TRANSYR – A System for Tactile Detection and Recognition of Autonomous Nervous System Response

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ABSTRACT
TRANSYR is a system for tactile analysis of the human autonomous nervous system (ANS) response. The device attempts to take advantage of the dynamic and adaptable signal processing capabilities of human brain to interpret the heart motion and to detect physiological and emotional responses. This paper outlines the design and evaluation of the TRANSYR tactile analysis system.

Keywords
Tactile display, emotion recognition

1. INTRODUCTION
Human communication relies heavily on visual and auditory cues such as gestures, facial expressions, and voice tone to convey the emotional content in a “face to face” communication. With globalization and advances in technology, face to face communication becomes a rare luxury, thus making communication more impersonal by stripping it of emotional content. Being able to convey emotional content can bring some of the lost face-to-face feel to the modern communication mediums.

The human autonomous nervous system, which controls the heart and breathing, is known to respond to external stimuli and change its response based on the physiological and emotional state of the person[8]. Recognizing and interpreting this response in real time is a rather difficult task for modern technology to handle. Multiple statistical, learning and adaptive algorithm approaches have been investigated, and although the results are promising [8], they are not easily adaptable for a real-time implementation.

By using a tactile display, this work attempted to shift the emotional and physiological recognition and interpretation of the ANS response to the human brain in order to take advantage of its dynamic and adaptable real-time signal processing capabilities.

2. RELATED WORK
2.1 Tactile displays
Tele-tactile sensor research is of great interest for many industries. A good overview of tactile sensor application and software is given by a group at Aristotle University of Thessaloniki, Greece [5]. It includes areas such as graphic display, medicine, military and aids for the sensory impaired. Researchers at Berkeley University, CA quantified several perceptual capabilities of the human tactile system needed for teletaction [1]. Biophysics group at University of Exter, UK [2] is investigating strategies for the transmission of temporal, spatial and spatio-temporal information to subjects using special purpose hardware such as tactile arrays which deliver complex stimuli to the fingertip via a close-packed set of vibratory transducers. Tactile arrays are also used in eSmileys project at University of Tampere, Finland [3], one of the few studies that is using tactile stimulus to detect emotions. Graphical images of emotions (smiley) were displayed as composite electro-tactile patterns (CETP) on the human tongue. An interesting study by MIT Media Lab [4] introduced ComTouch, a device that augments remote voice communication with touch, by converting hand pressure into vibration intensity between users in real-time.

2.2 Emotional recognition
Emotional recognition from the ANS response has been studied by several research groups. Department of Computer Science, Orlando, FL [6] leads a research in mapping physiological signals such as are heart rate, galvanic skin response, and temperature to their corresponding emotions using non-invasive wearable computers (BodyMedia Sensewear Armband). Another group at the University of Tokyo, Japan [7] has described a model that determines emotion using electromyography (EMG) and skin conductance trying to enhance gaming experience between a human user and a 3D humanoid agent.

3. DESIGN AND IMPLEMENTATION

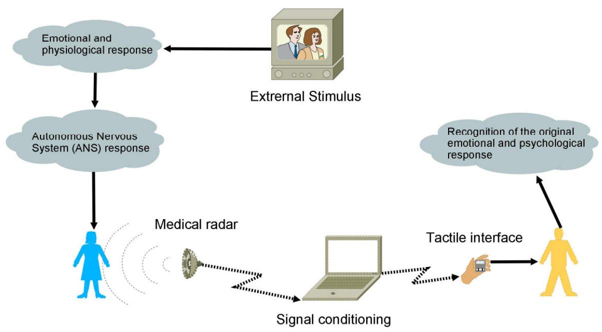

Figure 1: System Structure

3.1 Heart and Respiration Sensing

The heart and lung motion data retrieval was done using a "Wireless 2000" PAM™ bed sensor. The sensor is medical radar which uses extremely short (order of nano-seconds) radio pulses in order to detect the mechanical motion of the human heart and lungs. The data is normally processed using an onboard processor and only the determined rates are transmitted wirelessly to a host PC. For our application, high resolution raw motion data was captured for offline processing on a host PC.

3.2 Signal conditioning

The captured data was then translated, separated into heart and respiration streams, and pre-processed. The pre-processing stage contained equalization and motion artifacts removal to prepare the data for further processing. The data was then filtered using correlation filtering and band filtering to separate and clean-up the heart and respiration signals. All of the processing was done using GNU Octave, a high-level numerical computations tool, which provides an environment and an interface for solving various mathematical problems in a manner most comparable to Matlab. The resulting waveforms were then mapped and translated into a signal suitable for a force feedback device driving circuitry.

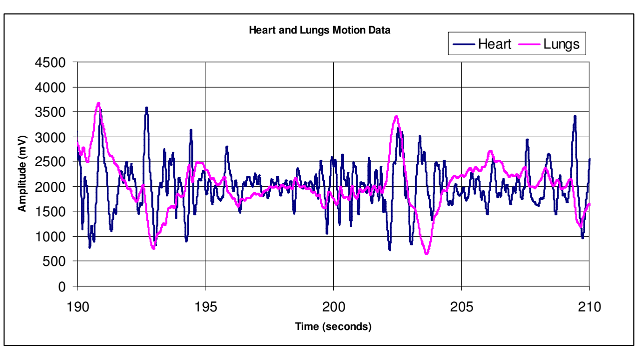

Figure 2: Pre-processed data

3.3 Tactile display

Two tactile display devices were developed for the TRANSYR system. One device utilized a stepper motor for re-creating the heart motion, while the other was based on a linear actuator. Both devices created linear surface movement at the user's palm using rotational to linear motion translation. Both devices included transparent controllers which allowed for streaming of the data from a host PC. The actuators were placed in wooden housings and soft material was placed over the actuator head:

Figure 3: Tactile display in use

4. USER STUDY

4.1 Emotion Elicitation

We have concentrated on elicitation of the three basic emotions: sadness, anger and fear. The emotional response was elicited using visual (video) stimulus. The cardiopulmonary radar data was captured during the visual stimulation. The users were then asked to rate the intensity and type of their emotional response to each visual stimulus.

