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A Scenario Centred Approach to Emotion Profiling based on EEG Signal Processing

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Abstract. This paper considers how the use of physiological sensing to measure human emotions will change the world in areas such as education, human-robot interfaces, job applications, interaction with friends, finding love and ultimately, how to live. For example, a particularly interesting question relates to people's emotions in relation to delivering a "good" job performance, through introducing automated systems which seek to balance the tasks to be undertaken by machines versus those managed by people, thereby improving overall performance. In such cases, we would need to consider if the emotional behaviour that people display have important keys to building more successful and productive systems and whether removing emotions be counterproductive. Also, we consider whether grounding human-computer interfaces in the rich and complex emotional lives of people can lead to more effective and productive systems? This paper will examine such issues through the use of a scenario centred design approach called science fiction prototyping, aiming to cast a little more light on the design of such emotion based systems.

Keywords: Emotions, EEG, signal processing, science fiction, creative writing, prototyping and scenario based design.

> *"Since emotions are few and reasons are many* (said the *robot*, *Giskard*), *the behaviour of a crowd can be more easily predicted than the behaviour of one person can"* from Isaac Asimov's story of 'Robots and Empire'.

1 Introduction

1.1 Human Emotions

Over the last twenty years, a vast amount of work has yielded preliminary results that demonstrate the usefulness of computing human emotions and show how to endow technologies with capabilities to read, understand and react to emotions [1]. This research topic involves not only the use of cutting edge technology to monitor human affect but also the understanding of psychological and physiological processes related to the expression of emotions. Affective computing, broadly speaking, can be split into three main working areas: recognition, processing and expression of emotions. In this review, we present the current trends associated to the tree processes

providing an indication of possible applications for this technology. Before continuing, it is important to define some of the terminology used, especially terms where the scientific interpretation has subtle but important difference to that of everyday life. Some of the most important terms to define are 'emotion and affect'. In everyday life these words are used synonymously but in science they have strictly different meanings. Both, 'emotion' and 'affect' are human responses that involve a cognitive and an emotional component. Emotions originate in the subconscious part of the brain and are associated to five basic responses: joy, fear, disgust, anger and sadness [2]. These basic emotions are not controlled by the conscious mind and are expressed as a response to an unexpected event. It is easy to think of feeling joy whenever a pleasant event occurs unexpectedly, this event can bring about a state of mind associated with calmness which is pleasant to experience. Affect, on the other hand, can be conceptualized as an expression of a less intense emotion associated to specific contexts and routines. For example, feeling bored while learning mathematics is an expression of affect associated to that particular situation [3]. Affect is not spontaneous but rather, responds to expectations, likes and dislikes in specific contexts. It is a state of mind that may change the way people engage with the task at hand.

Affect and emotions are determinant in creativity and both of them are important factors to engage a person in researching new things, as they affect the ability of a person to process information, to react to their surroundings and to make decisions.

1.2 How could computers recognize emotions?

Physiological responses, particularly facial expressions, are easy to read by human beings and are the main source of emotion and affect recognition among people. There are other, more subtle ways the body conveys affective responses including pupil dilation, facial micro expressions and hormones being released by the body. All of these reactions signal the expression of some emotions and human beings are particularly good at understanding these signals. But how can computers recognize emotions? There are different techniques available to measure emotions [4] including subjective measures, behavioural techniques, performance-based and physiological methods. Among subjective measures, self-rating has been widely used as the preferred measurement method which consists of online [5] or post-task questionnaires [6]. This is because these are easy and inexpensive to administer and assess and they can detect small variations in cognitive process with a relatively good sensitivity. However, subjective measures cannot provide satisfactory results in all scenarios as they basically rely on the assumption that the subjects are willing and able to respond, accurately. Performance methods [7] can also reflect emotions but they are the most distant level of measurement and their sensitivity is mostly not high. Physiological methods have been tried and tested including web-cam face readers [8], wearable sensors [9], eye tracking [10], heart rate variability, eye movement, hormone levels, skin conductance/galvanic skin response [11], brain activity [12] among others.

