World Academy of Science, Engineering and Technology
International Journal of Computer and Information Engineering
Vol:10, No:11, 2016

Authoring Tactile Gestures: Case Study for Emotion Stimulation

Rodrigo Ceballos, Beatrice Ionascu, Friederike A. Eyssel, Scandar Copti, Mohamad Eid

Abstract**—**The haptic modality has brought a new dimension to human computer interaction by engaging the human sense of touch. However, designing appropriate haptic stimuli, and in particular tactile stimuli, for various applications is still challenging. To tackle this issue, we present an intuitive system that facilitates the authoring of tactile gestures for various applications. The system transforms a hand gesture into a tactile gesture that can be rendering using a home-made haptic jacket. A case study is presented to demonstrate the ability of the system to develop tactile gestures that are recognizable by human subjects. Four tactile gestures are identified and tested to intensify the following four emotional responses: high valence – high arousal, high valence – low arousal, low valence – high arousal, and low valence – low arousal. A usability study with 20 participants demonstrated high correlation between the selected tactile gestures and the intended emotional reaction. Results from this study can be used in a wide spectrum of applications ranging from gaming to interpersonal communication and multimodal simulations.

Keywords**—**Tactile stimulation, tactile gesture, emotion reactions, arousal, valence.

Open Science Index, Computer and Information Engineering Vol:10, No:11, 2016 publications.waset.org/10005787/pdf

I. INTRODUCTION

RECENT advancements in information technology allow the creation of more and more immersive multimedia systems, ranging from 3D authoring to sound spatialization and higher quality 2D/3D displays. However, these systems are still limited to the simulation of audio and visual senses. Studies in multimodal human computer interaction have shown that haptic feedback seems to enhance the quality of user experience [1]. For instance, several studies have demonstrated that haptic stimulation is successfully used to intensify emotional immersion during media consumption, and is particularly effective in communicating valence and arousal [2].

Most research in haptic-based interaction focuses on the use of tactile cues [3]. Several technologies allow users to feel haptic effects synchronized with audio-visual contents [4], from vibration motors embedded in wearable devices to moving chairs in 4D film. In addition to the complexity and perceptual challenges, designing haptic gestures is very challenging task due to the large number of parameters contributing to the perception of these gestures (such as intensity, frequency, location, and duration of vibration). Therefore, the limited use of tactile gestures in multimodal applications is mainly due to the lack of simple and intuitive way to design then – designing them manually is a very time consuming and tedious process.

A recent study demonstrated an organic relationship between hand gestures and tactile gestures [5]. In this paper, we propose a system that provides an intuitive and natural means that empowers designers to author haptic gestures on the fly using hand gesture. A case study to author haptic gestures for emotional stimulation is presented to demonstrate the effectiveness of the proposed system. Results showed that the designed set of haptic gestures are effective to intensify various emotional reactions on the arousal-valence space.

II. RELATED WORK

Today the ability to display tactile gestures is well studied. Various wearable devices with haptic features are available in the literature. An early work in this direction was the TapTap prototype, which is a wearable haptic interface that can record and playback patterns of touch in order to experience the affective human touch [6]. A subsequent effort at Philips Research Europe demonstrated a haptic jacket (with 64 tactile actuators) that focuses on influencing the emotions of movie watchers [7]. Cha et al. [8] implemented HugMe, a synchronous haptic teleconferencing system where a home-made haptic jacket is utilized to display tactile feedback to a local user who is touched by a remote user. Krishna et al. developed a haptic glove (named VibroGlove) to deliver facial expressions of an interacting partner to people who are blind or visually impaired [9]. Vibrotactile motors, mounted on the back of a glove, provide a means for conveying haptic emoticons that represent the six basic human emotions and the neutral expression of the user’s interaction partner. On the other hand, authoring tactile gestures for various applications seem to be less mature compared to the development of tactile display technologies. For instance, Immersion Corporation presented a programmable tactile display that permits to control various attributes of the tactile gesture such as vibration intensity, frequency, and pattern [10]. However, these parameters would have to be controlled individually and un-intuitively. Réhman et al. strived to create a library of tactile gestures (called Feel Effect) where a FE comprises a haptic component and a semantic component [11]. The haptic component specifies how the sensation unfolds over time and location via parameter settings for SOA (stimulus onset asynchrony), duration, intensity, and ramp-up for each actuator in an array of vibration motors. The semantic

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Rodrigo Ceballos and Beatrice Ionascu are undergraduate students at New York University Abu Dhabi, United Arab Emirates (e-mail: rc2529@nyu.edu, beatrice.ionascu@nyu.edu).

