an exam, or while in an hospital waiting room. In this work we devise a decision system for a robotic aroma diffusion device designed to lessen stress and anxiety-related behaviors. The robot is intended as designed for deployments in closed environments that resembles the aspect and structure of a waiting room with different chairs where people sit and wait. The robot can be remotely driven by means of an artificial intelligence based on Radial Basis Function Neural Networks classifiers. The latter is responsible to recognize when stress or anxiety levels are arising so that the diffusion of specific aromas could relax the bystanders. We make use of thermal images to infer the level of stress by means of an ad hoc feature extraction approach. The system is prone to future improvements such as the refinement of the classification process also by means of accurate psychometric studies that could be based on standardized tests or derivatives.

Keywords: Artificial Intelligence · Neural Networks · Robotics · Feature Extraction · Human Machine Interaction · Social Psychology.

1 Introduction

In our society we are nowadays experiencing a constant increase in stress and anxiety levels as never seen before. Since such a phenomenon is a typically observed within industrial and hyper-urbanized areas, common belief relates stress and anxiety to an overwhelming amount of work and occupation. On the contrary stress and anxiety are a twofold part of the human mental process which is often related to boredom [1]. In facts, while it has been proven many times that occupied time feels shorter than unoccupied time [7], the lack of a practical involvement during a long waiting time and the related boredom are typical precursors for well known mentalization processes that often end in overthinking [19].

While generally considered a detrimental habit, overthinking is often also an unavoidably yield by circumstances and situations such as waiting for a flight at the airport gate, hanging around before an exam, or while in an hospital waiting room. It has been proven that the quality of the time spent in a waiting room also affect the perceived quality of the awaited service, especially in healthcare-related contests [3]. The latter are also often positively or negatively affected by the perceived quality of service that, in the second case, could also tamper with the therapeutic efficacy of the treatments (e.g. for psychological counseling or and psychotherapy [9]).

Many techniques has been developed to relieve anxiety and lessen stress, among such techniques several of them focuses on the psychological impact of the surrounding environment and its perception. Aromatherapy has been proven to be an effective remedy for stress and anxiety-related behaviors due to the apparent interaction between sense of smell and pituitary gland's physiology [4]. In particular several aroma has been show to significantly lower the blood's levels of cortisol [20]. Therefore aroma inhalation could be a very effective stress management method in several contests ranging from medical care centers to school and studyrooms [18]. However, while more basic research is needed to fully understand the mechanisms underlying the effects of aromatherapy [6], the clinical trials seems to suggest that aromatherapy may decrease sympathetic nervous system activity and increase parasympathetic nervous system [5]. Finally, aromatherapy-enhanced mindfulness state has been studied in order to develop new therapeutic intervention against stress and anxiety in hospitalized people [16, 17].

In this work we devised a robotic aroma diffusion device for deployments in waiting rooms, airports, hallways and similar environments. Such a robot as been designed to be remotely driven by means of an artificial intelligence that is responsible to recognize when the stress or anxiety levels are arising and the diffusion of specific aromas could relax the bystanders. The devised robot could easily blend with other similar device which are nowadays diffused for different use ranging from cleaning to healthcare applications [2]. The overall system architecture and design are described in the following.

2 The developed system

Our approach provides aromatherapy in closed environments that resembles the aspect and design of a waiting room with several chairs where people sit and

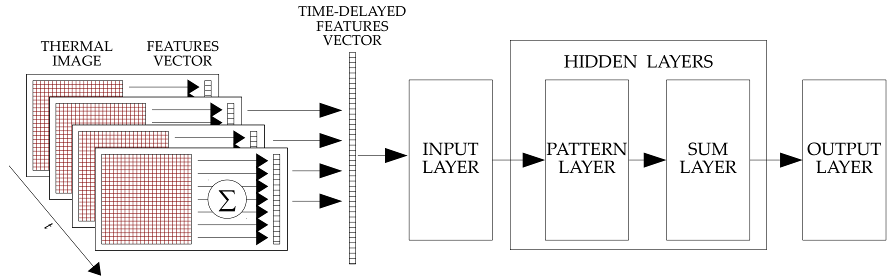

Fig. 1. An overall schema of the feature extraction and classification process. Starting from thermal images singular feature vectors are extracted. Groups of 4 consecutive feature vectors are joined and used as input for a radial basis function neural network.

wait. It follows that we can imagine people's locations as fixed points in space and suppose that each person will remain on the same position during all his staying. In this kind of setting we use a thermal camera to acquire images during time. Such images are at the basis of our classification task to decide whether or not aromatherapy is needed. If we can dispose of several cameras that produce frames, then those frames can be geometrically segmented and normalized in order to depict only one person at the time. It has been shown the existence of strong correlations between stress and thermal effects on several body parts (e.g. see [11, 14]). The feature extraction and classification system (see Fig. 1) is explained in the following.

