Affective Computing

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Abstract

This paper describes the intellectual framework and field of study of affective computing. This is a seminar paper written for course Tik-111.590 Digital media research seminar, spring 2001: "Space Odyssey 2001". The paper is based on a literature study of affective computing.

1 INTRODUCTION

The latest scientific findings indicate that emotions play an essential role in decision making, perception, learning and more. They influence the very mechanisms of rational thinking. Not only too much, but also too little emotion can impair decision making. According to Rosalin Picard (Picard, 1998), if we want computers to be genuinely intelligent and to interact naturally with us, we must give computers the ability to recognize, understand, and even to have and express emotions.

Affective computing is a young field of research dealing with the issues regarding emotions and computers. The most prominent research questions of the field are: What is the foundation of recognizing, understanding and expressing emotions? How do emotions interact with intellectual processes? How can we build a computer able to *feel*? Should we do it?

In this paper I try to provide the intellectual framework for affective computing. I depict the background on human emotions and their role in behaviour and intelligence, requirements for emotionally capable computers, applications for affective computing, and moral and social questions raised by the issue. Design and construction of affective computers together with their field of applicability is treated. Finally, current developments and future possibilities are discussed.

2 BACKGROUND

Affective computing deals with emotions. Emotions themselves are very human matter, of which there is no clear theory or understanding. The necessary background for affective computing is the knowledge on emotions and their role in human behaviour and cognitive processes.

2.1 Emotions

What are emotions? It largely remains an open question. Some define it as the physiological changes caused in our body, while the others treat it as purely intellectual thought-process.

Emotions are closely related to perception. We understand each other's emotions through visual, auditory and tactile senses. Lack of sensory data causes misunderstandings. Widespread use of email has caused many emotional misunderstandings when affectual meanings have been communicated via textual messages that cannot carry the affective information.

Understanding emotion also has to do with getting to know a person. We can assume the emotions of a person we know. We have built some kind of emotional model of that person on which we can reflect the situation.

2.2 Emotions and intelligence

Emotions are much more fundamental in nature than rational intelligence. A puppy can understand the mood of your commands, and behave accordingly, but it can never think rationally about it's (much less your) world. Still, with its very bounded rationality it is nonquestionaly superior to any computer device when it comes to surviving and acting in physical reality. The current computers, with their unlimited calculating power and memory, are on the intellectual level of a limp cockroach, at their best. Maybe emotions are much more important for survival in the real world?

The actual seat of emotion in human brain is not unambiguous, but we know something about it. Paul MacLean has modeled the human brain as three regions: neocortex, limbic system(s), and reptilian brain (MacLean, 1970). The neocortex is traditionally the best studied, and contains the visual cortex and auditory cortex; it is where the majority of perceptional processing has been assumed to occur. The limbic system is the primary seat of emotion, attention, and memory.

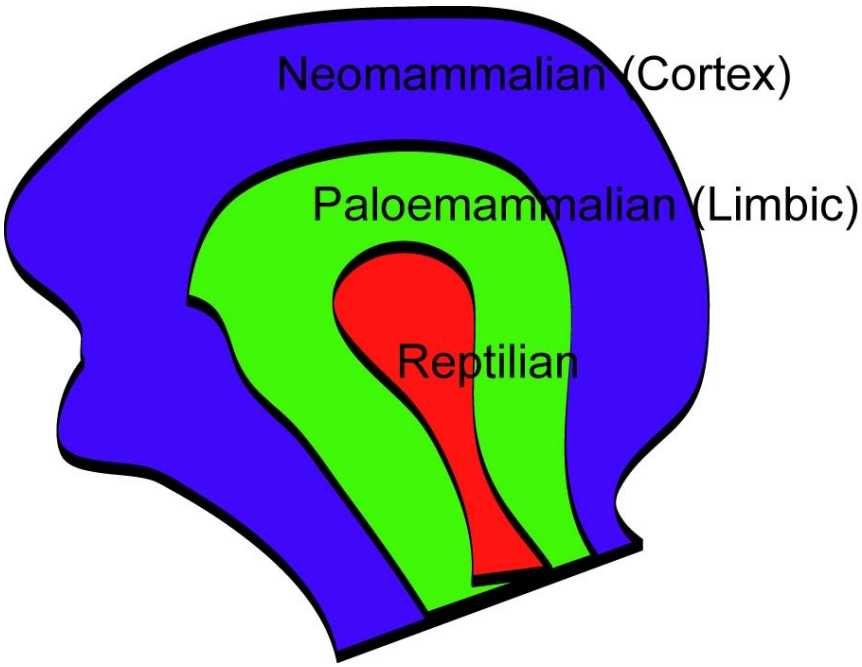

Figure 1: Paul MacLean's "triune brain" (MacLean, 1970). Although clear division between regions are shown, the functions are not disctinctly divided in reality.

