CHAPTER ONE

INTRODUCTION

Mind reading is a way to detect or infer the other's mental states. The simplest way for mind reading can be done by simply seeing and understanding the facial expression. For example a smile can give us an expression of happiness. But now it may be possible that not only one human can understand other's mental states but also a computer might understand the mental states of a person. This paper describes the ways how a computer might infer the mental state of a person and thus becomes the mind reading computer. It emphasize on the ways by which a computer might infer the mental state, one method is by facial expression analysis (FEA) and the second one by using a futuristic headband. Mind reading computer infers the thoughts of a human being based on various technologies for example by scanning the facial expressions along with head gestures and by identifying the volume and oxygen level inside the blood which is flowing in the vicinity of the brain. With exponential development in the technologies we can say that in future we might have number of technologies that will lead into making the flawless mind reading computer.

The ability of mind reading by a computer can provides us many applications in the field of medical, crime and one's life also. The mind-reading computer system presents information about your mental state as easily as a keyboard and mouse present text and commands. Imagine a future where we are surrounded with mobile phones, cars and online services that can read our minds and react to our moods. How would that change our use of technology and our lives? We are working with a major car manufacturer to implement this system in cars to detect driver mental states such as drowsiness, distraction and anger. Current projects in Cambridge are considering further inputs such as body posture and gestures to improve the inference. We can then use the same models to control the animation of cartoon avatars. We are also looking at the use of mind-reading to support on-line shopping and learning systems. The mind-reading computer system may also be used to monitor and suggest improvements in human-human interaction. The Affective Computing Group at the MIT Media Laboratory is developing an emotional-social intelligence prosthesis that explores new technologies to augment and improve people's social interactions and communication skills. Mind reading technical machines was introduced and developed by Cambridge University, by gaining thoughts and ideas from various

fields like psychology, visions on computer those equipmentation is done with the data from psychology and vision of computers. It has the theory of mind reading We the people express all our thoughts, emotions, feelings, frustrations, mental condition through postures, gestures, facial expressions, vocal nuance and desires. These relations and feelings are true when we go ahead with the machines and interacting with them with the observation of those feelings also in occurrence with their internal hidden feelings over periods with the model **Dynamic Bayesian Networks.** People express their mental states, including emotions, thoughts, and desires, all the time through facial expressions, vocal nuances and gestures. This is true even when they are interacting with machines. Our mental states shape the decisions that we make, govern how we communicate with others, and affect our performance. The ability to attribute mental states to others from their behavior and to use that knowledge to guide our own actions and predict those of others is known as theory of mind or mind-reading.

Existing human-computer interfaces are mind-blind oblivious to the user's mental states and intentions. A computer may wait indefinitely for input from a user who is no longer there, or decide to do irrelevant tasks while a user is frantically working towards an imminent deadline.

As a result, existing computer technologies often frustrate the user, have little persuasive power and cannot initiate interactions with the user. Even if they do take the initiative, like the now retired Microsoft Paperclip, they are often misguided and irrelevant, and simply frustrate the user. With the increasing complexity of computer technologies and the ubiquity of mobile and wearable devices, there is a need for machines that are aware of the user's mental state and that adaptively respond to these mental states. Mind-reading or theory of mind is the terminology used in psychology to describe people's ability to attribute mental states to others from their behavior, and to use that knowledge to guide one's own actions and predict those of others. It is not, as the word is often used in colloquial English, a mystical form of telepathy or thought reading. The mental states that people can express and attribute to each other include affective states or emotions, cognitive states, intentions, beliefs and desires. An essential component of social intelligence, mind-reading enables us to determine the communicative intent of an interaction, take account of others' interests in conversation, empathize with the emotions of other people and persuade them to change their beliefs and actions. Besides social competence, mind-reading has a central role in the processes underlying decision-making, perception and memory. Recent findings in neuroscience show that emotions regulate and bias these processes

in a way that contributes positively to intelligent functioning. In decision-making, our own intentions, the social context and our appraisal of other people's mental states all affect the choices we make everyday. Indeed, the lack of emotional aptitude in people who have had traumatic brain injuries results in impaired reasoning. Consequently, there is an emerging consensus that emotions should be embedded within models of human reasoning.