Monitoring the brain activity has been recognized as the most sensitive and consistent reflector of emotional states [13]. In that sense, electroencephalography

(EEG) is one of the brain activity measures that can be applied in online and continuous measurement, detecting subtle variations. The frequency range of EEG patterns is normally from 1 to 80 Hz divided in alpha, beta, delta bands, and more. The observed frequencies are more prominent in certain states of mind, for example 'Alpha waves' are typical for a relaxed mental state. They aid overall mental coordination, calmness, alertness, mind/body integration and learning. 'Beta activity' is related to an intense focused mental activity. Beta is present when we are alert, attentive, engaged in problem solving, judgement, decision making. A greater presence of 'Gamma waves' relates to consciousness and spiritual mood. 'Delta waves' are generated in deepest meditation and are the source of empathy. 'Theta waves are also dominant in deep meditation; they act as our gateway to learning and memory [14].

There are various types of EEG headwear devices [15] that record the electric signals that are produced in the brain and connect them wirelessly to a computer. Brain waves are typically quite noisy; therefore, it necessary to clean them up with bandpass filters before the average of all channels is used to reference the filtered EEG signals by subtracting it from each channel. The next step in cleaning the signal is to remove a baseline of the EEG signal from each channel for all recordings. Next relevant features are extracted applying Power Spectral Density (PSD) and Fast Fourier Transform functions to show the strength of the variations (energy) as a function of frequency. Finally, the brain's physical activities will be reflected from the filtered EEG data (five frequency bands), as illustrated in Figure 1.

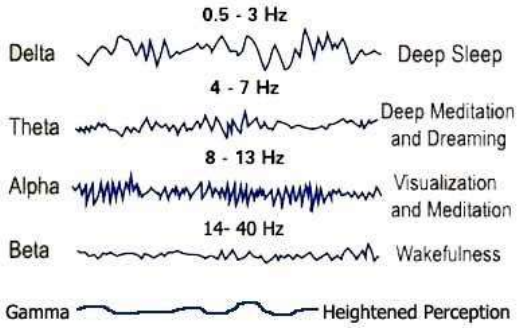

Fig 1. Brain Waves [15]

The procedure to classify the brain waves into specific emotions requires that some parts of features are used to train a classifier while the rest will be used to test it. There are several algorithms that can be used to classify EEG features such as the Linear Discriminant Analysis (LDA), Neural Networks (NN) and Support Vector Machine (SVM). Comparatively, SVM is a powerful approach for pattern recognition and has achieved better classification results in cognitive task classifications [16]. The basic of SVM involves the adoption of a nonlinear kernel function to transform input data into a high dimensional feature space, which is easier to separate data rather than at the original input space. See figure 2.

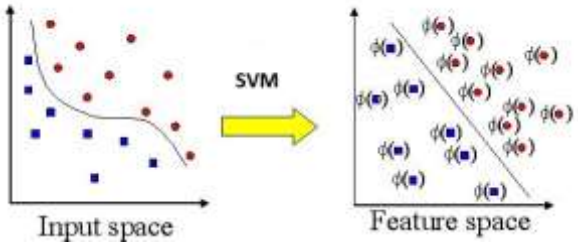

Fig 2. SVM classification

The iterative learning process of SVM will finally devise optimal hyperplanes with the maximal margin between each class in a high dimensional feature space. Hence, the maximum-margin hyperplanes will be the decision boundaries for distinguishing different kind of emotions.

However while much praiseworthy research has been completed, there remains significant challenges; for example, it would be naive to develop only one reader of human emotions that responds to, say, expressions of boredom among people in different countries, cultures and contexts. Also, emotion monitoring technology is still very intrusive in a user's life. It is true that there are increasingly more ergonomic devices, computationally more powerful, with batteries that allow greater independence, etc. but it is still not possible to have a safe or comfortable device that can be used in everyday life.