Emotions are much more fundamental in human behaviour than intellect. They can hijack our rationality in situations of fear, panic, or love. They can strongly affect our decision making even in normal situations – someone might be called very emotional person.

Evidence indicates that laws and rules do not operate without emotion in two highly cognitive tasks: decision making and perception.

2.2.1 Decision Making

Antonio Damasio (1994) made remarkable findings for the paradigm shift for importance of emotions in thinking processes. His patients have frontal-lobe disorders, affecting a key part of the cortex that communicates with the limbic system, causing certain lack of emotional capabilities. Otherwise, the patients appear to have normal intelligence. At first encounter, they appear like Star Trek's Mr. Spock: unexpressive of emotions and unusually rational. One might expect them to be also highly intelligent, like Spock. But in real life, Damasio's patients make disastrous decisions. Losing money with an investment, a healthy people would learn it's a bad one and stop investing in it. But the patients would continue investing until all the money is gone. Moreover, this pattern appears in all fields of life, causing the people to lose their jobs, friends, family, and more. Another patient had enormous difficulties making *any* decisions. He would consider all the possibilities involved and continue analysing them ad infinitum, simply unable to come into any conclusion.

These findings point to an essential role of emotion in rational thinking. Humans associate judgements of value and valience with important decisions. Even the massive parallelism of the human brain cannot fully search the large spaces involved in many day-to-day decisions. There is no time to consider everything. Valience and "gut feeling" help to cope with these issues. Therefore affective computing could be able to provide better decision-making systems. Pure reasoning might be the Platonic ideal but in successful cognitive systems it's a logical howler.

2.2.2 Learning

Emotions play an important role in human learning. Emotions are hypothesized to provide the flexibility not present in traditional stimulus-response theories of learning. Learning is best thought as a two-step procedure, first creating an emotion for learning, before the stimulus-response (Mowrer, 1960). Consider a rat that learns to leave his box upon hearing a tone after being experienced that tone paired with a painful shock. First, the rat learns to *fear* the tone, and second, upon hearing the tone tries to reduce the fear. The emotional state of fear motivates the rat to seek methods of escape. This more flexible theory of learning explains how a rat might develop alternative solutions for the situation, but always motivated by its emotional state.

2.2.3 Memory

The same emotion that affects decision making and learning also influences memory retrieval. Scientists believe that emotional valence attaches to concepts, ideas, plans, and evey experience stored in our memories. Good feelings likely encode knowledge of effectiveness, familiarity, opportunity, and associations with positive outcomes. Bad feelings likely encode knowledge of ineffectiveness, unfamiliarity, risk, and associations with negative outcomes. Because memory is intricately involved in decision-making and almost every aspect of cognition, it may be that the way in which emotion works so many of its influences is via its influence on memory. The findings of Bower and Cohen (1982) on mood-congruent memory retrieval and learning have influenced several models dor representing emotion-memory interactions and their impact on cognitive processes.

3 EMOTIONS AND COMPUTERS

Affective computing consists of four related areas. For communication, computers can both recognize and express emotion. Emotions can be expressed without really having them, like an actor playing a role. Having emotions is a separate, but very profound question. Last, computers could be able to have emotional intelligence. Lately very fashionable in human psychology, it deals with reasoning and understanding of emotions.

Affective computing also bears its potential concerns and moral hazards, which are discussed last.