This Mind reading encompasses our ability to attribute mental states to others, and is essential for operating in a complex social environment. The goal in building mind reading machines is to enable computer technologies to understand and react to people's emotions and mental states. This paper describes a system for the automated inference of cognitive mental states from observed facial expressions and head gestures in video. The system is based on a multilevel dynamic Bayesian network classifier which models cognitive mental states as a number of interacting facial and head displays. Experimental results yield an average recognition rate of 87.4% for 6 mental states groups: agreement, concentrating, and disagreement, interested, thinking and unsure. Real time performance, unobtrusiveness and lack of preprocessing make our system particularly suitable for User-independent human computer interaction.

CHAPTER TWO

LITERATURE REVIEW

MIND-READING

Mind-reading, theory of mind, or mentalizing, refers to the set of representational abilities that allow one to make inferences about others' mental states. In colloquial English, mind-reading is the act of "discerning, or appearing to discern, the thoughts of another person" or "guessing or knowing by intuition what somebody is thinking". Following the works of Baron-Cohen et al. and others such as Realo et al., this dissertation uses mind-reading in a scientific sense to denote the set of abilities that allow a person to infer others' mental states from nonverbal cues and observed behaviour. From the point of view of an observer who mind-reads, the input is an array of observations, such as visual, auditory and even tactile stimuli, as well as context cues; the output is a set of mental states that are attributed to others. The types of mental states that people exhibit and attribute to each other include emotions, cognitive states, intentions, beliefs, desires and focus of attention. Mind-reading is often referred to in the developmental psychology literature as a specific faculty, separable from more general cognitive abilities such as general intelligence and executive function.

Interest in the functions and mechanisms of this ability has become a central and compelling question for cognitive scientists in recent years. Since Premack and Woodruff and Dennett first stimulated the interest of cognitive scientists in mind-reading, numerous tasks, methods and theories have accumulated in the literature on this topic. Developmental and experimental studies, as in Goldman and Sirpada, investigate theoretical models of how people mind-read. Other studies examine the neural basis of mind-reading using brain-imaging technologies like functional Magnetic Resonance Imaging. Examples include the studies by Baron-Cohen et al, Fletcher et al. and Gallagher et al. The findings from the two classes of studies contribute to our understanding of how the cognitive skills that enable high-level social cognition are organized in the human brain, and the role they play in everyday functioning.

THE FUNCTIONS OF MIND-READING

While subtle and somewhat elusive, mind-reading is fundamental to the social functions we take for granted. It is an important component of a broader set of abilities referred to as social intelligence. Through mind-reading we are able to make sense of other people's behaviour and

predict their future actions. It also allows us to communicate effectively with other people. In addition, mind-reading has been described as a cognitive component of empathy [BWL+02, HPB98]. A good empathizer can immediately sense when an emotional change has occurred in someone, what the causes of this change might be, and what might make this person feel better. Mind-reading is also a powerful tool in persuasion and negotiation by realizing that people's thoughts and beliefs are shaped by the information to which they are exposed, it is possible to persuade them to change what they know or how they think. Mind-reading is also a key component of other processes such as perception, learning, attention, memory and decision-making. In their studies, LeDoux [LeD96], Damasio [Dam94] and Adolphs [Ado02] uncover the parts of the brain that are responsible for higher order processing of emotion. These studies and others, like that by Purves [PAF+01], have shown that these brain areas are interconnected to other brain structures that are involved in the selection and initiation of future behaviour. These findings emphasize the interplay of emotion and cognition, and have led to a new understanding of the human brain, in which it is no longer considered as a purely cognitive information processing system; instead it is seen as a system in which affective and cognitive functions are inextricably integrated with one another. The implications for user-modelling in human-computer interaction (HCI) are clear: an accurate model of the user would have to incorporate the affective as well as the cognitive processes that drive the user's reasoning and actions.

