

Automated Analysis of the Configuration and Timing of Facial Expression

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Both the configuration of facial features and the timing of facial actions are important to emotion and communication (Ekman, 1992; Frank, Ekman, & Friesen, 1993). The papers here (Cohn, Zlochower, Lien, & Kanade, 1999; Schmidt, Cohn, & Tian, in press) represent the work of my interdisciplinary group of behavioral and computer scientists to develop and apply a computer-vision based approach, which we refer to as Automated Face Analysis (AFA), to these aspects of facial expression. What follows is a summary of our progress with AFA in the recognition and analysis of facial action units and emergent applications to problems in emotion theory and clinical practice.

Automated facial action unit recognition.

Cohn et al. described the first version of AFA in 1999. Since then, we have made three primary advances in automated facial action unit recognition. First, of the 30 action units that have a known anatomic basis (Kanade, Cohn, & Tian, 2000), AFA can now recognize 20 action units (Cohn, Xiao, Moriyama, Ambadar, & Kanade, in press; Tian, Kanade, & Cohn, 2001, 2002; Xiao, Moriyama, Kanade, & Cohn, in press), focusing on the ones most common in studies of emotion and related research (Cohn, Schmidt, Gross, & Ekman, 2002; Sayette, Cohn, Wertz, Perrott, & Parrott, 2001).

Second, AFA now recognizes action units both singly and in combination (Tian et al., 2001). Action unit combinations pose technical challenges because many action units modify the appearance of ones with which they co-occur, analogous to co-articulation effects in speech. The ability to recognize action units in combinations is a

critical advance, because possible action unit combinations number in the thousands. If AFA had to “learn” each combination separately, action unit recognition would quickly become intractable, because it would be impossible to obtain enough examples of each possible combination to train the system. Recognition of action unit combinations is also important because it suggests that AFA can make human-like perceptual judgments. That is, AFA can recognize common features of action units even when they are modified by their occurrence in novel patterns.

Third, AFA now recognizes action units as they occur spontaneously. In directed facial action tasks, head motion is relatively minor and typically parallel to the image plane of the camera. Affine or perspective normalization is adequate to control for this type of head motion (Lien, Kanade, Cohn, & Li, 2000). In spontaneous facial behavior, moderate to large head motion with out-of-plane rotation and occlusion is common, and a more complicated transformation becomes necessary. To separate rigid (head motion) from non-rigid (expression) motion in spontaneous facial behavior, we developed a 3-D head tracker (Xiao, Moriyama, Kanade, & Cohn, in press). The tracker precisely estimates the 6 degrees of freedom of head motion: movement in the horizontal and vertical planes (i.e., translation), movement toward and away from the camera (i.e., scale), rotation, pitch, and yaw. Once these parameters are estimated, the face image is stabilized, by warping each frame to a common orientation and size. In this way, motion due to expression is not confounded by rigid head motion. This development means that we can begin to use AFA to

recognize action units in spontaneous facial behavior.

As an initial test of AFA's ability to recognize action units in spontaneous facial behavior, we tested AFA for AU 45 (blink) and flutter in image data of 2-person interviews from Frank and Ekman (1977). These image data were originally collected to study deception. In 1-minute samples from 10 male subjects of diverse ethnic background, AFA proved 98% accurate for blink detection (Cohn et al., in press; Moriyama et al., 2002). In current work, we extend this testing in spontaneous facial behavior to the action units recognized previously in directed facial action tasks. With further development, we anticipate that AFA can reduce and eventually eliminate the need for manual FACS coding in behavioral research among other settings.

Temporal organization of action units.

The paper by Schmidt, Cohn, and Tian (in press) illustrates the power of AFA to analyze dynamic changes in facial features. Using feature tracking of lip-corner movement, we first found that the onset phase of AU 12, defined as the longest continuous increase in oblique lip-corner movement, is more intense – has higher amplitude – when occurring in a social context than in a solitary context. This result extended Fridlund's finding (1991), by showing that differences in smile amplitude related to social context occur within the initial onset phase of the smile. We then showed that regardless of context and the occurrence of other action units, including AU 6 and masking movements, the onset phase of spontaneous smiles has highly consistent temporal characteristics. The larger the amplitude of the smile onset, the faster is its peak velocity. This finding is consistent with ballistic motion and the hypothesis that the onset phase is a

stereotypic signal. Previous attempts to examine this issue were limited to relatively global measures, such as the duration of specific action units (Frank et al., 1993). Because AFA affords quantitative measures of rate of change – velocity – of facial motion, we were able to use more rigorous kinematic analyses to test hypotheses about the timing of spontaneous smiles.