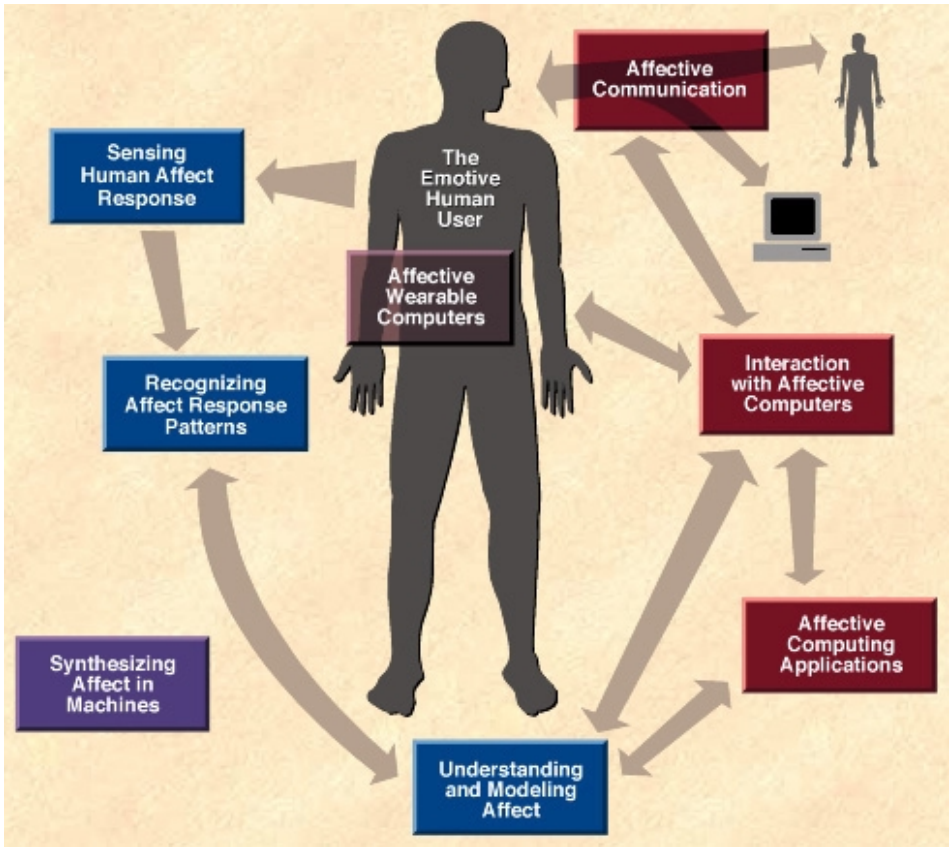

Figure 2: The research areas of affective computing as visualized by MIT (2001).

3.1 Recognizing emotions

The foundation of affective computing will be the ability to recognize emotions, to infer an emotional state from observation of emotional expressions and through reasoning about an emotion-generating situation.

For recognizing ordinary human emotions computer needs human senses like audio and video, gathering facial expressions and vocal intonations. Additionally, it can sense inputs that may not have analogs in human senses – reading infrared temperature, measuring electrothermal conductivity, and so forth. Once emotional expressions are sensed and recognized, the system can use its knowledge about emotion generation and situation to infer the underlying emotional state that most probably gave rise to the expressions.

When does a computer have this ability? One way to test it is to try replacing humans with computers in recognizing and interpreting emotions. If 70% of test persons watching a videotaped expression interpret the emotional state correctly, a computer that comes to the same conclusion with 70% probability should be regarded as able to recognize emotions.

A computer does not have to be bound to human senses when recognizing emotions. Video and audio input could be augmented with body temperature and skin conductivity, heart rate and respiration, and so forth. Wearable computers have access to lots of physiolochigal data that might be too revealing and intimate to be shared with

a public computer. Computers might also be able to recognize and label affective states that do not have particular name or meaning for humans.

Giving only the ability to recognize emotions might be enough to enable computer affectively. It might be also preferred. Being able to only recognize user's emotions and adapt its behaviour accordingly makes well-behaving computer. Nobody wants the negatively-emotional computer sulking and shouting insults at the user. However, human emotional system doesn't rely only on signal recognizion in interpreting emotions. Therefore also other emotional abilities should be given to a computer in order to make it emotionaly fully capable.

3.2 Expressing emotions

A computer can express emotion without actually *having* emotions, just as actors can express emotions that they do not have. The basic requirement for a computer to express emotions is to have channels of communication such as voice, image, and an ability to communicate affection over those channels. The ways of expressing emotion could be human, like showing a face, to easily communicate the emotion to human users. It could be also something totally different and new, as computers are not humans and don't genuinely have the same ways of expression.

Information age has brought a problem of feeding us too much information, leading to cognitive fatique and inability to process effectively new inputs. Information presented through the affective channel, through emotions, does not usually demand our conscious attention. Affective information is processed in parallel and could be utilized to lighten the cognitive load. A computer greeting at startup could inform with voice intonation the result of previous task or its current status. Saying "Hello" in a cheerful tone is more expressive and cognitively less demanding than saying neutrally "Hello. I am feeling currently more happy than usual".

Affective bandwidth is a characteristic that can be assigned to communication channels. It describes how much certain communication channel lets affective information through. With text it is minimal, increasing with voice and video. Ordinarily mediated communication channels have much less affective bandwidth than person-to-person, though in a virtual reality environment utilizing emotional data that humans cannot perceive (skin conductivity, temperature) it could be even higher.

