SenseCare: Using Automatic Emotional Analysis to Provide Effective Tools for Supporting Wellbeing

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Abstract— **Dementia has a severe impact on emotional functioning. People with dementia tend to find it difficult to recognize, articulate, and express their emotions. This can have a damaging effect on their mental health and the quality of their social relationships. With global populations increasingly aging, the need to address these issues becomes more prominent. One potential aid in tackling such problems is the use of sensor technologies and machine learning algorithms to make face-to-state analysis and classification of emotion status so as to provide care support. This paper describes the SenseCare system that uses affective computing methodology to capture, analyze, and store information on emotional outputs in the aim of providing effective tools for caregivers and medical professionals to provide more holistic care to people with dementia.**

Keywords— emotion, well-being, semantic data fusion, knowledge management and ecosystem portal, affective computing, dementia

I. Introduction

As our population increasingly ages, our society needs to be prepared for the challenges that come with older age [1]. One of the most pertinent challenges is managing dementia [2]. Dementia is a neurodegenerative disorder that damages various parts of the brain that are involved in cognition, memory, and emotion. Whilst it generally recognized that the cognitive damages done to people with dementia (PwD) is often severe, caregivers and family members often cite that the socio-emotional dysfunction caused by dementia as being the most impactful on their lives [3]. Dementia patients can struggle to recognize emotions in themselves and others, regulate and manage their emotional expression, and articulate their own emotion [4]. This can create multiple difficulties in the lives of people with dementia and their caregivers.

It is worth emphasizing the important role emotions play in human interaction in order to understand theconsequences of their dysfunction. Emotions are not only the qualitative feelings that a person consciously experiences, but also prepare people for action and act as social signals [5]. Emotions help people navigate the world successfully by alerting each person to potentially important stimuli [6], [7]. If the emotional centers in the brain are impaired, then the ability to make innocuous decisions – such as where to sit in a restaurant – also becomes impaired [8]. Such impairment can also cause people to experience extreme levels of emotions, which can be difficult to manage. People who experience such intense emotions and/or are unable to process their emotions are more likely to experience mental health issues [6]. Emotions are also important in the creation and maintenance of healthy relationships. People who honestly express emotions are more likely to be trusted, liked, and befriended than those who are unable to do so [9]. In regards to dementia, all these abilities are damaged. As a result, it is no coincidence that people with dementia tend to experience anxiety, depression, and a decline in the quality of their relationships [10]–[12].

Other factors affect the experience and expression of emotion. One of those is the personality of the person. Personality traits are typical patterns of affect, cognition, behavior, and motivation [13]–[15]. Personality traits are stable intra-personally but very inter-personally. Personality traits significantly predict several important life factors, such as the likelihood of experiencing particular forms of mental illnesses, the likelihood of developing certain forms of psychopathology, level ofgeneral well-being, and the quality and quantity of personal relationships [16]–[18]

Emotions are so intertwined with personality traits that it has been argued that the ultimate root of personality variation lies in the sensitivity of sub-cortical brain systems that underlie emotion [19]. For example, the personality trait Extraversion, which reflects how enthusiastic and assertive a person tends to be, seems to be underlined by the two brain systems that regulate positive emotion [15], [20]. It also has been argued that personality ultimately underlines emotion Under this view, personality acts as the structure of people's goal-oriented systems and emotions serve as indicators as to where the person is in relation to that goal (e.g. anger emerges as a result of a potential route to a goal being blocked). Regardless of which view is correct, it is clear that an understanding of emotions is incomplete without an understanding of personality and vice versa.

However, it is not clear how personality is affected by dementia. This is partially because the methods for personality analysis, self-report, are insufficient to those who experience sharp cognitive decline [3]. Therefore, there is a need for interventions that help manage the issues caused by emotional dysfunction whilst also offering insight into the changes dementia can cause to the long-term internal psychological configuration of the person. A system that can do both will provide a more holistic intervention that can be matched to the individuality of the person receiving care.