MIND-BLINDNESS

The ability to mind-read has been shown to develop during childhood. From as early as 18–30 months, children refer to a range of mental states including emotions, desires, beliefs, thoughts, dreams and pretence. By the age of five, most children can attribute many mental states to other people, and use them to predict even manipulate these people's actions. The lack of, or impairment in, the ability to reason about mental states is referred to as mind-blindness. Mind-blindness is thought to be the primary inhibitor of social and emotional intelligence in people with Autism Spectrum Disorders (ASD). Autism is a spectrum of neurodevelopmental conditions that is characterized by abnormalities in a triad of domains: social functioning, communication and repetitive behaviour/obsessive interests [Ass94]. The implications of being mind-blind include the inability to gauge the interest of others in conversation [FHF+95], withdrawal from

social contact [HMC01], insensitivity to social cues, indifference to others' opinions and inappropriate nonverbal communication
[HBCH99].

READING THE MIND IN THE FACE

MIND-READING MECHANISMS

Mind-reading involves two components that originate in different parts of the brain and develop at distinctive ages. These components may be impaired selectively across different populations of people [BWH+01, Sab04, TFS00]. The first component encompasses the **social-perceptual** component of mind-reading [TFS00], which involves detecting or decoding others' mental states based on immediately available, observable information. For example, one could attribute the mental state confused to a person given their facial expressions and/or tone of voice. As its name implies, this component involves perceptual, or bottom-up processing of facial or other stimuli. It also involves cognitive abilities, or top-down processing of abstract models that depict how people's behaviour generally map to corresponding mental states [CO00, PA03].

The second component is the **social-cognitive** component of mind-reading. This involves reasoning about mental states with the goal of explaining or predicting a person's actions. Examples include distinguishing jokes from lies, or predicting peoples' behaviour on the basis of false beliefs. False belief tasks test a person's understanding that other people's thoughts can be different from one another and from reality, and are the prototypical measure of the social-cognitive aspect of mind-reading [Fri01]. It is important to note that both the social-perceptual and the social-cognitive components of mind-reading are inherently uncertain—we are never 100% sure of a person's mental state. A person's mental state (John is thinking), and its content (what John is thinking about) are not directly available to an observer; instead they are inferred from observable behaviour and contextual information with varying degrees of certainty. Moreover, people often have expressions that reflect emotions or mental states that are different than their true feelings or thoughts. The discrepancy between expressed and true feelings, such as in lying and deception, can sometimes be identified from fleeting, subtle micro-expressions [Ekm92b]. The problem of identifying deception from facial expressions is beyond the scope of this dissertation.

READING THE MIND IN THE FACE

The research presented throughout this dissertation can be described as an attempt to automate the first of the two components of mind-reading. To gain a better understanding of this component, the various tasks have been devised to tap into social-perceptual understanding in people. These tasks test people's ability to recognize intentional, emotional or other person-related information such as personality traits, given perceptual stimuli like vocal expression [RBCW02], actions [PWS02] and facial expressions. Out of these cues, facial expressions have received the most attention.

Facial expressions are an important channel of nonverbal communication. They communicate a wide range of mental states, such as those in Figure 2.1, which shows the promotional material of actress Florence Lawrence (1890-1938). Besides conveying emotions, facial expressions act as social signals that enhance conversations and regulate turn-taking [EF78]. A face is comprised of permanent facial features that we perceive as components of the face such as the mouth, eyes and eyebrows, and transient features such as wrinkles and furrows. Facial muscles drive the motion and appearance of permanent facial features and produce transient wrinkles and furrows that we perceive as facial expressions. Head orientation, head gestures and eye gaze have also been acknowledged as significant cues in social-perceptual understanding. For example, Haidt et al. [HK99] show that gaze aversion, a controlled smile and a head turn are signals of embarrassment. Langton et al. [LWB00] emphasize the role of head orientation and eye gaze as an indicator of the focus of attention.