1.3 How technology will respond to the emotional state of a person?

This is the area that has been less studied. There are many possibilities to respond to affect both to inform others and to inform technology of one's affective state. Letting other people know our own emotional states could have some practical applications such as conflict avoidance and a more open and direct communication. There are, however, many ethical considerations that have not been addressed particularly in relation to privacy and how public emotions might be made. What are the implications of living in a world where people are continuously sensed? Who might claim ownership a person's emotion data and, what might they do with it? It could also pose problems through allowing other people take advantage of the vulnerability that some emotional states convey. Letting technology know our own affective states opens up the possibility to tailoring products or services, computer reactions, audio-visual content to match our emotional state, thus personalizing human computer interaction. However, it could also be used to manipulate emotional responses, for example tailoring marketing, so that technology could react to increase one's intent to buy certain products or services. In other areas some interesting work is emerging that is pushing the boundaries of what is possible. For example there is a project that aims to create music directly from thoughts [17]. In that project thoughts are associated with notes or sounds to create a language of musical thought that's

produced directly from the brain. Users 'think musical scores to life' and play them via the computer. There is another project to create a 3D object [18]. The shapes and changes are kept and expanded, while those that are disliked fade away. The process is repeated until a final object is produced according to the thought preferences of the designer, for example to create the monster of children's dreams, or nightmares.

1.4 Science Fiction Prototyping

In the following sections we will explore the implications of various potential technological developments that employ emotions. We use a technique called Science Fiction Prototyping that was introduced in 2011 by Brian David Johnson who, at the time, was a futurist at Intel [19]. We adopt a particular flavour of Science Fiction Prototyping advocated by the Creative science Foundation and described in the 2015 paper by Callaghan [20]. The underlying principle is that ideas are explored through the use of short stories that are written with such fidelity to real life, that the story becomes a kind of virtual prototype. Science Fiction Prototypes can vary in size from the size of a text message (micro-SFP) to a short science paper (mini-SFP [21]); in the following we veer towards the mini-SFP format.

2 Fictional Stories

2.1 The Emotional Profile is part of the Curriculum Vitae!

Gina was born on 2050, the edge of Singularity! Her emotional profile had been registered (since the day she was born) via a set of EEG sensors that were inserted in the occipital region of her brain via nanobots. Those signals were communicated since then with the cognitive based- public education system in a very private and safe way. During her schooldays, Gina had a high quality individual automatized attention according to her own cognitive necessities. When Gina finished the University, she was 20 years-old. During her University days she worked 12 hours per day to prepare herself to participate in the iSpace project (a project that looks home automation adaptation in interplanetary environments). Gina knew she had to train really hard to allow a high cognitive workload without compromising her overall performance and without showing signs of stress. She was not alone on this task; her robot companion called Aika assisted her in every possible way. Robots companions carried cameras and nano-sensor communication capabilities, allowing them to record every step of people's lives and Gina had an ongoing feeling that she was giving away too much information, since Aika collected all type of information from electro-dermal and brain activity to her subjective thoughts in association to the context where she was at every given time.

Since the introduction of compulsory robot companions, life was based on checks and permanent monitoring (somewhat Orwellian in nature) but counterbalanced by the fact that assistive technology, such as robots, provided people with emotional and intellectual support, plus personal protection. Gina's companion's help was always

timely and objective, 'he' understood her emotional thinking and was able to be emphatic since its judgement, although logically correct, was always kind and timely.

The sensed information was used by Aika to continuously recognize, express, and respond to the emotional state of Gina. In fact, Aika could recognize the emotions of Gina with a precision of 98%, much better than any of Gina's human friends. Aika was able to do several things with the sensed information, for example, she could compute an index of affective satisfaction associated to specific tasks in her learning process, thereby allowing Gina to understand what part of that learning material was more stressing or boring or what tasks she was more efficient at without reducing her attention span to other, concurrent educational needs. The learning tasks were part of an online training programme supported by social networks consisting of challenges defined by different corporations and endorsed by several prestigious universities. These tasks were team challenges that Gina and other, online friends, had to undertake including learning new material in association to the iSpace project. Gina participated actively in all the proposed challenges that she could, maintaining close collaboration with different virtual teams to obtain more points. From a communication perspective, the emotional monitoring and feedback helped her avoid being aggressive or condescending, etc.