The field of affective computing offers promising solutions in aiding people with dementia with these issues. In recent years, there have been increasing developments in the use of emotion detection technology [21]. One example is the rise of face-to-state analysis. The SenseCare project uses a live-action camera to record the facial movements of people and then by using machine learning algorithms it can classify the emotion expressed by the person [22], [23]. This classification system is based on Paul Ekman's basic emotion theory. Ekman posited that there existed a universal set of emotions, rooted in the central nervous system, that were expressed in similar ways across cultures [24]. These basic features were coded by facial action units, which decodes emotions in terms of particular muscle movements on the face. Essentially, forming the *Facial Action Coding System* (FACS) [25]. The SenseCare project aims to automate the recognition of these basic emotional states, via facial expressions and other important behavioral, cognitive, and physiological signals. It then creates a data archive for researchers to access and is made available for healthcare professionals to use. The rest of this paper will discuss the details the infrastructure of the SenseCare System, its implementation, preliminary results, and plans for future fieldwork.

II. SENSECARE SYSTEM INFRANSTRUCTURE

The infrastructure of the SenseCare system is illustrated in Figure 1.

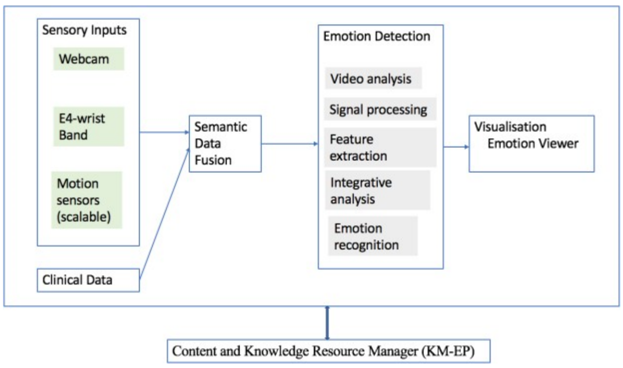

Figure 1 SenseCare System Infrastructure

A. *Inputs*

- A standard webcam either built into a laptop computer or an external device provides visual data for analysis.
- The Empatica E4: is a wearable sensor that is designed for the purposes of research and meets clinical standards [for more information, see: 26]. One of its main features is that it provides photoplethysmography (PPG). It also provides EDA analytics for galvanic skin response, autonomic arousal and excitement, sympathetic activation, an infrared skin temperature thermopile, and an accelerometer for movement data. It can be downloaded via the Empatica Manager for both Windows and Mac. The Empatica APA is suitable for the development of mobile, tablet, and PC apps.
- Passive Infrared Sensors (PIR) are used for the purposes of monitoring the movement of PwD in care settings. This provides information about the particular environment each person is and can be incorporated in order to provide a more contextually based emotion analysis.
- Clinical data are a vital aspect of providing holistic care. The data ranges from the stage of dementia each person is currently in, any conditions the person with dementia is experiencing, what medication each person is taking, and care notes that provide information about the particular needs each person needs in their care.
- Test Data: In the course of the SenseCare project, various test data sets have been produced to derive requirements and to test our solutions.The consortium partner INMARK has provided three video streams of persons engaging in discussions that are manually annotated with a set of six emotions (the positive and three negative emotions). The emotions have been recognized through psychologists and are manually annotated in an Excel file together with a timestamp of occurrence. FusionServer is an analysis software provided by Cork Institute of Technology This software fuse together emotion detection streams from various devices, as wristband and Video. Analyzed emotions are classified according to the seven emotion classes: *anger, sadness, fear, joy, surprise, disgust* and *contempt*. Each emotion is embedded in the sentiment (negative or positive) of the detected emotion, the intensity, and a timestamp. The results are summarized in Table 1 (for further information about this output, please contact one of the authors).