COMPUTATIONAL MODEL OF MIND-READING

The framework that I present for mental state recognition draws on the literature of mind-reading. Mind-reading, described in Chapter 2, is the ability to attribute a mental state to a person from the observed behaviour of that person. The theory of mind-reading describes a coherent framework of how people combine bottom-up perceptual processes with top-down reasoning to map low-level observable behaviour into high-level mental states. In bottom-up processing, facial expressions exhibit rich geometric and dynamic properties sufficient to select a corresponding mental state [EFA80, CBM+01, SC01]. In top-down reasoning, people utilize mental models that map observations of particular facial configurations to mental state labels

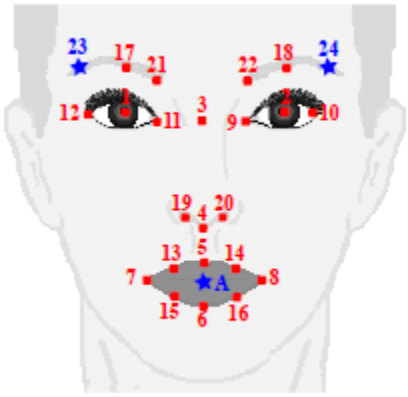
[PA03, GS05]. The theory of mind-reading also considers the uncertainty inherent in the process of reading other people's minds.

This uncertainty results from the stochastic nature of facial behaviour: people with the same mental state may exhibit different facial expressions, with varying intensities and durations. To simulate the process by which humans mind-read, a computational model of mind-reading would first have to build or "learn" mappings between mental state classes and patterns of facial behaviour as observed in video sequences. These mappings are then used during classification to infer the probability of an incoming video sequence being "caused" by each of the states.

FACE MODEL

A number of studies have shown that the visual properties of facial expressions can be described by the movement of points belonging to facial features [EF78, Bru86, PR00a]. These feature points are typically located on the eyes and eyebrows for the upper face, the lips and nose for the lower face. Figure 5.1 illustrates the 2D face model of the 25 feature points used throughout this work. By tracking these feature points over an image sequence and analyzing their displacements over multiple frames, a characteristic motion pattern for various action units (AUs) can be established. Cohn et al. [CZLK99] have shown that the results of automated extraction of AUs using methods based on feature point tracking match that of manual FACS coding [EF78].

Table 5.1 describes how the head AUs that are currently supported are measured. These are divided into different "sensing" channels based on rotation axis. Table 5.2 describes the facial AUs, which are grouped into lip, mouth and eyebrow sensors. Of the complete list of AUs in FACS, I have chosen those that were straightforward to identify and that, through observation, I deemed relevant to the mental states on which I chose to focus. As explained throughout the chapter, the measurements I describe for the lips and mouth AUs are more precise and more robust to rigid head motion compared to similar measurements that also use feature-point tracking. The table includes both additive and nonadditive facial AU combinations. In a nonadditive combination, the resulting facial action has a different appearance altogether than the individual AUs, and hence requires an analysis rule of its own. For instance, the combination of a lip corner pull (AU12) with the lips parted (AU25), has a different appearance from either AUs when occurring singly.



1. Right pupil
2. Left pupil
3. Nose root
4. Nose tip 16. Left lower lip
5. Upper lip center 17. Right eyebrow center
6. Lower lip center 18. Left eyebrow center
7. Right mouth corner 19. Right nostril
8. Left mouth corner 20. Left nostril
9. Left inner eye corner 21. Right inner eyebrow
10. Left outer eye corner 22. Left inner eyebrow
11. Right inner eye corner 23. Right outer eyebrow
12. Right outer eye corner 24. Left outer eyebrow

A. Anchor point

13. Right upper lip
14. Left upper lip
15. Right lower lip

CHAPTER THREE
METHODOLOGY/ARCHITECTURE

HOW MIND READING WORKS AND TECHNOLOGIES USED

The mind reading actually involves measuring the volume and oxygen level of the blood around the subject's brain, using technology called functional near-infrared spectroscopy (fNIRS). The user wears a sort of futuristic headband that sends light in that spectrum into the tissues of the head where it is absorbed by active, blood-filled tissues. The headband then measures how much light was not absorbed, letting the computer gauge the metabolic demands that the brain is making. The results are often compared to an MRI, but can be gathered with lightweight, non-invasive equipment. Wearing the fNIRS sensor, experimental subjects were asked to count the number of squares on a rotating onscreen cube and to perform other tasks. The subjects were then asked to rate the difficulty of the tasks, and their ratings agreed with the work intensity detected by the fNIRS system up to 83 percent of the time. "We don't know how specific we can be about identifying users' different emotional states," cautioned Sergio Fantini, a biomedical engineering professor at Tufts. "However, the particular area of the brain where the blood-flow change occurs should provide indications of the brain's metabolic changes and by extension workload, which could be a proxy for emotions like frustration." "Measuring mental workload, frustration and distraction is typically limited to qualitatively observing computer users or to administering surveys after completion of a task, potentially missing valuable insight into the users' changing experiences. A computer program which can read silently spoken words by analyzing nerve signals in our mouths and throats has been developed by NASA. Preliminary results show that using button-sized sensors, which attach under the chin and on the side of the Adam's apple, it is possible to pick up and recognize nerve signals and patterns from the tongue and vocal cords that correspond to specific words. "Biological signals arise when reading or speaking to oneself with or without actual lip or facial movement," says Chuck Jorgensen, a neuroengineer at NASA's Ames Research Center in Moffett Field, California, in charge of the research. Just the slightest movement in the voice box and tongue is all it needs to work, he says.

