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Determining Anxiety in Obsessive Compulsive Disorder through Behavioural Clustering and Variations in Repetition Intensity

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ABSTRACT

Background and objectives: Over the last decade, the application of computer vision techniques to the analysis of behavioural patterns has seen a considerable increase in research interest. One such interesting and recent application is the visual behavioural analysis of mental disorders. Despite the very recent surge in interest in this area, relatively little has been done thus far to assist individuals living with Obsessive Compulsive Disorder. The work proposed herein represents a proof of concept system designed to demonstrate the efficacy of such an approach, from the computational perspective. The specific focus of this work lies in demonstrating a mechanism for clustering different kinds of Obsessive Compulsive Disorder behaviours and then comparing new behaviours to existing behaviours to determine the approximate level of anxiety represented by a compulsive behaviour.

Methods: The proposed system uses Temporal Motion Heat Maps, SURF descriptors, a visual bag of words model and SVM-based classification to categorise representations of various behaviours commonly seen in OCD. Moreover, we apply a set of statistical measures to the images in a given category in order to derive an approximate anxiety level for a given compulsive behaviour. This proof of concept is an essential step in the direction of integrating computational approaches into the treatment of psychiatric conditions such as Obsessive Compulsive Disorder, for more effective recovery.

Results: Results gleaned from experimental simulations indicate that the proposed system is capable of correctly classifying different types of simulated Obsessive Compulsive Disorder behaviour classes 75% of the time, with the misclassifications almost exclusively occurring when two behavioural clusters appear highly similar. Based on this information the proposed system is then able to assign an approximate behavioural anxiety level to the compulsive behaviours that meets the approval of a mental health professional.

Conclusions: The proposed system demonstrates a good ability to categorise various types of simulated OCD behaviour, in addition to establishing an approximate anxiety level for a given compulsive behaviour. This research demonstrates strong potential for the use of such systems in assisting mental health professionals looking to better understand their patients' condition and treatment progress across time.

1. Introduction

Computer-vision-based behaviour analysis and classification is a topic that has been of interest to researchers for some time now [1–8]. Much of this interest stems from the wide variety of applications available to researchers studying the topic, from crowd analysis [9], to security-based surveillance and anomaly detection [10,11], to gait recognition [12,13], assisted living [14,15], emotion recognition [16] and more recently, mental health applications [17,18]. Arguably one of the most valuable applications of late, computer-vision-based mental health analysis has relied upon increases in computing power and algorithmic sophistication that have only relatively recently allowed researchers to discern the subtle behavioural cues that can be observed in everything from stress [19] to depression [20,21], dementia [22], bipolar disorder [23] and Autism Spectrum Disorder (ASD) [24]. Despite this keen interest, little has been done to exploit the naturally visible behavioural compulsions evident in Obsessive Compulsive Disorder (OCD). As these behavioural manifestations are related to the level of anxiety that an individual is experiencing at a given time we see strong potential in such research regarding its value to mental

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health professionals in more deeply understanding their patients' needs [25].

Conventional approaches to treating and understanding patients with OCD have tended to focus on a combination of therapeutic interventions, such as Cognitive Behavioural Therapy (CBT), and self-report measures. While such approaches have been demonstrated to be quite successful, they nevertheless entail multiple drawbacks. Arguably chief among these drawbacks is the fact that patient feedback relies on human memory, which is not only highly subjective, but is also known to be highly volatile [26,27]. Conversely, the aim of the proposed system is to provide a proof-of-concept for analysing the behavioural compulsions typical of OCD in an objective manner with a view to the future application of such systems by mental health professionals to not only better understand their patients' individual compulsions, but also better understand the nature of the physical signs of the condition in greater depth. The proposed system aims to substantiate this approach by grouping different physical compulsions together based on their visual similarity and then ascribing an approximate anxiety level to each behaviour in turn, based on the intensity of its visual repetitiveness. Through this new method of visually analysing and understanding OCD compulsions and their related anxiety, we believe that the proposed system demonstrates the viability of computer vision based OCD monitoring to aid mental health professionals in improving their understanding and treatment of their individual OCD patients.