Table I. Timestamped Emotional Analysis

Positive			**Negative**		
Happiness	Interested	Enthusiasm	Bored	Angry	Frustrated
Focus Group: BA Capital					
00:50:30	00:21:00	02:00:40	00:35:12	01:10:15	01:48:20
01:32:00	00:40:30		00:41:10		
01:35:55	01:00:35		01:20:41		
	01:05:20		01:25:15		
	01:07:15		01:45:30		
			01:51:30		

B. *Semantic Data Fusion*

In SenseCare the process of delivering and fusion of user(s) cognitive/affective state takes place in personal caregiving environments and lasts for a considerable amount of time. During this, personal data will be generated: sensory data, clinical data, care plan/execution data, and communications. A sensor, in the broad sense, is defined "*a device that responds to a physical stimulus (as heat, light, sound, pressure, magnetism, or a particular motion) and transmits a resulting impulse (as for measurement or operating a control)*"[1]. In fact, from this definition, a broad range of available devices could act as a sensor. In SenseCare we will only apply these sensors that capture data of a person wellbeing in-home care scenarios (e.g. through video or physiological data) to analyze the emotional state of an observed person.

C. *Emotion Detection*

The Emotion Viewer analyses real-time video feed and uses machine learning to automatically classify emotion. The system takes video footage, either already existing or captured via a webcam. It also contains tools that can be edited on the fly for controlling misclassifications

D. *SenseCare KM-EP*

The KM-EP has been developed with the purpose of providing powerful tools for managing knowledge and content [27]. In each project, the KM-EP is extended to satisfy the unique requirements of the project. Following that same principle, the SenseCare KM-EP is developed on the KM-EP with new features and changes that support caregivers, medical professionals and researcher in this field in their works.

III. Implementation

A. *Emotion Viewer*

The Emotion Viewer has been developed to analyze real-time video and automatically classify emotions using a machine learning approach. The Emotion Viewer is designed as a webservice that allows users to stream video via a standard PC or laptop webcam. The users receive back an emotional classification via an HTML webpage format. Figure 2 illustrates the system's process of events from a high-level perspective.

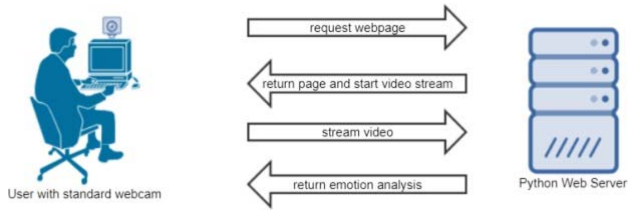

Figure 2 Sequence of Events in the Emotion Viewer

There are many different features which can be extracted from a human face to be used as parameters in machine learning algorithms. In order to analyze in real-time, it was necessary to leverage existing methods for extracting features of a human face. One of these methods is to use facial landmarks. Facial landmarks are defined as the detection and localization of certain key points on a human face. They are also known as vertices or anchor points. The Emotion Viewer uses the 68-point facial landmarks created by Multi- PIE [28].

The Multi-PIE mark-up, which is illustrated in Figure 3, is applied to both the training data and unseen data which also allowed the use of multiple training databases which do not use compatible mark-ups in their own annotations of the images. Using these facial landmarks, parameters were chosen to be the Euclidean distance from each point to every other point forming a mesh-like structure. Each line represents a parameter. Using this method with various existing facial expression databases, a model was created which can detect the six basic emotions.

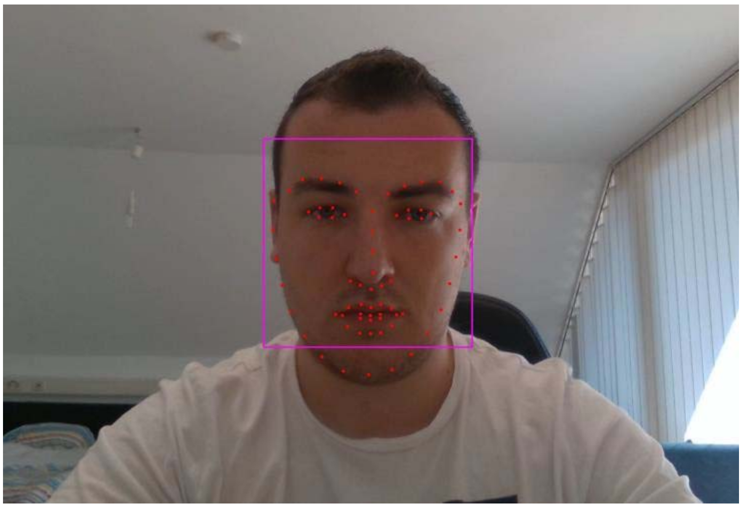

Figure 3 Illustration of 68-point Landmark Features Extracted by the Emotion Viewer

This model was then uploaded to our web service which outputs emotional classification for the video. A sample screenshot of the application can be seen in Figure 4 and a full review of the system and machine learning model can be found in this paper [28].