There were 6 participants in the elicitation experiment with 10 emotional responses captured: 4 of fear, 4 of anger and 2 of sadness. Eliciting emotions proved to be difficult task as different participants had varying emotional responses when presented with the same visual stimulus. Moreover, the intensity of the emotional response varied greatly throughout the subject group.

4.2 Emotion recognition using tactile interface

A user study with 10 participants was conducted for the emotional recognition portion. The subject group had mixed gender and age makeup. Participants were asked to use each device with three samples for each device. They were then asked to recognize the emotional content within each sample. They were also asked to state if they can distinguish between emotions of anger, fear and sadness and if they could grade them.

The study also included more general questions about what they liked of disliked while using the tactile device.

5. RESULTS

All study participants claimed they could sense different vibrations and some thought they could distinguish between different emotions. None of the participant could grade the intensity of emotions. The summary of the questionnaire data is given below:

Sensing heartbeat rate using tactile device without training	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I can feel vibrations				5	5
I can distinguish the anger vibration	1	1	1	4	3
I can distinguish the fear vibration	1	1	1	4	3
I can distinguish the sadness vibration	1	1	2	3	3
I can exctract people's emotions by sensing their heartbeat rate through this tactile device		1	4	4	1
I can determine the degree of people's anger through this tactile device		2	5	2	1
I can determine the degree of people's fear through this tactile device		2	8		
I can determine the degree of people's sadness through this tactile device		2	8		
I can sense the vibration but I can't distinguish any emotions from the vibration	2	2	2		4
Distinguishing emotions from sensing heartbeat rate through the tactile device is difficult		3	2	1	4

Figure 4: Study questionnaire summary

We could not find the difference in male and female abilities to detect different emotions but female participants were taking the task of detecting emotions with more enthusiasm. Emotion detection was less than 50% successful for all of the cases. Sadness was the emotion detected with most success (30%). We did not see significant difference in emotion recognition using either of the 2 tactile devices:

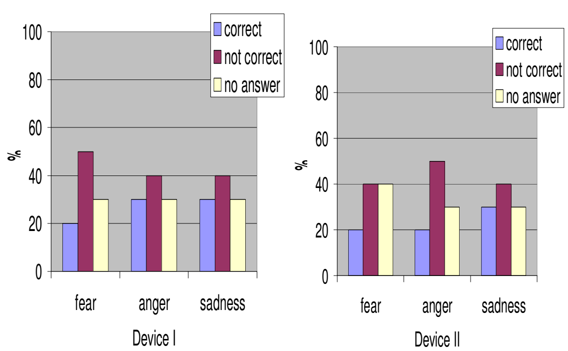

Figure 5: Emotional recognition summary

Overall, the study has shown lack of success in emotional recognition using the current prototype system.

6. FUTURE WORK

The first objective for further work on emotion recognition system is to improve the emotion elicitation methods using more immersive environments and augmented sensory stimulation. Since emotional response does not occur throughout the entire elicitation session – there is a need for a mechanism (such as a button interface) to allow the subject to indicate his perceived emotional response throughout the stimulation experience. This information could then be used to extract the sections of the data that should contain emotional responses.

Another section that needs to be improved is the tactile display. The current prototypes had difficulty displaying the motion data accurately due to their dynamic range and response limitations. A more suitable option is to use voice coil actuators which could not be used for this study due to time limitations.

The pre-processed waveforms can also be further manipulated and analyzed in GNU Octave to implement a software-based emotional recognizer. This task could focus on using machine learning algorithms in combination with neural-network based data analysis. The effectiveness of the software recognizer can then be evaluated against the test subjects.

An alternative approach to using tactile display of heart and lung motion would be to sonify the waveforms and present them in a form of a sonic landscape. The waveforms could be further analyzed and sonified using SuperCollider - an environment and programming language for real time audio synthesis and algorithmic composition. SuperCollider is ideally suited for this task because of its array and list processing capability, its methodology for spawning multiple musical events and its support of customized user interfaces. The resulting sonification can then be used in conjunction with the tactile display or on its own. The effectiveness of a sonic display can also be evaluated against the software recognizer and against the tactile display.

7. CONCLUSION

The user study has shown that the system requires significant improvements before it can be successfully evaluated. Some study participants have suggested expanding emotions to excitement, and happiness finding sadness, anger and fear too similar and negative emotions. The most interesting comment was that movements at times seamed like mix of emotions which made it hard to isolate a specific emotion. We found this to be a problem during emotion elicitation phase as subjects had difficulty indicating which emotion they have felt.

We believe that the suggested system has the potential of enhancing the modern communication by bringing some of the face-to-face emotional content into the modern communication mediums. However the limitations of our prototypes were too significant to explore those new approaches to communication.

8. ACKNOWLEDGMENTS

We would like to thank Dr.Sidney Fels for providing us with guidance and advice during the course of this project. We would also like to thank all the subjects who kindly participated in this study.

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