Friederike A. Eyssel is an associate professor of psychology, Bielefeld University, Germany, (e-mail: friederike.eyssel@uni-bielefeld.de).

Scandar Copti is professor of Film and New Media, New York University Abu Dhabi, United Arab Emirates (email: scandar.copti@nyu.edu).

Mohamad Eid is an assistant professor of Electrical and Computer Engineering, New York University Abu Dhabi

component describes what experience the sensation feels like. Results confirmed that semantically similar FEs lie in close proximity in haptic parameter space. Other studies focused on mapping audio signal to haptic effects [12] or visual signals (particularly motion) into haptic effects [13].

In this paper, we propose to use hand movements to create tactile gestures in order to provide on-the-fly and intuitive means to design tactile gestures. Users are presented with an interface showing the layout of the vibrotactile motors in the haptic jacket. The user waves their hand along any path and the system translates and plays via the haptic jacket with the same stroke sequence and speed of movement. The closer the user is to the screen, the higher the intensity of vibration. Once a gesture is fine-tuned, the user can save that tactile gesture for later playback.

III. PROPOSED SYSTEM

A tactile gesture authoring system is designed to convert a hand gesture into a haptic gesture, and renders the generated haptic gestures via a haptic jacket. As shown in Fig. 1, four components compose this system: Motion Tracker, Motion-Tactile Mapping, Haptic Rendering, and Haptic Jacket. The Motion Tracker uses a web camera and signal processing to detect the hand and track its movements. The features of hand gesture are translated into tactile gesture features via the Motion-Tactile Mapping component. The Haptic Rendering component displays the tactile gesture based via the Haptic Jacket.

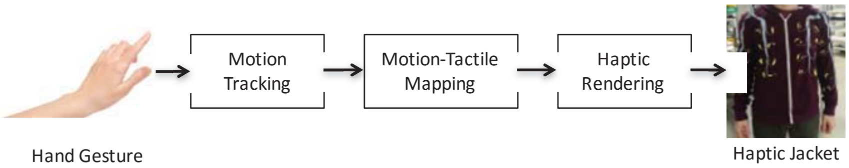


Fig. 1 Tactile gesture authoring system

A. Motion Tracking

The actuators on the jacket are controlled remotely using a home-made software interface application. The application allows for complete control over each of the 48 actuators by means of a video input interface. This visual interface was chosen in order to provide an intuitive and natural means of generating tactile gestures that can be rendered on the fly. The motion tracking component processes each video frame and identifies the location, size, and distance-to-camera of the hand. The distance-to-camera of the hand is used to define the intensity of vibration intensity.

B. Motion-Tactile Mapping

Using the video input interface as shown in Fig. 2, gestures are created by mapping pixel intensity above a certain threshold into proportional actuation of a specific motor. Specifically, an outline of the front and back views of the jacket, with the positions of the actuators, is shown on a white background and the user is able to manually draw or programmatically overlay a pattern onto the outline of the jacket, which actuates the motors that are closest to the region selected by the user.

After selecting a transmission frequency [5-20 Hz], each frame is mapped into a 96-bit matrix that controls the intensity at which each motor is actuated. The indices of the elements refer to the number of the motor, whereas each consecutive two bits refer to the intensity of the vibration in a range of three steps. For instance, if the first two bits of the matrix are 00, it means that the first motor (index 0) will be turned off. The motors are numbered 0-47 as shown in Fig. 2.