Traditional applications of visual behavioural analysis have focused on a wide-variety of behaviours, with many of these being common human behaviours for such applications as surveillance, workplace ergonomics, assisted living, detecting emotional states, and even driver vigilance [28–33]. However, only relatively recently has the analysis of abnormal behaviours characteristic of mental disorders become a topic of considerable research interest. Of this body of research, the primary focus has been on both the detection and analysis of behaviours characteristic of specific disorders. Much of this research has been driven by an attempt to understand the current progress and severity of the disorder, as well as to assist mental health professionals in early diagnosis or determining the most effective treatment strategies.

For example, MADRIM, proposed by Mugica et al. was designed to monitor patients with Major Depressive Disorder and analyse their progress during treatment [34]. In a similar vein, Joshi et al. proposed a system for the visual analysis of behavioural cues in individuals with depression, based on upper body movements and intra-facial muscle movements [35]. Additionally, Goodwin et al. used accelerometers and pattern recognition techniques to detect behaviours typical of individuals with ASD [36]. Amor et al. proposed a system for analysing individuals with Bipolar Disorder using Personalised Ambient Monitoring [23]. Finally, multiple computer-vision based approaches have been proposed to address the increasing burden of dementia, most notably Alzheimer's Disease [37,38]. Despite this notable interest in psychiatric interventions, no research that we have encountered has focused specifically on OCD and its associated anxiety-driven physical compulsions. Furthermore, no research has focused on using visual compulsion detection and analysis to produce anxiety ratings, which could be of great value to mental health professionals. These points are what the research presented herein is designed to address.

In total, the proposed system comprises the following contributions:

- **Demonstrated a method capable of classifying different patterns of simulated compulsive behaviour:** As part of the proposed system, we herein demonstrate a method that is capable of accurately clustering similar compulsive behaviours that are typical of OCD. This is achieved by deriving SURF descriptors from Temporal Motion Heat Maps (Temporal Motion Heat Maps) of compulsive behaviour from our prior research. The SURF descriptors are then used to classify various labelled instances of simulated compulsive behaviour using n-fold cross-validation. This results in a robust system that is scale and translation invariant and requires only a basic set of manually labelled behaviour instances to be trained.
- **Presented a useful method of establishing the relative anxiety of various compulsive behaviours:** We have provided a method that could, for example, be used by mental health professionals to quickly and easily view the relative anxiety one of their patient's compulsions. While the current system is a proof of concept, we see this research as demonstrating a strong potential for such future applications. We achieved this by producing a baseline average (mean) for each compulsive TMHM in a given behaviour cluster and then used this to compare each example of behaviour to the baseline for that cluster. This demonstrates the viability of such an approach to comparing compulsive behaviours, both across time and within a given time period, to determine whether any given example of compulsive behaviour is more or less anxiety-driven than usual for an individual.

The remainder of this paper is organised as follows: Section 2 presents the material that the reader will need to understand the content in subsequent sections. Section 3 provides an in-depth explanation of the proposed system and its components. Section 4 explains how the experiments were set up and executed as well as the parameters that were used. Section 5 presents the results from our experiments and discusses their implications for the utility of the proposed system. Section 6 provides a brief discussion of the pertinent literature and Section 7 recapitulates our findings, as well as the limitations and benefits of the proposed system, before briefly mentioning future research that we plan to undertake.

2. Background

This section provides a brief overview of the foundational material that is needed to understand the information in subsequent sections. It includes a Section 2.1 describing SURF descriptors and how they have been integrated with the proposed system in order to provide robust compulsive behaviour classification.

2.1. SURF descriptors

Speeded-up Robust Features (SURF) is a scale and rotation-invariant feature detector and descriptor, which is designed to be highly robust and efficient [39]. It achieves these goals via a simplified Hessian-based matrix measure. Thus, simply put, when an image is fed to SURF it will create a set of representative, orientation-invariant feature descriptors from the image, which can then be compared for similarity with other descriptors from other images. The efficiency and general orientation invariance of SURF make it highly useful when applied to certain problems in computer vision, including object recognition and tracking. The need for such an algorithm was to fill a void in the ability to detect individuals at different scales and slightly different positions during compulsive behaviours. For example, an individual may move closer to or further from the camera during the same compulsion performed at different times. By making the system scale invariant, it is better able to recognise similar behaviours regardless of scale, among other traits. This is why SURF was a valuable asset, as it is able to perform at a similar accuracy level to SIFT, but with more efficiency, thus making it apt for the proposed system. The formula