Deliberate smiles often appear false even when they include Duchenne's marker (AU 6). Why? In a preliminary study (Cohn & Schmidt, 2003), we found that an important visual cue signaling a smile as deliberate or spontaneous appears to be the timing of the onset phase. While the parameters of the onset phase of diverse spontaneous smiles are highly consistent, the same does not apply for deliberate smiles. In the latter, the timing parameters are uncorrelated (Cohn & Schmidt, 2003). This finding is consistent with Rinn's (1984) hypothesis that separate motor pathways control voluntary and spontaneous facial expression. Our findings suggest further that any differences in motor control between Duchenne and non-Duchenne smiles (Frank et al., 1993) must occur after the initial onset phase. By quantifying motion vectors of facial features, AFA enables more in-depth investigation of the temporal organization and motor control of facial expression than would otherwise be possible.

Applications. We have begun to use AFA to investigate theoretical and applied issues of facial expression even while this method is still in development.. These include facial asymmetry in biometrics (Liu, Schmidt, Cohn, & Mitra, in press), emotion expression in adults (Schmidt, Cohn, & Liu, submitted) and in infants (Bolzani-Dinehart, Messinger, Acosta, Cassel, Ambadar, & Cohn, 2003), variation in the timing of spontaneous smiles in depression (with Ian

Reed), mother-infant reciprocity and synchrony (Cohn, Tian, & Forbes, 2000), discrimination between spontaneous and deliberate expressions (Cohn & Schmidt, 2003; Zlochower, 2001), and individual differences in facial expression (Cohn, Schmidt, Gross, & Ekman, 2002). We also are investigating the integration of facial and vocal expression in emotion and paralinguistic communication (Cohn & Katz; 1998; Fox, Gross, Cohn, de Chazal, & Reilly, submitted).

In clinical applications, we have used AFA to assess facial neuromuscular impairment (Wachtman, 2001), Bell's phenomenon (Deleyiannis, Van Swearingen, Wachtman, Ambadar, Schmidt, & Cohn, in preparation), and the relation between impairment in smiling and depressive symptomatology (Van Swearingen, Cohn, & Bajaj-Luthra, 1999). Kenneth Prkachin, Patricia Solomon, and I are using AFA to develop improved measures of pain from facial behavior. In assessment of psychopathology, diagnostic interviews lack systematic ways of utilizing behavioral observation, and diagnosis and assessment are limited almost entirely to verbal responses. As an adjunct to clinical interviewing, AFA will provide the clinical researcher and clinician with objective measures of affective behavior to include in diagnosis and assessment of treatment efficacy.

With the development of computer facial animation, there is an emerging need to provide normative data on multimodal communication. While a great deal is known about the relation between facial action units and emotion and communicative intentions, as illustrated by this volume, we know relatively little about the timing of facial actions in relation to each other and to spontaneous gesture and vocalization. With the addition of computer vision based

analyses of gesture and gait and acoustic analyses of prosody, we are on the verge of modeling multimodal behavior for a deeper understanding of human behavior and a wide range of theoretical, clinical, and technological uses.

References

- Bolzani-Dinehart, L., Messinger, D. S., Acosta, S., Cassel, T., Ambadar, Z., & Cohn, J. F. (2003, April). A *dimensional approach to infant facial expressions*. Poster session presented at the Society for Research in Child Development, Tampa, FL.
- Cohn, J. F. & Katz, G. S. (1998). Bimodal expression of emotion by face and voice. *ACM and ATR Workshop on Face/Gesture Recognition and Their Applications* (pp. 41-44). Bristol, United Kingdom.
- Cohn, J. G. & Schmidt, K. S. (Invited)(2003). The timing of facial motion in posed and spontaneous smiles. *Proceedings of the 2nd International conference on Active Media Technology (ICMAT 2003)*(pp. 57-72). Chongqing, China.
- Cohn, J. F., Schmidt, K., Gross, R., & Ekman, P. (2002). Individual differences in facial expression: Stability over time, relation to self-reported emotion, and ability to inform person identification. *Proceedings of the International Conference on Multimodal User Interfaces (ICMI 2002), USA*. 491-496.
- Cohn, J. F., Tian, Y. L., & Forbes, E. (2000, July). Detection, tracking and classification of facial action units in infant caregiver facial expression. *International Conference on Infant Studies*. Brighton, England.
- Cohn, J. F., Xiao, J., Moriyama, T., Ambadar, Z., & Kanade, T. (in press).