C. Haptic Rendering

The matrix is encoded into a 12-byte packet that is sent over to the microcontroller. The microcontroller is programmed to receive instructions in the form of bytes over a serial port. One byte at a time is read and decoded and then saved into a matrix in the microcontroller's memory. After 12 bytes are received, the decoded matrix is used to set the output value for each channel. The PWM values are set as follows: '00' corresponds to zero duty cycle, or off; '01' corresponds to ¼ of the maximum duty cycle (1023); '10' corresponds to ½ of the maximum duty cycle (2047); '11' corresponds to ¾ of the maximum duty cycle (3071). The motors are updated at a rate of 20 Hz. We can create different vibration patterns and the illusion of apparent motion. The interface application allows for a real-time control of the haptic jacket by using the built-in webcam. This can be used for quick testing of any gesture.

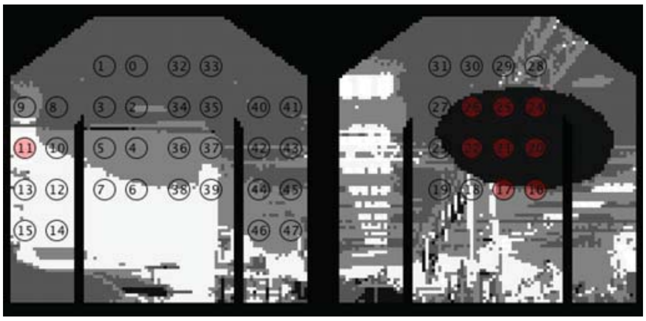


Fig. 2 Video-based gesture generation software

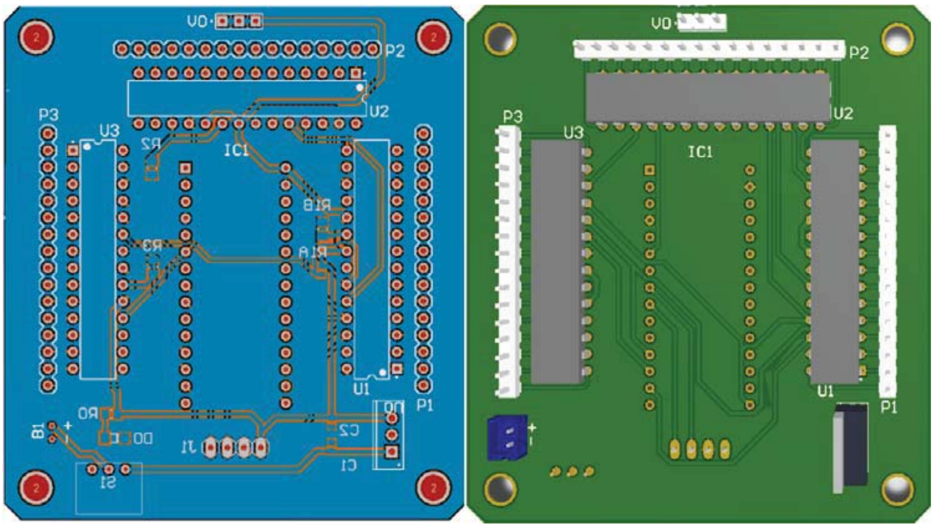
D. Haptic Jacket

The haptic jacket is a garment with embedded actuators that can simulate various tactile stimuli. A network of 48 actuators is distributed over the flexible inner layer of a jacket as shown in Fig. 3. A zipper allows for easy access to the actuators. The jacket, including all hardware components detailed below, weighs 750 grams.

The hardware design includes 48 actuators distributed on the jacket, flexible cabling, and a custom-made Printed Circuit Board (PCB) that contains the actuator control circuitry. The PCB comprises a microcontroller, three 16-channel TLC drivers, a Bluetooth module, and a step-up regulator (Fig. 4). An Arduino Nano microcontroller is used to control the entire system. It is programmed to receive serial commands from an external device to operate the actuators. The 16-channel TLC drivers are Pulse Width Modulation (PWM) units with 12-bit duty cycle control (0 - 4095). The PWM technique is used to control the intensity of vibration. The three TLC drivers are daisy chained so that the number of PWM outputs is expanded to 48. In this way, the microcontroller can output to the 48 channels controlling the actuators at the same time. A JY-MCU Bluetooth module is used for wireless communication to a remote application.