Electroencephalograph (EEG): Is a device used by medical researchers to pick up electrical currents from various parts of the brain.

Functional near-infrared spectroscopy (fNIRS): Technology which measures the volume and oxygen level of the blood around the subject's brain.

Futuristic headband: That sends light into the tissues of the head where it is absorbed by active, blood-filled tissues then it measures how much light was not absorbed.

FUTURISTIC HEADBAND

HOW DOES ITWORKS?

The system of it contains a headband that repeatedly send light emission to the tissues of the head where it is active ,the band first measures the oxygen and then measures the blood around the people's brain which uses a technology called as functional. The user who uses this mind reading system uses the band on head which has a futuristic Head Band Spectroscopy (fNIRS).

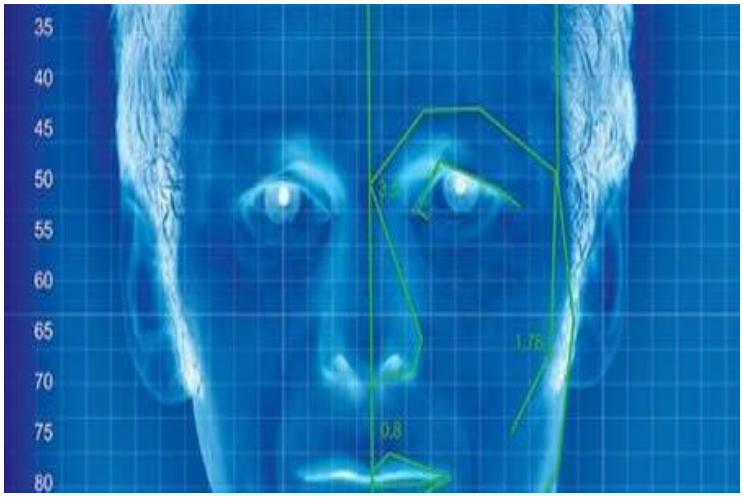
RESULTS CAN BE EVALUATED IN THE FOLLOWING WAY

By wearing the fNIRS head band which is of light weight which sensors the noninvasive experimental subjects of the equipments for that the users are asked to count the squares on the cube which displays on the screen and also to perform the other tasks. Observation have done and executed in NASA by silently reading the spoken words and analyzing the nerves in the

mouth of the user and the final results show on throats. Preliminary results are given by the throat measures. The measuring of all the stress factors is typically done in a computer program which can be measured by users. The stress factors include distractions, disruptions, perplexing and anger. “With or without the facial movements biological signals arise when reading or speaking”