[1] http://www.merriam-webster.com/dictionary/sensor

Figure 4 Sample Output from Emotion Video

B. Semantic Data Fusion

One of the primary aims of SenseCare is the use of sensors to provide emotional analysis. However, importantly we expect to apply more than one sensor of a specific modality (e.g. video) or various sensors of different types (multimodal like video and physiological measurements) at a time to capture person wellbeing. Hence, the managed data within the SenseCare portal comes from distributed sources which are inherently of heterogeneous nature. To enable its comprehensive reuse in later access scenarios, it is required to enrich this data with further relevant information from associated databases and furthermore to convert it into a consistent and superordinate representation format. Commonly such processes are defined as *Data Fusion*. To enable broad subsequent processing, data exchange throughout system barriers and comprehensive knowledge management with managed data, the semantic data fusion will be realized by means of a semantic information integration process.

Having various semantic data fusion service instances deployed into a distributed server landscape leads directly to the challenge of data availability. This is because a service instance could be deployed on server 'A' and 'B', and, over time, e.g. through a load balancing event, automatically redeployment to a server 'C'. The availability of data in a distributed server environment, has been solved through the aggregation of server storage through GlusterFS[2], that in our case has been proved as a stable and powerful solution.

Ontologies in the semantic data fusion layer will be specified to build a global structure that enables semantically enrichment and fusion of all resources available in session control protocol and their interrelations. Therefore, the SenseCare Data Fusion Ontology (SDFO) has been developed consisting of three layers. The first layer (core) addresses all high-level healthcare related concepts as upper ontology. The Middle layer addresses concepts and interrelations of dementia care and connected health and serves domain-specific ontologies. Those ontologies do not serve all requirements from SenseCare, so that so-called domain adapters will refine the domain ontologies with respect to further concepts and interrelations required. This architecture is displayed in Figure 5. Readers are referred to [29] for a detailed description of the ontology implementation.

Figure 5 SenseCare Data Fusion Ontology Architecture

The SenseCare Data Fusion Layer applies a micro-service architecture, realized on a base of docker containers[3] that are managed in swarm mode[4]. This enables a decentralized service design, with services communicating through REST interfaces, effective cluster management including load balancing and easy service scaling. Figure 6 is a screenshot of a recent swarm deployment. In this deployment, all services are replicated (scaled) twice to ensure stable availability, distributed over three virtual machines to enable load balancing.

To this point in time, the Data Fusion is integrated into the Content and Knowledge Resource Manager (KM-EP) through a REST interface sharing the same authentication mechanism.

Figure 6 Recent Swarm Development of SenseCare System

[2] https://github.com/gluster/glusterfs

[3] https://www.docker.com/why-docker

[4] https://docs.docker.com/engine/swarm/

C. SenseCare KM-EP

The KM-EP is comprised of 5 subsystems and each of them has several components of its own. The Information Retrieval Subsystem (IRS) indexes contents and lets the user search for content using keywords, faceted search, and taxonomies. The Learning Management Subsystem (LMS) provides tools for authors and trainers to create e-learning courses using the contents in the KM-EP. The user can later register in these courses to obtain new knowledge. The Content and Knowledge Management Subsystem (CKMS) acts as a central repository for publications, multimedia, software, dialogs or medical records in the case of the SenseCare KM-EP. The authors use components in this subsystem to import, create, manage and classify their contents. The user can access these contents and rate their quality. The User Management Subsystem (UMS) manages all portal users and groups. Other systems can ask to authenticate KM-EP user's identity using OpenID Connect [5] integrated into this subsystem. The Storage Management Subsystem (SMS) provides storage for files and documents. They can either be stored in a local server or on the cloud for better access speed and availability. Figure 7 describes the core architecture of the KM-EP [30].