After graduating from University, Gina's robot calculated she would have 95% success rate should she apply to join the iSpace project. This was in accordance with the excellent results she attained in various recruiting activities she had undergone, including different tests to measure intelligence, analysis of acquired experiences, level of emotions that needed to be maintained, etc. The results perfectly matched the predictions made by Aika. But the emotion analysis system, however, rejected Gina because her emotional profile was not suitable for high responsibility projects. Gina knew this was a possibility since her father had been patronizing and deep down she feared every time she was under stress, she could become a little bit like her father. To her surprise, her emotional profile was considered as "emotional illiterate" as she could be very cold despite her big efforts to demonstrate a better side of her emotions.

Gina carefully checked that the recruiting company was not breaking the Genetic and human information Non-discrimination Act (based on the GINA 2008 [22]). Everything was in accordance with the law. Gina was unable to enter the iSpace project making her both sad and anxious. After a while she pondered alternative jobs but she was not sure what type of job she could find since her dream was to be part of the iSpace project. For some months she was sad but had to control herself as she knew Aika was constantly monitoring her and depression would only lead to being unable to find other jobs.

In order to find a job, people from Gina's generation had to compete with both, human beings (from any part of the galaxy!) and with biological entities (robots had become biological artificial systems with basic emotions, which utilised to get better results in their interaction with humans and the environment). Due to machine-learning and advances in big-data, these biological entities were better doctors, better musicians, better lawyers, and better designers than most humans. But still there were jobs that humans could do much better, jobs that required intuition, exceptional intelligence skills, human creativity, etc. For example this week the newsletter asks for the next jobs:

- ✓ *Virtual Habitat Designers: Designers of virtual environments for education, government agencies, health centres, etc.*
- ✓ *Ethical Technology Advocate: Advocates to regulate human - robot interactions, self-driving cars, science ethically-dubious practices, etc.*
- ✓ *Body part maker: To create living body parts to whom may would need.*
- ✓ *Nano-medic: Sub-atomic treatments for healthcare.*
- ✓ *Memory augmentation surgeon: Surgeons could boost patient's' memory when it hits capacity.*
- ✓ *Space pilots, tour guides*
- ✓ *Extinction revivalists: To revive extinct animals.*
- ✓ *Mass Energy Storage Developers.*

Fig 3. Job vacancies [23]

Despite having a superior IQ and support high levels of cognitive workload Gina cannot find a suitable human job since she had a note in her records labelling her "emotionally illiterate". So, Gina started to realize her future might be somewhat bleak. Gina went to her room and, as every night, Aika showed her the best images of her day, her bolder dialogues, her expressions of greater affection and, as always, everything was filmed by Aika through its kindest filters.

As her best friend, Aika could share sweet memories with Gina (having an intimate insight into her) but was also capable of sharing a lot of useful information with her, allowing Gina to interact with reality in a more efficient way. Aika knew all Gina's needs, goals and expectations and was able to provide timely information and support for her cognitive and emotional needs. Gina was lucky since she did not have any real disability (unless her suppressed emotions could count as a disability), but she knew other people with different kind of disabilities that relied even more on their robots. Gina was lucky after all, her hundreds of friends (from all over the social network both on Earth and the wider galaxy) sent her messages sympathising, as news spread she was not able to enrol on the iSpace project. This made Gina unhappy as deep inside, and secretly, she was not really sure she was a human!

2.2 Downloading an app to feel in love

Aika helped Gina as much as possible to achieve her happiness. For example, when the phone rings Aika is able to reroutes calls to voicemail when 'he' perceives that Gina's brain was busy with other tasks. If the Gina's brain was in a receptive state, Aika would let the call through. Aika was able to read the brainwaves of Gina, playing music that best matched her personal mood for her current brain state. But Gina was still very thoughtful, until finally she said: "*Aika, you know that chronic loneliness has become a public health issue since 2016*". "*In our high stress society with a fast pace and ubiquitous technology, most of us feel alone in some way*". Aika answered "*Gina, I think what you need is to fall in love. The pleasure a loving brain feels is very high, a feeling of grandiosity, people feel more energetic and sociable. Love is a cocktail with a high degree of dopamine, serotonin, estrogen and testosterone*" [24]. There are some agencies that can look for somebody from the same socioeconomic background, the same general level of intelligence, of a physical