Computer generated affective information promises to be fairly easily generated. Clark Elliott of DePaul University conducted a test on computer generated emotions. He videotaped an actor expressing different emotions while speaking, and a computer that generated facial expressions and vocal intonations to express the emotional states. In tests with human viewers, roughly 70% of the persons recognized the emotions generated by the computer, while only 50% recognized correctly those expressed by the human actor (Elliott, 1997).

Another test of effectivity of affective communication is how much, if at all, a computer is able to induce emotion in its user. A computer is able to express emotions effectively if it can cheer up and make its depressed, angry user feel happy.

Computer may have unique emotional states, which call for correspondingly unique ways of expressing them. For example, a computer running out of memory may feel uncomfortable with receiving large chunks of data. These emotions can be communicated between computing machinery in their unique ways, or translated into some suitable human emotion to be expressed to the user.

A computer can express emotions without really "having" emotions, or without really "feeling", as when programmed to be cheerful. Humans on the other hand always have emotions, whether or not they can express them. Emotional state and expressing emotion is also coupled. Making a smile can make a person feel happy. A person feeling outraged can very hardly make a convincing happy face, however sincerely he tried. Having amotions affects the ability to express them. This bias-exclusion effect should be considered when designing systems with emotional capabilities.

3.3 Having emotions

Can computers *feel?* Certainly this is the most profound question in the field of affective computing. Feelings are usually considered to be the division between a human and a machine. The question is closely related to the issue of computers having consciousness., even more debated topic. Consciousness is also a prerequisite for many human emotions, like shame and quilt – if you don't have consciousness, there's no reason to be ashamed of anything. Picard (1998) proposes s model of five components that all should be present in a system if it is to have emotions.

Picard calls the first component "emergent emotions." Emergent emotions are those which are attributed to systems based on their observable emotional behaviour, especially when the system at hand doesn't have any explicit internal mechanism or representation to emotions. Mac showing a smiling face at bootup can be seen as having "positive emotions towards serving the user". In reality the Mac doesn't really *have* any emotions, the user just perceives these emergent emotions.

Second component are fast primary emotions. Many animals including humans have hard-wired, innate responses, especially to potentially harmful events. We can feel startled, angry, or afraid before the signals event get to the cortex, and before becoming aware of what is happening. These primary emotions work through two communicating pattern recognizion systems: a rough system that acts fast and can hijack the cortex, and a finer system that is slower but more precise.

A third component of having emotions are cognitive emotions, involving explicit cognitive reasoning in their generation. For example, completing a difficult task can generate an intense feeling of satisfaction. In healthy human, cognitively generated emotions usually provoke an emotional experience with subjective feelings, activating limbic responses and bodily feelings.

The fourth component is emotional experience. A feeling system is able to label its emotional behaviours, and understand its own affective system. Then it can be said to have a rudimentary awareness of its emotional behaviours. Second aspect of experience is awareness of the emotions' physiological accompaniments. For humans these include heart rate, breathing, cold feet, and so forth. Most computers don't have sensors that

could discern their physical state but those could be added. For computers awareness of their internal "software" state is probably more relevant. Third aspect of emotional experience are the tricky "gut feelings" that let's you know subjectively something is good or bad, that you like or dislike something.

Body-mind interactions constitute the fifth and the last component. Emotions influence decision making, perception, interest, learning, priorities, creativity, and more. Emotions influence cognition, and therefore intelligence, especially when it involves social decision making and interaction. The human emotions not only influence cognitition but also physiological systems outside ot brain – vocal and facial expressions, posture and movement. Emotions intricately interact with the human body and mind. Not only does emotion infuence cognitive and bodily functions, but the emotion is itself affected by them. As previously described, cognitive thoughts can generate emotions. Also biochemical processes like hormons and neurotransmitters and physical drives like hunger evoke emotions. The aspect of emotion's interaction with body and mind thjat may be most important for computers is the influence of emotion on cognitive processes.

3.4 Emotional intelligence

We all cognitively manage our emotions. Emotions can be powerful motivators. If you enjoy interacting with people, you may seek opportunities to do so. However, you are able to self-regulate the pursuit of pleasure and recognize that sometimes negative feelings or emotional restraints have to be tolarated in order to reach something greater.

A computer with emotional inteligence will be one that is skilled at understanding and expressing its own emotions, recognizing emotion in others, regulating affect, and using moods and emotions to motivate adaptive behaviours. Recognizion of emotion in others includes reasoning about what emotion is likely to be generated in a situation, ultimately understading what is important to other person, what are his goals, preferences and biases. Regulating one's own emotional reactions is a characteristic of a civilized adult. Ability to utilize emotions, both with self and in others, for higher cognitive goals like learning, creativity, and attention is a powerful skill.