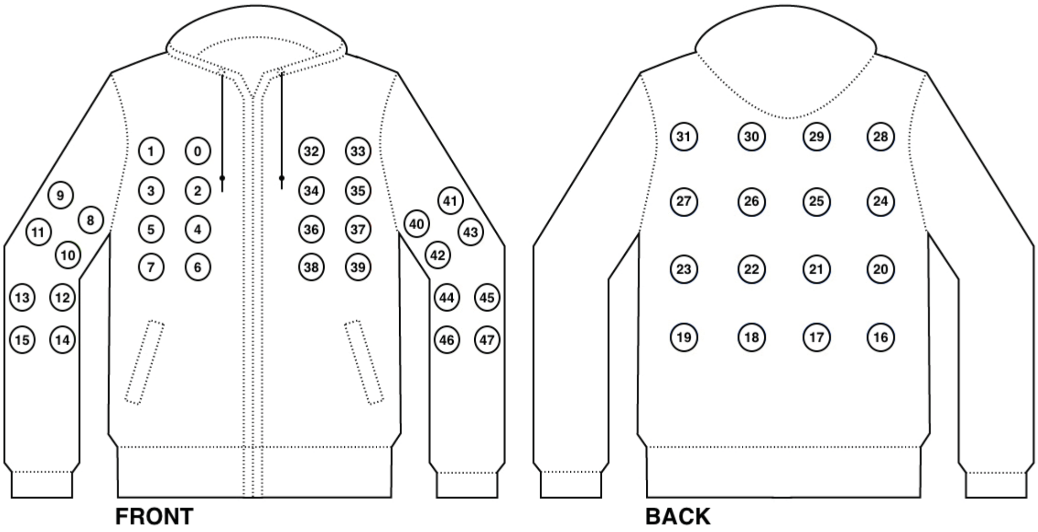

(a) (b) (c)

Fig. 3 Exterior view of jacket (a), front view of jacket turned inside-out (b), back view of jacket turned inside-out (c)



(a) (b)

Fig. 4 Haptic jacket PCB design (a), 3D render (b)



(a) (b)

Fig. 5 The distribution of actuators Front and arms (a) and back (b) of the jacket

Piezoceramic disk actuators were chosen because they are lightweight, thin, and inexpensive motors that can generate strong albeit non-audible vibration. The distribution and ordering of the actuators over the body is shown schematically in Fig. 5. The vibration motors and the PCB are powered from one 3.7 Lithium Ion battery. A step-up regulator is used on the PCB to accommodate the 5 V requirement of the microcontroller. With a 3.7 V rechargeable battery that delivers 1200 mAh, the haptic jacket has an operational lifetime of one hour when driving all 48 motors at the same time.

IV. Case Study: Design of Affective Tactile Gestures

In order to demonstrate the effectiveness of the proposed system, we consider a case study that involves authoring tactile gestures to intensify emotional reactions. Studies have demonstrated the ability of haptic stimulation to display various emotions [14], [15]. For instance, a recent study utilized a haptic jacket with an array of vibrotactile motors, a temperature actuator and a heartbeat sensor to facilitate the display of the six universal emotions: love, joy, surprise, anger, sadness, and fear [16], [17]. Results showed that the overall quality of user immersion is enhanced when a haptic jacket is used while watching a movie [18], [19].

A. *Tactile Gestures Optimization*

A pilot study is conducted with three participants to determine the best parameters to convey both valence and arousal in an intuitive, self-explanatory way. Both the average accuracy of recognition and comments provided by the participants are then used to alter parameters and optimize the gestures used in the next iteration of the optimization process. This process is repeated three times such that a total of six different gestures are tested for each parameter being evaluated (valence and arousal). One final round of testing involving the top five gestures for each parameter is conducted with a different set of three participants and the gestures are ranked. Results from these pilot tests, shown in Table I (valence) and Table II (arousal), are used to find both the optimal frequency and intensity to map both valence and arousal most effectively. A remarkable finding of this pilot study is that direction of apparent motion was more relevant than stimuli position when attempting to convey valence. Consequently, four candidate tactile gestures are considered for intensifying the valence-arousal reactions (Table III lists the configurations for these tactile gestures). As literature describes both arousal and valence as being function of frequency, we established a linear relationship such that frequency increases with both arousal and valence.