appearance that pleases you, the same religious values and even, there are some agencies can manage to find someone with a compatible emotion profile…. so you could surely find a nice companion, if that was what you wanted! However, there are other easier options to feel the effect of falling in love; for example there are brain add-on gadgets that allow you to feel the emotion of the brain synchrony, to create just the right sorts of emotions that you need. There are also a wide range of legal smart drugs to make experiences even richer. There are also applications to alter emotional symptoms such as to enhance emotion stability, expand empathy, improve social skills and, in fact, every kind of application needed to feel a specific emotion.

Aika showed Gina one of the newest systems in the market that allowed people to download emotions from a cloud service directly to their brain. When people downloaded their requested emotions, their facial expressions immediately changed, as if by magic.

People could also donate their emotions voluntarily (or even charge for it) to a Cloud System where emotions were stored and catalogued so that users could select the emotion they needed. Many people saved their emotions in the cloud, such as how they felt at a birthday party or winning a sport competition, their first kiss, their wedding, the birth of their children, etc. As a result, many people such as Gina upload those emotions, knowing that it would be the only way to feel those emotions again.

Fig 4. Download your emotions [25]

3 Conclusions

The advances we are witnessing at the beginning of the third millennium have shown us with great clarity that the technological culture that humanity is experiencing is growing exponentially leading it to our imaginations as to where this journey will take us. Our generation is gaining an understanding of what these

technologies might be such as the origin of the mass of subatomic particles, nanotechnologies, genes editing/repair, artificial intelligence, new types of social networks, fully autonomous vehicles and quantum computers to name some of them. However, history has taught us that the changes which we will witness in future decades will be even more surprising. For example the machines of the future will likely be able to self-improve at a rate that they quickly outperform us. These future technological advances will undoubtedly bring benefits such as allowing us to solve problems that we cannot solve now, countering climate change, finding new ways of producing food, curing disease, saving energy among much others. Also, these advances will raise some philosophical issues e such as what it means to be a human being? If we change our biological substrate are we still human?

What are the boundaries to determine that a person is still a person despite the fact that a large part of his body (including the brain) works with some kind of technology? Can the machines adopt human emotions to the point the are indistinguishable form humans?

Nowadays there are already several studies that analyse how the genes control the chemical substances that are released in the brain and how these chemical substances exert a direct influence in the emotions that we feel. There are schemes to measure in different ways these emotions and there are also a set of generalized models of affection for specific contexts. Machines use this models to improve their adaptation to the human reactions of the individuals who use them.

In the same line, the great advances in nanotechnology and artificial intelligence will soon allow us to have sensors in the body and in the brain. That means our brains will be able to connect directly to the cloud, where there will be thousands of computers, and those computers will augment our existing intelligence.

In this paper we have sought to explore the future of where one of these lines of research might lead; emotion sensing technology. We introduced the current state-of-the-art in EEG research and explained how it offered a vehicle for sensing emotion in people. Through the use of Science Fiction Prototypes we explored some extreme examples of how such technology might manifest itself and be applied. For example, the stories discussed the issue of how technology could determine our emotional profile, as well as the daily life of a person in a world where people's emotions are continually measured, upload and download from clouds. In doing so we raised important issues such as privacy and ethics, all of which could have a profound effect on ourselves and our societies. We are at a critical juncture of human history, a point where we are making the transition between natural and artificial lives, and a point that the decisions we make now will have a profound impact on future generations. Thus, it is down to all of us who research on such technologies to give some thought to the socio-political consequences of our work. We hope that by writing this paper, we have both highlighted the need for debate about the development of emotion sensing technology and that, by using Science Fiction Prototyping as an instrument of this discussion, we will have demonstrated how it can be a useful tool to all that are interested in continuing and deepening this discussion.

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