- Automatic recognition of eye blinking in spontaneously occurring behavior. *Behavior Research Methods, Instruments, and Computers*.
- Cohn, J. F., Zlochower, A., Lien, J., & Kanade, T. (1999). Automated face analysis by feature point tracking has high concurrent validity with manual FACS coding. *Psychophysiology*, 36, 35-43.
- Ekman, P. (1992). *Telling lies: Clues to deceit in the marketplace, politics, & marriages*. New York: W. W. Norton.
- Fox, N., Gross, R., Cohn, J. F., de Chazal, P., & Reilly, R. (2003). *Person identification based on the integration of audio, image and video based methodologies*. Manuscript submitted for publication.
- Frank, M. & Ekman, P. (1997). The ability to detect deceit generalizes across different types of high-stake lies. *Journal of Personality & Social Psychology*, 72, 1429-1939.
- Frank, M. G., Ekman, P., & Friesen, W. V. (1993). Behavioral markers and recognizability of the smile of enjoyment. *Journal of Personality and Social Psychology*, 64, 83-93.
- Fridlund, A. J. (1991). Sociality of solitary smiling: Potentiation by an implicit audience. *Journal of Personality and Social Psychology*, 60, 229-240.
- Kanade, T., Cohn, J. F., & Tian, Y. (2000). Comprehensive database for facial expression analysis. *Proceedings of the fourth IEEE International conference on Automatic Face and Gesture Recognition (FG2000)* (pp. 46-53). Grenoble, France.
- Liu, Y., Schmidt, K., Cohn, J. F., & Mitra, S. (in press). Facial asymmetry quantification for expression invariant human identification. *Computer Vision and Image Understanding*.
- Moriyama, t., Kanade, T., Cohn, J. F., Xiao, J., Ambadar, Z., Gao, J., et al. (2002). Automatic recognition of eye blinking in spontaneously occurring behavior. *Proceedings of the International Conference on Pattern Recognition (ICPR 2002)*, Canada, 4, 78-81.
- Rinn, W. E. (1984). The neuropsychology of facial expression: A review of the neurological and psychological mechanisms for producing facial expressions. *Psychological bulletin*, 95, 52-77.
- Sayette, M. A., Cohn, J. F., Wertz, J. M., Perrott, M. A., and Parrott, D. J. (2001). A psychometric evaluation of the Facial Action Coding system for assessing spontaneous expression. *Journal of Nonverbal Behavior*, 25, 167-186.
- Schmidt, K. L. & Cohn, J. F. (2001). Human facial expressions as adaptations: Evolutionary questions in facial expression. *Yearbook of Physical Anthropology*, 44, 3-24.
- Schmidt, K. L., Cohn, J. F., & Liu, Y. (2003). *The role of structural facial asymmetry in asymmetry of peak facial expressions*. Manuscript submitted for publication.
- Schmidt, K., Cohn, J. F., & Tian, Y. L. (in press). Signal characteristics of spontaneous facial expressions: Automatic movement in solitary and social smiles. *Biological Psychology*.
- Tian, Y., Kanade, T., & Cohn, J. F. (2000). Eye-state detection by local regional information. In T. Tan, Y. Shi, & W. Gao (Eds.). *Proceedings of the International Conference on Multimodal User Interfaces (ICMI 2000)*, China. *Lecture Notes in Computer Science*, 1948, 143-150. New York: Springer.
- Tian, Y. L., Kanade, T., & Cohn, J. F. (2001). Recognizing action units for facial expression analysis. *IEEE*

- Transactions on Pattern Analysis and Machine Intelligence*, 23, 97-116.
- Van Swearingen, J. M., Cohn, J. F., & Bajaj-Luthra, A. (1999). Specific impairment of smiling increases severity of depressive symptoms in patients with facial neuromuscular disorders. *Journal of Aesthetic Plastic Surgery*, 23, 416-423.
- Wachtman, G. S., Cohn, J. F., Van Swearingen, J.M., & Manders, E. K. (2001). Automated tracking of facial features in facial neuromotor disorders. *Plastic and Reconstructive Surgery*, 107, 1124-1133.
- Xiao, J., Moriyama, T., Kanade, T., & Cohn, J. F. (in press). Robust full-motion recovery of head by dynamic templates and re-registration techniques. *International Journal of Imaging Systems and Technology*.
- Zlochow, A. (2001) *Automated face analysis (AFA) distinguishes deliberate from spontaneous smiles on the basis of quantitative differences in intensity and asymmetry*. Unpublished doctoral dissertation, University of Pittsburgh.

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