Context Aware Multi-Sensor Systems

Emil M. Petriu

School of Electrical Engineering and Computer Science
University of Ottawa

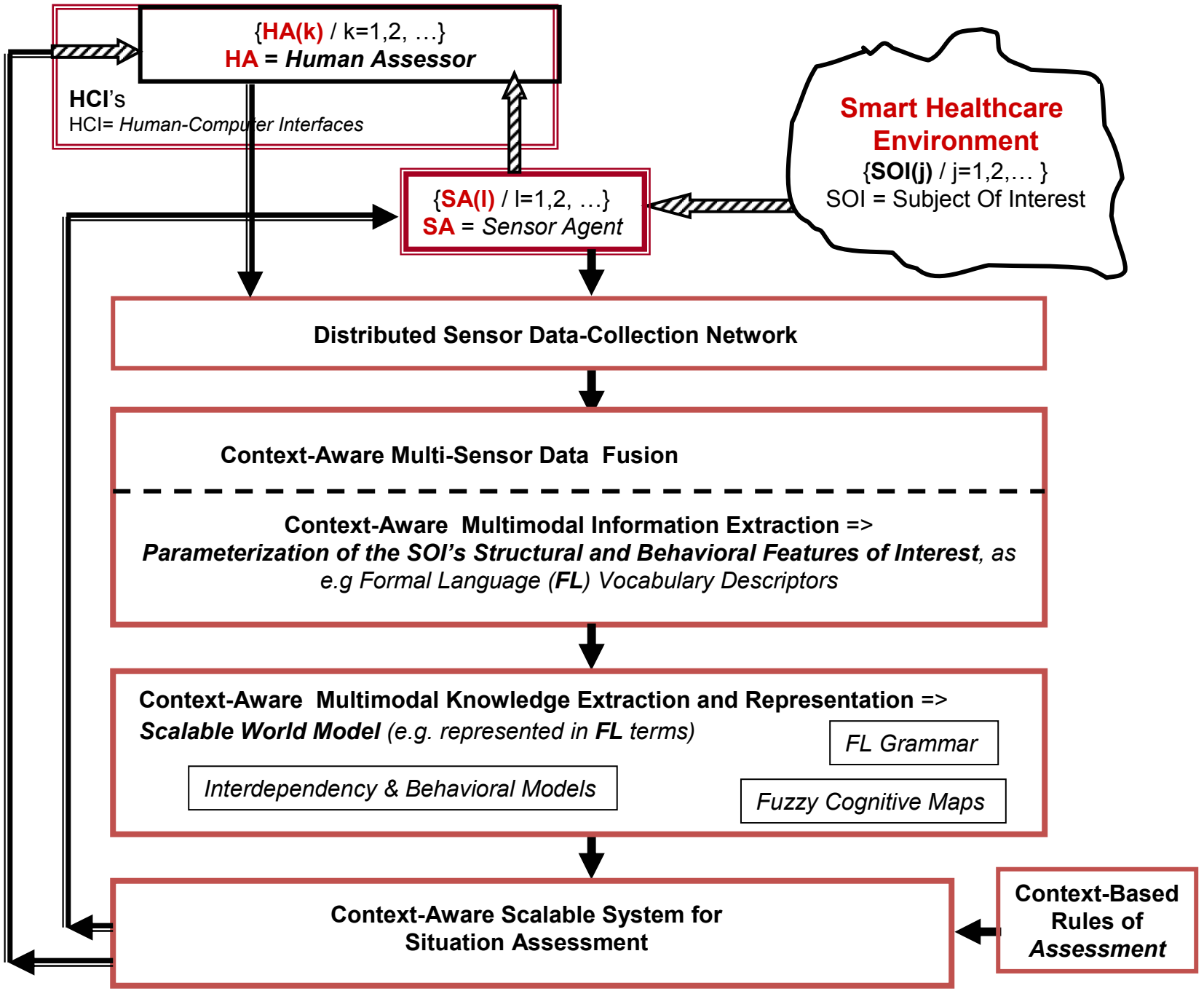
hSITE Annual Research Review
June 04-05, 2012

Our team works on the development of **Clinical Care Grade Solutions for Information Gathering from the Complex Multi-Sensor Environments** (*Project 2.2*) for **Critical Care** (*Context* #1) and **Home Care** (*Context #2*) applications.