B. *Tactile Gestures Optimization*

20 subjects participated in the experiment to test the effectiveness of the selected tactile gestures to intensify arousal/valence reactions. Prior to the experiment, participants were fitted with the haptic jacket. During the experiment, participants could press a button to initiate a haptic gesture from the four gestures described in Table III. Each gesture played on the jacket for 10 seconds. Self-Assessment Manikin (SAM) scale for valence and arousal was given to the user (shown in Fig. 6). This procedure was repeated 40 times, such that each gesture was rated 10 times by using a pseudo-random in order to make sure that the same gesture was not repeated twice in a row. During the experiments, participants were not aware of how many total gestures were being tested or the parameters used to create them (direction, frequency and intensity).

TABLE I
The Configuration for the Four Tactile Gestures Used in the Experimental Study

Rank	Low Valence	High Valence
1	Frequency: 0.5 Hz Direction: Downwards and Out	Frequency: 1.4 Hz Direction: Upward and In
2	Frequency: 0.3 Hz Direction: Out	Frequency: 2 Hz Direction: Upward
3	Frequency: 1 Hz Discontinuous Position: Arms and Back	Frequency: 1 Hz Direction: Out
4	Frequency: 1 Hz Direction: Downwards	Frequency: 2 Hz Continuous Position: Chest and Stomach
5	Frequency: 2 Hz Discontinuous Direction: Arms and Back	Frequency: 1 Hz Continuous Direction: Chest and Arms

TABLE II
The Configuration for the Four Tactile Gestures Used in the Experimental Study

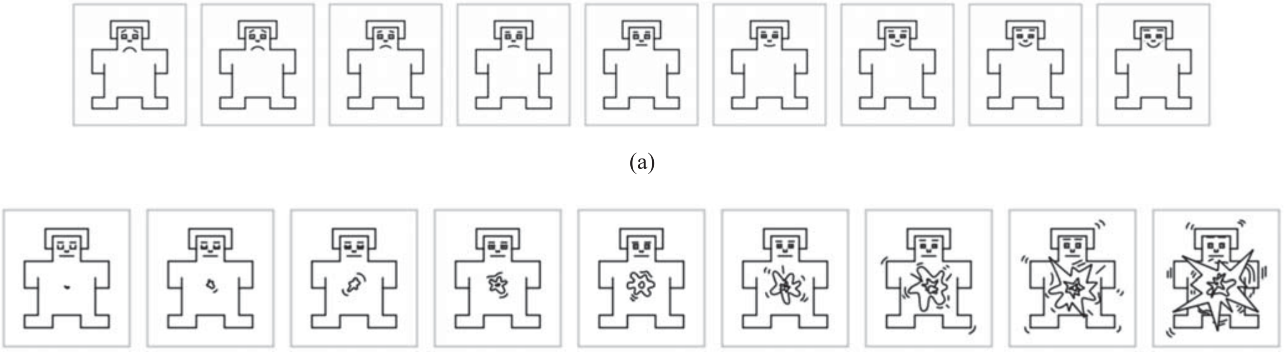
Rank	Low Arousal	High Arousal
1	Frequency: 0.5 Hz Intensity: 40%	Frequency: 1.4 Hz Intensity: 90%
2	Frequency: 0.7 Hz Intensity: 40%	Frequency: 2 Hz Intensity: 90%
3	Frequency: 0.5 Hz Intensity: 30%	Frequency: 0.5 Hz Intensity: 90%
4	Frequency: 0.45 Hz Intensity: 50%	Frequency: 2 Hz Intensity: 40%
5	Frequency: 1 Hz Intensity: 50%	Frequency: 2 Hz Intensity: 60%

TABLE III
The Configuration for the Four Tactile Gestures Used in the Experimental Study