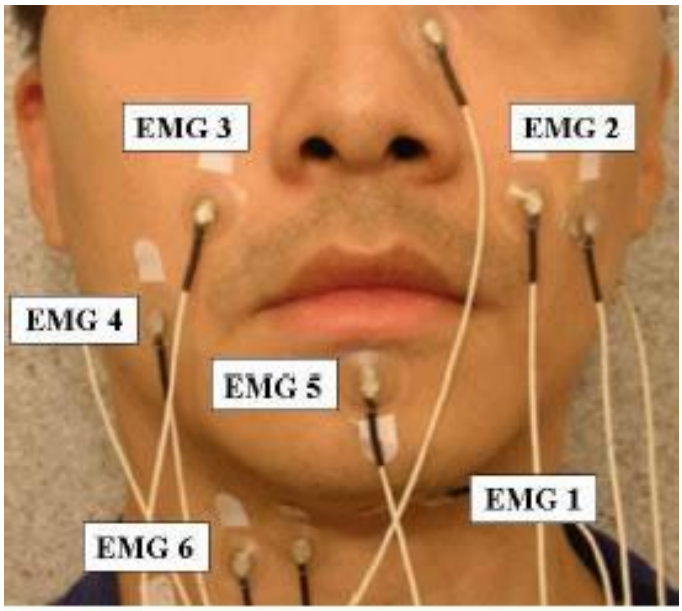
TECHNIQUES

Facial Affect Detection: It is done using hidden Markov Model, Neural Network processing or active appearance model.



Emotional Classification: Classification by Paul Ekman Anger, Fear, Happiness, Disgust, Sadness, Surprise.

Facial Electromyography: It is used to measure the electrical activity of the facial muscles. Muscles used are “corrugator supercilii muscle” and others.



Galvanic Skin Response: It is a measure of skin conductivity, which is dependent on how moist the skin is.

Blood Volume Pulse: it is measured by a process called photo plethysmography. It produces a graph indicating blood flow through the extremities.

MIND READING & NECESSITY OF MIND READING

Mind reading may be defined as the inferring of the human thoughts, emotions and desires etc. First simplest step of mind reading is by simply understanding the facial expression given by the person as people express their mental states mostly through facial expressions and gestures. No matter whether they are interacting or not. Our mental states shape the decisions that we make, make us react the way we react in a particular situation and thus affect our performance. All over our thoughts are the causes of all the things that are happening. Imagine what happened if we have a computer that can reads mind and after predicting the mental states , if there is any wrong intention possess by any person we can prevent it. And what happened if a wrong intention can be changed into good one by a computer. A computer that can reads and moulds the emotions into the required one, especially in case of a criminal; here no need for a stringent punishment rather a computer is required that can change the mind and hence make the better world than it is now. However, this technology by computer, to change the mind according to a desire is not established now. But in future it might be developed some day. So for all mind reading computer is just the basic step. Also consider a situation where we are surrounded with mobile phones, online services and cars and the all these systems can read our minds and react accordingly. It makes life so easy as by just thinking we can order our system to work accordingly. Moreover it becomes a boom for a physically handicapped person because he will able to drive a car, access online services and mobile phones just by thinking. All we can do is to give a mind reading machine that will be able to read mind by scanning the facial expression.

The mind reading computer system might also be used to monitor and suggest improvements in human-human interaction. The affective computing group at the MIT Media laboratory is developing emotional-social intelligence prosthesis that explores new technologies to improve people's social interactions and communication skills.

Thus mind reading is necessary for all this to make happened.

MIND READING COMPUTER

The team member of University of Cambridge had been working on a model of mind reading in a computer laboratory and has developed mind reading machines that implement a computational model of mind reading to infer mental states of human being from their facial expressions and head gestures.

The machine works by using digital video cameras which analyzes a person's facial expression in real time and infer person's underlying mental state such as thinking, confused, interested, bored, agreeing, disagreeing, happy, sad and angry.

Prior knowledge of how particular mental states are expressed by the facial expressions and head gestures and storing it in the database of the machine and then by matching to give the mental state. The model represents these at different granularities, storing with face and head movements and representing those in 3D space to form a clear model of which particular mental state is represented by which facial expressions and head gestures. Software from Navension identifies 22 feature points on the face and tracks them in real time. Movement, shape and color are the parameters which are then analyzed to identify gestures like a half closed eyes and open mouth. Combination of these occurring over real time indicates mental states. For example inner raise of eyebrows might indicate thinking.