We are concentrating on two tasks: Task 2.2.1 *Sensor Information Acquisition and Feature Extraction for the real-time interpretation of patient and workflow information from video feeds*, and Task 2.2.3 *Context Aware Multimodal Information Fusion.*

We continued evaluating *real-time algorithms developed for the hand gesture recognition in combination with the body-posture analysis*. We also studied *context inference engine architectures based on statistic and machine learning techniques* in the Context Management Framework studied by the group working on Task 2.1.2.

We continued investigating *hardware/software real-time implementation solutions for the body posture recovery, hand gesture and face expression recognition* for the experimental multi-sensor setup to be deployed in home care (Context #2) applications


{HA(k) / k=1,2, …}
HA = Human Assessor
HCI's
HCI= Human-Computer Interfaces
{SA(l) / l=1,2, …}
SA = Sensor Agent
Smart Healthcare Environment
{SOI(j) / j=1,2,… }
SOI = Subject Of Interest
Distributed Sensor Data-Collection Network
Context-Aware Multi-Sensor Data Fusion
Context-Aware Multimodal Information Extraction =>
Parameterization of the SOI's Structural and Behavioral Features of Interest, as
e.g Formal Language (FL) Vocabulary Descriptors
Context-Aware Multimodal Knowledge Extraction and Representation =>
Scalable World Model (e.g. represented in FL terms)
FL Grammar
Interdependency & Behavioral Models
Fuzzy Cognitive Maps
Context-Aware Scalable System for Situation Assessment
Context-Based Rules of Assessment

Smart-healthcare environments incorporate a multitude of *time-* and *location-dependent sensor-data*, from which is possible to extract relevant information about *patient condition* (identity, location, physiological parameters), *clinical staff status* (identity, location, readiness), *specific clinical activities, medication, supplies, and equipment status* (identity, location, specs), *operating room readiness, state of the ambient environment*, etc.

Context understanding in these environments require dynamic sensor configurations and measurement capabilities similar to human perception, which pose a considerable challenge to the traditional sensor fusion methods. *Location, together with time, represents one of the basic contextual information to any context-aware system*.

Research Group

Name of student / PDF	Program	Task	Start date	Graduation	Funded by:
N. Dardas	Ph.D.	2..2.1.	Jan. 2010	Aug. 2014	hSITE & other
Md. A. Hossain	PhD	2.2.3	Jan. 2010	July 2014	hSITE & other
Haifa Maamar	PhD	2.2.3	Jan. 2010	Aug. 2014	hSITE & other
Alexandros Stathakis	MASc.	2.2.1	Sept. 2010	Aug. 2012	hSITE & other
Feng Shi	PhD	2.2.3	Sept 2010	Aug/ 2014	hSITE & other
Eric Torunski	PhD	2.2.3	Sept. 2010	Aug. 2014	hSITE & other
Adrian Taylor	PhD	2.2.3	Sept. 2010	Aug. 2014	hSITE & other
Suzan Ureten	PhD	2.2.1	Sept. 2010	Aug. 2014	hSITE & other
Yisu Zhao	PhD	2.2.1	Jan 2010	Aug. 2014	hSITE & other

We met the objectives for the following milestones:

- [**M2.8.c** / *Task 2.2.1*] Evaluation of the linguistic pattern recognition algorithms developed for the hand gesture recognition in combination with the body-posture analysis, [Dard11]
- [**M2.14.b** / *Task 2.2.3*] Study of context inference engine architectures based on statistic and machine learning techniques in the Context Management Framework studied by the group working on Task 2.1.2, [Prec12], [Zhao12b].
- [**M2.14c** / *Task 2.2.3*] Development of Context inference engine based on statistic and machine learning techniques, [Shi11]
- [**M2.15a** / *Task 2.2.1*] Development of new algorithms for video interpretation of the human face expression and eye gaze in combination with hand gesture and body posture analysis, [Zhao12a], [Zhao12b], [Zhao11]
- [**D/P 2.d**] Further deployment and evaluation of the experimental sensor setup. [Maam11], [Foua11], [Petr11], [Drag11], [Stat11]
- [**D/P 2.e**] Hardware/software implementation of the real-time algorithms for the body posture recovery and hand gesture recognition into the multi-sensor setup. [Zhao12a], [Zhao12b], [Toru11]

We are currently working on the following milestones

- [**M2.15b** / *Task 2.2.1*] Development of new algorithms for video interpretation of the human face expression and eye gaze in combination with hand gesture and body posture analysis.