	Low Valence	High Valence
High Arousal	Frequency: 0.5 HzIntensity: 90 % Discontinuous Direction: Downwards and Out	Frequency: 1.4 Hz Intensity: 90 % Continuous Direction: Upwards and In
Low Arousal	Frequency: 0.4 Hz Intensity: 50 % Discontinuous Direction: Downwards and Out	Frequency: 1 Hz Intensity: 50 % Continuous Direction: Upwards and In

C. *Tactile Gestures Evaluation*

As reported in the literature, creating a completely intuitive set of gestures that would map valence irrespective of subjects proved difficult. While our preliminary tests suggested that direction and frequency could be used effectively to accomplish this goal, a larger sample size showed that valence mapping of haptic gestures is very subject dependent. In this sense, the candidate tactile gestures were not highly successful in intensifying valence, as shown in Fig. 7. On the other hand, arousal was successfully intensified by the corresponding tactile gesture as is evident by the fact than in more than 80% of trials, participants correctly associated arousal reactions with the corresponding tactile gestures (Fig. 7).



(a)

(b)

Fig. 6 Valence self-assessment rating (a), arousal self-assessment rating (b)

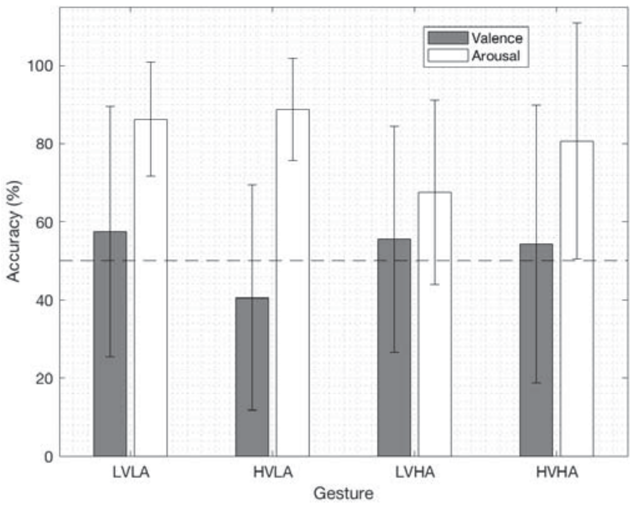


Fig. 7 Average accuracy (and standard deviation) for valence and arousal mapping of tactile gestures

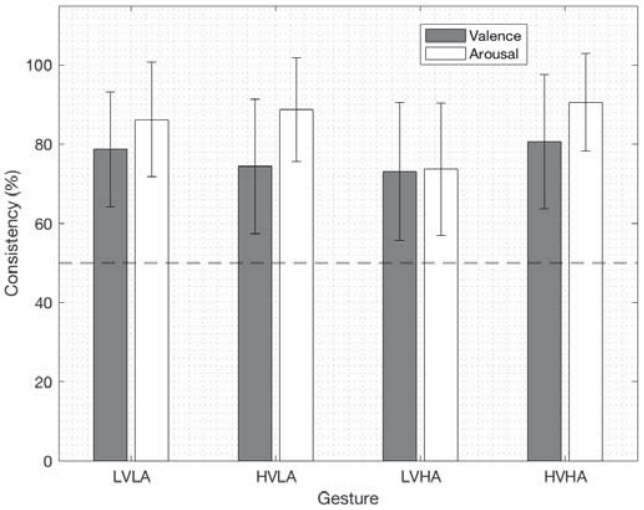


Fig. 8 Average consistency (and standard deviation) for valence and arousal mapping of tactile gestures

The low accuracy in mapping valence to tactile gestures can also be explained by the fact that subjects have different but internally consistent associations between tactile gestures and valence. While subjects did not agree with each other about the correct mapping between gestures, individual subjects were still very consistent in their gesture mappings without knowing or being asked to try to rate similar gestures consistently. Fig. 8 shows how consistently individual subjects rated each gesture. That is what percentage of their responses for gesture N matched the mode of their responses for that gesture.