These components of emotional intelligence rely on the three abilities of affective computing presented above: recognizing and expressing emotions, and "having" emotions. Computers that have emotions have to be aware of them, and will need to be able to regulate and utilize them.

3.5 Potential concerns

Unfortunately, technology almost always has a darker side. The suddenly consciousness computer systems with emotionally hostile attitude towards whole human race have been regular theme of entertainment industry for decades, from HAL to Terminator. Computers start to make *emotionally* distorted, harmful decisions. Emotions and computers have potentially harmful outcomes which the developers of affective computing should address.

Emotional decision making has strong negative connotations. It is usually connected to non-rational, bad, non-intelligent decisions. When somebody is said to act emotionally, it usually means he's doing bad for himself and possibly for others, too. Making the computer decision making process emotional is a delicate matter. A balance should be found where the positive effects of emotionality can be utilized without slipping into unrational behaviour. A strong regulation of affection is needed.

Emotional manipulation, from tv shop sales pitches to Nazi propaganda, is a well-known activity. Like humans, emotionally capable computers will have the ability to mislead and deceive users. Computers could be also used in large-scale monitoring and manipulation of emotions, scaringly powerful tool for an authoritatian government.

4 APPLICATIONS

Real-life applications of affective computing are still somewhat few. The field has so far been dominated by research, not applications. Nonetheless, future forms of computing can be seen to call for affective capabilities, for example wearable computers could have much use of emotional capabilities.

4.1 Affective computing foundations

Human emotions are communicated though sensory data. Therefore effective processing of visual and auditory data is the fundamental of getting emotions into computers. Digital signal processing is the low level recognizion of emotions. Analyzing video and audio data the computer can try to connect some input signals to emotions.The system needs also some kind of high-level, symbolic models of emotions and moods.

In building affective computers the tools of pattern recognizion and analysis are used for recognizing and synthesizing facial expressions, recognizing and synthesizing vocal inflection, recognizing physiological patterns corresponding to affective states, and modelling emotional behaviour. Research in the area is very new, but the results so far have proved promising results.

Emotion synthesis, the process of generating emotional states and communicating them, can utilize models employing both cognitive and non-cognitive mechanisms. Cognitively generated emotions have been the easiest to implement with AI based systems, since they are rule-based and lend to imlementation in a computer.

4.2 Affection-to-go

Wearable computers could get to know you very well, adapt to your situation and serve you in a much more powerful way, were they enabled with emotions. Soon you could build a relationship with your computer, and, like your underwear, they come very personal and you will not want to borrow it to others.

Applications of affective wearable computers are such as a portable music player that plays music depending on your mood and listening preferences, glasses that show other people's affective state (trasmitted by wearabe devices) and conductor's sensor-net jacket that augments the ability to express emotion and intentionality. (MIT, 2001).

Wearable computers have full access to you, and should be under total control of the human wearer not to cause any anxiety.

4.3 Persuasive computing

Persuasive computing is a research field studying use of computers in *persuading* humans (Fogg, 1999). The application migh be from simple user-interface features to software that trains heroin-addicts out of the habit.

Technology can be made persuasive with logic and intention, but coupled with emotional capabilities of affective computing, it can really get the means of persuasion.

5 FUTURE DIRECTIONS

The research field of affective computing is very young, but promising. Most of the roads are still there to be taken.

Computers have penetrated the human society, gaining importance in our everyday life. They also take care of many of the most important processes, like flight control, telecommunications, medicare systems. Getting them to work with humans better, more intuitively, more attentatively would be important. Finally putting the computers to adapt to *us*, after all these years of humans adapting to irky computers, would be a victory to human kind.

Affective computing promises to give us means for that. Emotional computers will not be the next giant step in computing, but building emotional capabilities into many, if not all, computing devices surrounding us will improve the understanding and communication between us and them. Wearable computers are the first natural application field, having direct access to their users.

6 CONCLUSIONS

Affective computing could provide for massive improvements in human-computer interaction, in the form of usable, intuitive interfaces. Machines and software could adapt their behaviour to yours.

Because emotions and rational intelligence are very intertwined in humans, it could be believed that emotions are a prerequisite for truly intelligent computer. By building affective computers we could finally reach the promises failed by the field of artificial intelligence.

7 SUMMARY

Affective computing is a relatively new field of study researching the use of emotional capabilities in computing machines. Its background relies on findings and theories emphasizing the importance of emotions in decision making, learning, memory, and virtually all cognitive processes.

Building emotional capabilities into computers could both make them easier to interact with, and also make them cognitively radically more capable.

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