FACIAL ACTION UNIT ANALYSIS

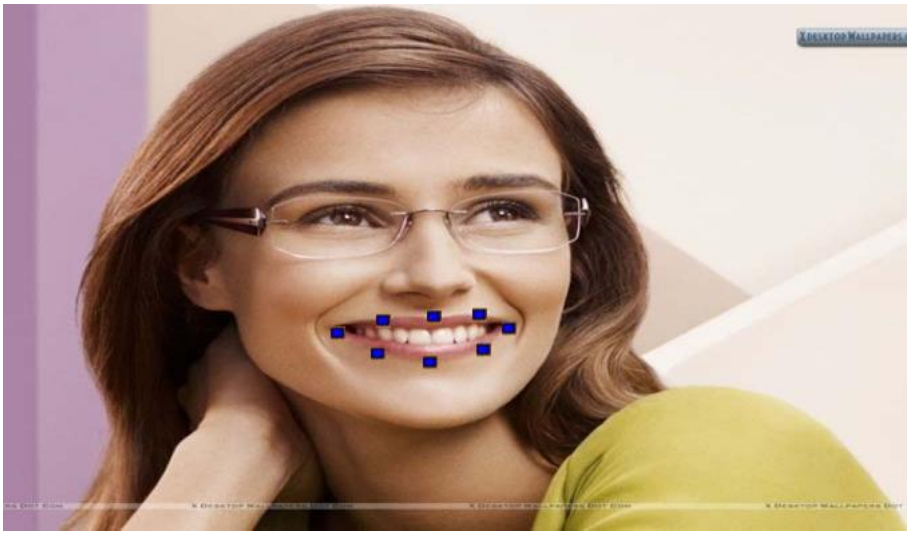
It is done by facial Action Coding System (FACS) [Ekman, 1978]. It could analysis facial action units by examining pitch up and down, yaw left and right, lip pull, lip pucker, depress and stretch, mouth stretch, jaw drop, lips apart, eyebrow raise inner and outer etc.

HEAD POSE ESTIMATION

It use expression – invariant feature points to estimate pitch (500), yaw (500) and roll(300) for example estimation of head yaw using ratio of left point to right point of eye widths and estimation of head roll using the angle between the two inner eye corners.

Facial actions are identified from feature points comprised of motion, shape and color descriptors. Motion and shape-based analysis are particularly suitable for a real time video system color based analysis is computationally efficient and is invariant to the scale or viewpoint of the face, especially when combined with feature localization (i.e. limited to regions already defines by feature point tracking).

For lip shape tracking that identifies for example lip corner pull (smile) and lip pucker the polar distance between each of the two mouth corners and the anchor point is computed. The average percentage change in polar distance calculated with respect to an initial frame is used to discern mouth displays.



Color descriptors can tell that whether the mouth is closed or open by differentiating the teeth and aperture by different color. For example teeth are represented by green color and aperture is represented by red color.

Another way of mind reading could be accomplished by using a futuristic headband which is to be wears over the head.

In this way measurement of volume and oxygen level of the blood around the person's brain is done, using technology called functional near-infrared spectroscopy (FNIRS).

The futuristic headband sends light in infrared spectrum that penetrates the tissues of the head where it is absorbed by active, blood – filled tissues. The headband then measures the light which was not absorbed, and then making the computer to measure the metabolic activities that the brain is making. The results are often compared to an MRI.

Another way or we can precisely say another technology of mind reading is existed in which electroencephalograph, a device used by medical researchers to pick up electrical currents from various parts of the brain. If we could learn to identify brain waves generated by specific thoughts, emotions or desires, we might be able to teach same skill to the computer.

ADVANTAGES AND APPLICATION

Mind reading computer could help paralyze patients, handicapped people, and people have been in comma, people who cannot speak.

For example a prototype mind controlled wheelchair developed from the University of Electro Communications is Japan. This works by mapping brain waves when you think about moving left, right, forward or back and work accordingly.

Mind reading computer can be used in military purposes, sting operations and severe investigations (as in the form of lie detector).Mind reading computer can prevent from terrorism. Also it can be combined with consoles and used for mind gaming.

APPLICATIONS

Prediction of Bankruptcy.

Facial recognition.

Marketing.

Knows what the Eye can see.

Converts Thoughts into Speech.

Can be used for Sting Operations.

Help Paralytic Patients.

DISADVANTAGES

It can be breaches in privacy and can extract important and confidential information through the person which may be about the country. In this way information may be gained by any terrorist or criminal then it can be highly dangerous. Also these mind reading computers cannot be 100% accurate as human mind is much more complex than a computer, after all human had created the computer. But the accuracy could be reached up to 86.4%.