To assess the relationship between the authored tactile gestures and the valence/arousal recognition, we determined the correlation between the tactile gestures and the recognition of emotional recognition (valence-arousal) by performing ANOVA analysis. Results from the ANOVA analysis indicate that the specific tactile gestures produced higher means than the means obtained from other tactile gestures when the corresponding valence-arousal response is expected.

The balanced one-way ANOVA of the proposed tactile gestures was performed for the high valence – high arousal recognition. Very small p values for all the four tactile gestures that are obtained from ANOVA ($p_{LVLA} = 3.70e^{-8}$, $p_{HVLA} = 1.03e^{-9}$, $p_{LVHA} = 6.33e^{-8}$, $p_{HVHA} = 1.90e^{-16}$) indicate that at least one valence-arousal sample mean is significantly different from the other valence-arousal sample means. The type of tactile gesture whose sample mean is significantly different from the other can be statistically distinguished and decoded from the other tactile gestures by observing the accuracy rate of the corresponding gesture (Fig. 7). The accuracy rate for high valence – high arousal recognition is much higher than the false detections (an average of 79% accurate detection and less than 10% false recognitions for other tactile gestures). Therefore, tactile gesture 4 (HVHA) contains the mean value of valence-arousal significantly higher than that of the other tactile gestures. Therefore, tactile gesture 4 is highly correlated to high arousal – high valence. Similarly, tactile gesture 3 is highly correlated to high arousal

– low valence. A similar ANOVA analysis can be conducted to demonstrate the correlation between low valence – low arousal and tactile gesture 1 (LVLA) and between high valence – low arousal and tactile gesture 2 (HVLA).

D.Discussion

The software design and hardware implementation proved effective allowing for arbitrary gestures to be generated and tested easily. In particular, the implementation of video-based gesture generation system allowed for online experimentation using a live camera that aided in the generation of initial gesture sets. Additionally, this implementation provided live visual feedback that drastically reduced debugging and gesture testing times.

From the result of Fig. 6, we can conclude that while universally intuitive valence gestures might not be possible, it should be possible and feasible to train subject specific gestures that those subjects consistently match to a given valence. Furthermore, it is clear that there are effective tactile gestures that stimulate arousal reactions, universally, and consistently.

While this study aimed to find gestures sets that were intuitive, accurate, and effective at transmitting the six fundamental emotions, there is still much work to be done in the area of haptic emotion transmission. The gesture space is both vast and largely unexplored, and together with the added dimensions of vibration frequency, intensity functions, and actuator placement it is unlikely that the gestures described here are truly optimal. Moreover, while finding gesture sets and devices that can transmit six emotions is an important milestone, a truly successful system should aim at more nuanced information delivery. In particular, systems that would encode gestures emotional spectrums rather than discrete labels. An ability to do this would render a much more fluid experience that better captures human emotional states.

Finally, just as many emotion recognition systems today achieve higher accuracies by performing automatic training on individual subjects, a truly adaptive emotion display system would take into consideration the large subject-to-subject variability of emotional elicitation. Such a system would incorporate machine learning capabilities to automatically derive customized displays that adapt to individual users.

V.CONCLUSION

In this paper, we presented a system for authoring tactile gestures using hand gestures. The proposed system provides an intuitive, easy way to design and test tactile gestures for various applications. A case study for authoring tactile gestures for emotional stimulation is also presented. Findings from this case study show opportunities and promises to author tactile gestures for the communication of emotions. In future study, we plan to author tactile gestures to enhance emotional reactions for use in the film industry. Another interesting future direction includes a thorough investigation of the contribution of tactile gesture properties towards enhancing the user quality of experience (such as intensity, frequency, motion type (continuous versus discontinuous), direction of tactile stimulation, and body parts where the tactile stimulation must be applied).