- [**M2.16a** / *Task 2.2.3*] Development of a rule-based multi-sensor fusion system using the Context Management Framework midleware developed in Task 2.1.2 for healthcare applications in the homecare context.

- [**D/P**] Integration of *Kinect* camera and specific image processing algorithms for the human face expression and eye gaze, hand gesture and body posture with the multi sensor setup

Video interpretation of human face expression and eye gaze in combination with hand gesture and body posture

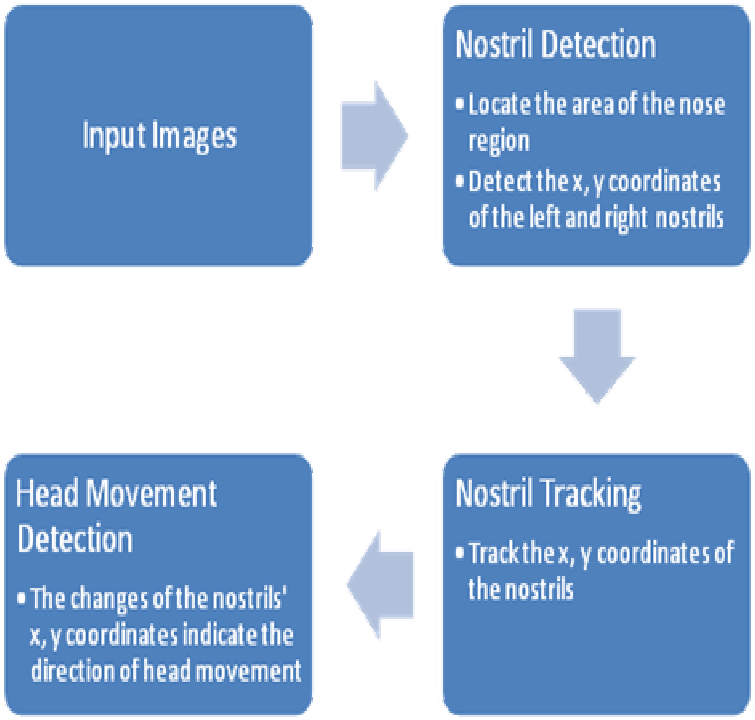
[Zhao12b] Y. Zhao, X. Wang, M. Goubran, T.E. Whalen E. M. Petriu, “Human Emotion and Cognition Recognition from Body Language of the Head Using Soft Computing Techniques,” (in press), *Journal of Ambient Intelligence and Humanized Computing*, Springer Berlin / Heidelberg.

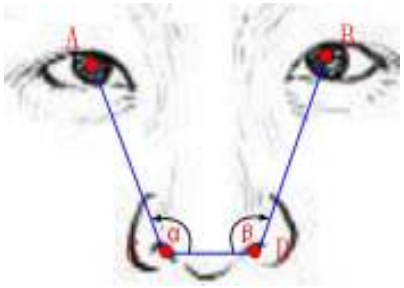
[Zhao12a] Y. Zhao, M.D. Cordea, E.M. Petriu, T.E. Whalen, "Multimedia-Based Affective Human-Computer Interaction," in *Multimedia Image and Video Processing* (2nd edition), (L.Guan, Y. He, S.-Y. Kung Edit.), pp. 173-196, CRC Press, 2012,

Video interpretation of human face expression and eye gaze in combination with hand gesture and body posture