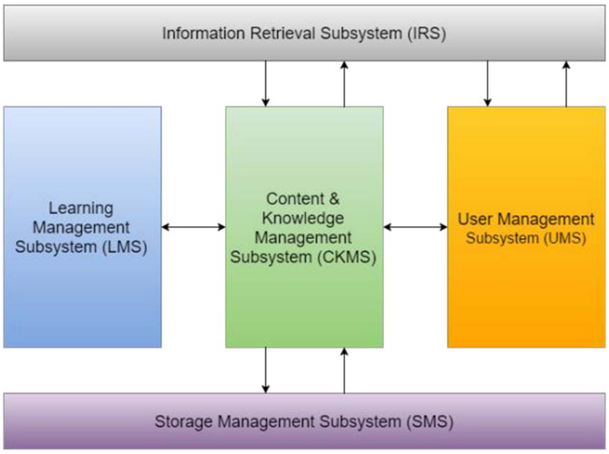

Figure 7 KM-EP's Core Architecture

The KM-EP is developed using the Symfony framework, one of the leading PHP frameworks supporting the creation of web applications[6]. On the front end, some frameworks and libraries, such as AngularJS, jQuery, Bootstrap3, are used to provide a seamless experience for the users.

IV. Preliminary Results

The SenseCare system is still under development. Currently, the Emotion Viewer has been developed. The SVM is implemented for emotion detection with an overall accuracy of ~88% [21]. System testing has been conducted using real-time videos, featuring political speeches from both Barack Obama and Donald Trump TV-shows, and TV-commercials. The emotion viewer classifies six basic emotions: anger, happiness, surprise, disgust, fear, sadness. A demonstration of the emotion viewer on each of the above videos can be found via the following link:

https://www.youtube.com/playlist?list=PLwagddoyFHYZOCeOVoTnM2UFYKhyMuwEJ

The semantic data fusion and the KM-EP have been implemented and integrated. This has led to the development of several content and knowledge management aids including:

- A Centralized digital library and media archive for content objects. The system functions as a digital library for publications and various media contents, such as presentations and recordings. This makes the contents more accessible. The system is also robust in that it prevents the loss of important materials if the provider is out of business or their server is down.
- Unified access rights: The system enables cross-organization access with the use of OpenID authentication. New systems users do not require separate accounts for separate organizations.
- Detailed metadata: Content is provided quicker and more efficiently through the use of the content object's meta-data.
- Simple faceted search with categorization: The system comes with a clear taxonomy of organization. The contents within the organization are categorized by author and experts. This enables more efficient content searching for users. (Further information on these is given in [30])

V. Summary and Future Work

Affective Computing has produced promising results in its ability to provide an automatic classification of emotions. The SenseCare system described above has pushed this technological capability to provide real-time analysis of video footage. The software has been created in a manner that allows it to be of use to healthcare professionals. This pushes the field closer to providing more effective care towards those who suffer from the impairments caused by dementia.

The next step in the refinement and development of this system is laboratory studies. Non-clinical members of the population will be recruited to take part in a two-part experiment. In the first part of the experiment, participants will be asked to fulfill an extensive personality questionnaire, which will break down their personality into 15 factors, composing of five major factors and ten subfactors. In the second part of the experiment, the participants will be invited to a laboratory setting where they will be exposed to a variety of standardized emotional stimuli in order to evoke the basic emotions they will do so in front of the SenseCare Intel camera whilst wearing the E4 wristband. The aim of this experiment is two-fold. First, to create a real-time video database for future research in order to improve emotion classification, reproducibility, and functionality for health-care professionals. Second, to gain a deeper health-care understanding of the relationship between personality traits and emotional experience and expression in order to understand the deeper causes of the psychological issues caused by dementia.

[5] https://openid.net/connect/

[6] https://symfony.com/what-is-symfony

ACKNOWLEDGMENT

This work is funded by the European Commission Horizon 2020 program through the SenseCare grant agreement number H2020-MSCA-RISE-690862. Authors would like to thank and acknowledge Dr. Haiying Wang and Dr. Raymond Bond from Ulster University, for providing useful discussion and feedback during the development of this paper.

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