REFERENCES

[1] M. Reiner, “The Role of Haptics in Immersive Telecommunication Environments,” IEEE Transactions on Circuits and Systems for Video Technology, 14(3): 392–401, 2004.
[2] M. A. Eid and H. Al Osman, "Affective Haptics: Current Research and Future Directions," IEEE Access, vol. 4, pp. 26-40, 2016.
[3] M. Eid, M. Orozco, and A. El Saddik, “A guided tour in haptic audio visual environments and applications,” International Journal of Advanced Media and Communication, vol. 1, no. 3, pp. 265-297, 2007.
[4] F. Danieau, A. L´ecuyer, P. Guillotel, J. Fleureau, N. Mollet, M. Christie, “Enhancing audiovisual experience with haptic feedback: a survey on HAV,” vol. 6, pp. 193–205, 2013.
[5] H.Y. Joung and E.Y. Do, “Tactile hand gesture recognition through haptic feedback for affective online communication,” 6th international conference on Universal access in human-computer interaction: users diversity - Volume Part II (UAHCI'11), Springer-Verlag, Berlin, Heidelberg, 555-563.
[6] L. Bonanni, C. Vaucelle, J. Lieberman, and O. Zuckerman, “TapTap: a haptic wearable for asynchronous distributed touch therapy,” CHI '06 Extended Abstracts on Human Factors in Computing Systems (CHI EA '06), pp. 580-585, 2006.
[7] P. Lemmens, F. Crompvoets, D. Brokken, J. van den Eerenbeemd, and G. de Vries, “A body-conforming tactile jacket to enrich movie viewing,” EuroHaptics conference and Symposium on Haptic Interfaces for Virtual Environment and Teleoperator Systems, pp. 7–12, 2009.
[8] J. Cha, M. Eid, A. Barghout, A.S.M.M Rahman, and A. El Saddik, “Hugme: synchronous haptic teleconferencing,” Proceedings of the seventeenth ACM international conference on Multimedia, pp. 1135–1136, 2009.
[9] S. Krishna, S. Bala, T. McDaniel, S. McGuire, and S. Panchanathan, “VibroGlove: an assistive technology aid for conveying facial expressions,” Extended Abstracts on Human Factors in Computing Systems, CHI EA '10, 2010.
[10] Immersion Corporation, http://ir.immersion.com, accessed May 2, 2016.
[11] S. ur Réhman, M. S. L. Khan, L. Li, and H. Li, "Vibrotactile TV for immersive experience," Signal and Information Processing Association Annual Summit and Conference (APSIPA), 2014 Asia-Pacific, Siem Reap, 2014, pp. 1-4.
[12] A. B. Weddle and Hua Yu, "How does audio-haptic enhancement influence emotional response to mobile media?," 2013 Fifth International Workshop on Quality of Multimedia Experience (QoMEX), 2013, pp. 158-163.
[13] M. Rashid, S. A. R. Abu-Bakar, and M. Mokji, “Human emotion recognition from videos using spatio-temporal and audio features,” vol. 29, issue 12, pp 1269-1275, December 2013.
[14] K. Sun, J. Yu, Y. Huang and X. Hu, "An improved valence-arousal emotion space for video affective content representation and recognition," Multimedia and Expo, 2009. ICME 2009. IEEE International Conference on, New York, NY, 2009, pp. 566-569.
[15] V.V. Kryssanov, E.W. Cooper, H. Ogawa and I. Kurose, "A computational model to relay emotions with tactile stimuli," 3rd International Conference on Affective Computing and Intelligent Interaction and Workshops, pp. 1-6, 2009.
[16] F. Arafsha, K. Masudul Alam, and A. Saddik, “Design and development of a user centric affective haptic jacket,” Multimedia Tools and Applications, vol. 74, no. 9, pp. 3035-3052, 2015.
[17] A. Mazzoni and N. Bryan-Kinns, "How does it feel like? An exploratory study of a prototype system to convey emotion through haptic wearable devices," 7th International Conference on Intelligent Technologies for Interactive Entertainment (INTETAIN), pp. 64-68, 2015.
[18] F. Danieau, J. Fleureau, A. Cabec, P. Kerbiriou, and P Guillotel "Framework for enhancing video viewing experience with haptic effects of motion," IEEE Haptics Symposium (HAPTICS), pp. 541-546, 2012.
[19] A. Schaefer, F. Nils, X. Sanchez, and P. Philippot, “Assessing the effectiveness of a large database of emotion-eliciting films: A new tool for emotion researchers,” Cognition and Emotion, 24(7), 1153–1172, 2010.