2.1 Feature extraction

Each thermal image frame, regarding the k-th person at a discrete time step τ, can be represented as an $N \times M$ matrix $A^k(\tau)$ of pixels $p_{ij}^k(\tau)$ where i and j represents the row and column indexes respectively. To each matrix $A^k(\tau)$ we can associate a features vector $\underline{a}^k(\tau)$ of components $a_i^k(\tau)$ defined as

$$a_i^k(\tau) = \sum_{j=1}^{M} p_{ij}^k(\tau) \qquad \forall\ k, i, \tau \tag{1}$$

From each feature vector, we can compute the variation at each time step as $\delta_i^k(\tau) = a_i^k(\tau) - a_i^k(\tau - 1)$. Starting from such variations we can define a $4N \times 1$ time-delayed features vector $\mathbf{x}^k(\tau)$ as a concatenation of 4 time steps so that:

$$\mathbf{x}^k(\tau) = \left[\delta_i^k(\tau-3)|\delta_i^k(\tau-2)|\delta_i^k(\tau-1)|\delta_i^k(\tau)\right] \qquad \forall\ k, i, \tau \geq 4 \tag{2}$$

The vector $\mathbf{x}^k(\tau)$ can be used as input $\boldsymbol{u}$ for a classification system since it stores values proportional to an horizontal orthogonal projection of the time-dependent variations of temperature in the k-th person body. In facts, due to the body symmetry, and the top-bottom mechanism of the physiological actions on blood pressure and supply from the sympathetic and parasympathetic nervous system, we are interested to the distribution of temperature along the vertical axis. In order to classify these features we can use a radial basis function neural network (RBFNN).

2.2 RBF-based classifier

For the purpose of stress level classification from thermal images, it is possible to implement a dedicated system based on Radial Basis Function Neural Networks (RBFNN). The said network has a topology similar to common four-layer Feed Forward Neural Networks (FFNN), with a Radial Basis Function (RBF) used for its first hidden layer and a purely linear activation function on his its second hidden layer. This kind of neural architecture can generate a model of the latent features [13] for which there is a non explicit correlation to an high level of stress or anxiety. If we name ρ the chosen RBF activation function, then the new output of the first hidden layer for the j-esime neurone will be

$$\mathbf{x}_j^{(1)} = \rho\left(\frac{||\mathbf{u} - \mathbf{C}_j^{(1)}||}{\beta}\right), \tag{3}$$

where $\boldsymbol{u}$ is the input vector, $\mathbf{C}_j^{(1)}$ the RBF distribution centroid for the j-th neuron, and β is a distribution shape control parameter.

The second hidden layer computes a weighted sums of values received from the preceding neurons. This second hidden layer is called summation layer with the output of the k-esime summation unit

$$\mathbf{x}_k^{(2)} = \sum_j W_{jk}\mathbf{x}_j^{(1)}, \tag{4}$$

where W_{jk} represents the weight matrix elements. Such a weight matrix is composed by a weight value for each connection from the j-esime pattern units to the k-esime summation unit. The output layer fulfils the nonlinear mapping for classification. In fact, the first hidden layer of the RBPNN is responsible for the fundamental task expected (see [21] for more details). The number of the summation units in the second hidden layer is equal to the number of output units, these should match the number of classes we are interested in to have the inputs classified. In this application we make use of 3 classes to represent the absence of stress as well as a mild or strong stress condition. It is then possible to obtain psychological status evaluation $s^k(\tau) \in \{0, 1, 2\}$ correlated to the level of stress and corresponding to the classification of the RBFNN.

2.3 Robotic device

In our scenario each person sit on a fixed spot, therefore it is possible to assign a geometrical location $L(k)$ to each person k in the set of people K. It follows that we can obtain a statistical distribution of the estimated level of stress both as a global distribution $S(\tau)$ for each person in the room, and as many as possible local distributions $S_l(\tau)$ so that

$$S(\tau) = \frac{1}{|K|}\sum_{k=1}^{|K|} s_k(\tau) \qquad S_l(\tau) = \frac{1}{|\Lambda_l|}\sum_{k\in\Lambda_l} s_k(\tau) \qquad K = \bigcup_l \Lambda_l \tag{5}$$

where Λ_l is the set of people k that belongs to the l-th location. It follows that, given two threshold σ_m (to identify a mild stress level) and σ_h (to identify high stress levels) we can drive the robot to diffuse different aromas in different locations l of the room when $S_l(\tau) > \sigma_m$ or $S_l(\tau) > \sigma_h$.

3 Conclusion

The devised decision system, based on thermal imagery and Radial Basis Function Nerual Networks, seems promising for the development of a robotic aroma diffusion devices to be deployed in closed environments that resembles the aspect and design of a waiting room with several chairs where people sit and wait. Since the robot can be remotely driven by means of an artificial intelligence it could release aromas in the air only when and when it is needed, therefore only when the stress or anxiety levels are arising in the room or in a smaller portion of it. The system is prone to future improvements such as the refinement of the classification process also by means of accurate psychometric studies that could be based on well known tests (e.g. MASLAC [12], OSI [15], MSP [8]) or by means of a mixture of them, and possibly supported by a cloud-based solution for standardization and testing (e.g. [10]).

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