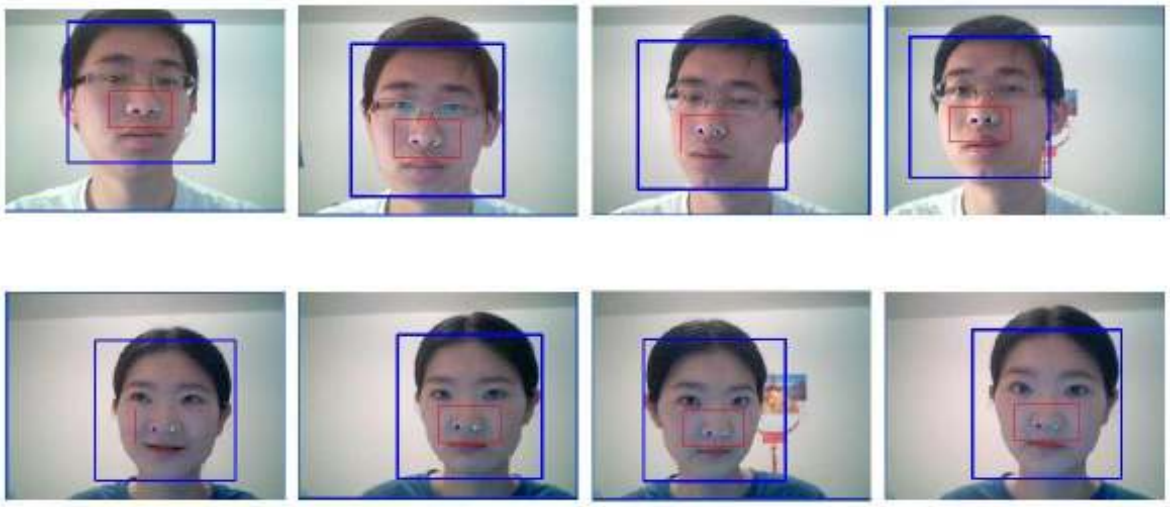
- We explored new ways to distinguish between subtler emotions and cognitions by integrating information from the body language of the head. In particular, we concentrated on integrating *facial expressions*, *eye gaze direction*, and *head movements*.
- These three modalities were detected and mapped into emotional and cognitive states by a fuzzy inference system. We defined the fuzzy rules based on a questionnaire answered by non-expert participants. Although the creation of the fuzzy rules is culture-based, the idea of integrating the different modalities of the body language of the head is generic enough to be used by different target user groups in different cultures.
- Experimental results show that our method can be used to successfully recognize ten different emotions and cognitions. In the future, other modalities such as hand gestures and body postures will be combined with head information to detect a broader range of emotions and cognitions more precisely.

Video interpretation of human face expression and eye gaze in combination with hand gesture and body posture



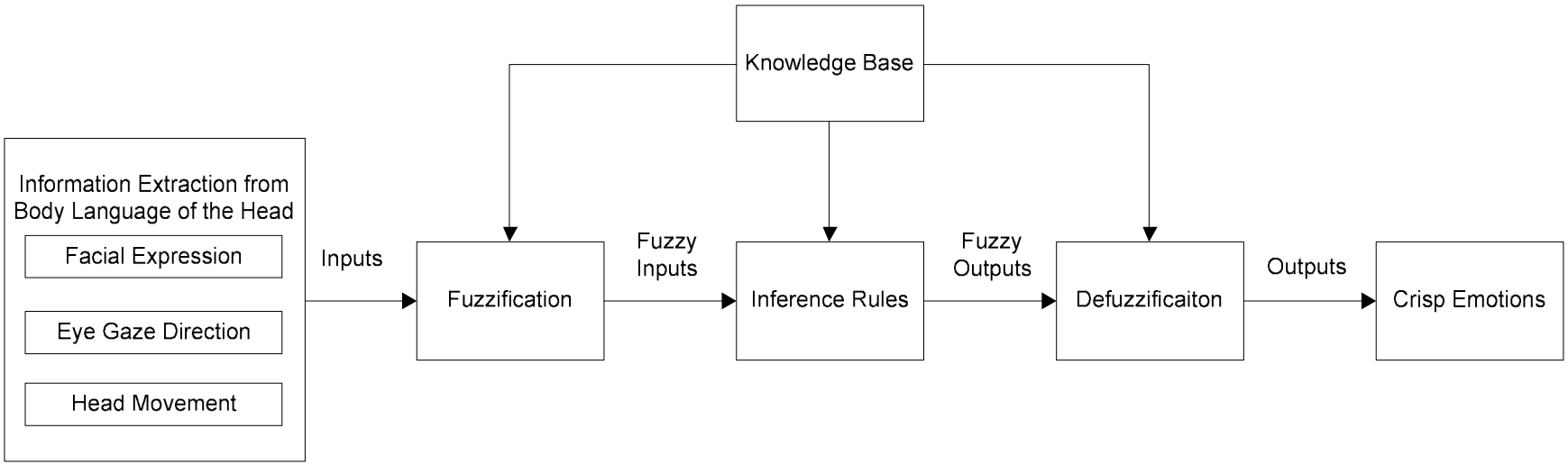


Video interpretation of human face expression and eye gaze in combination with hand gesture and body posture

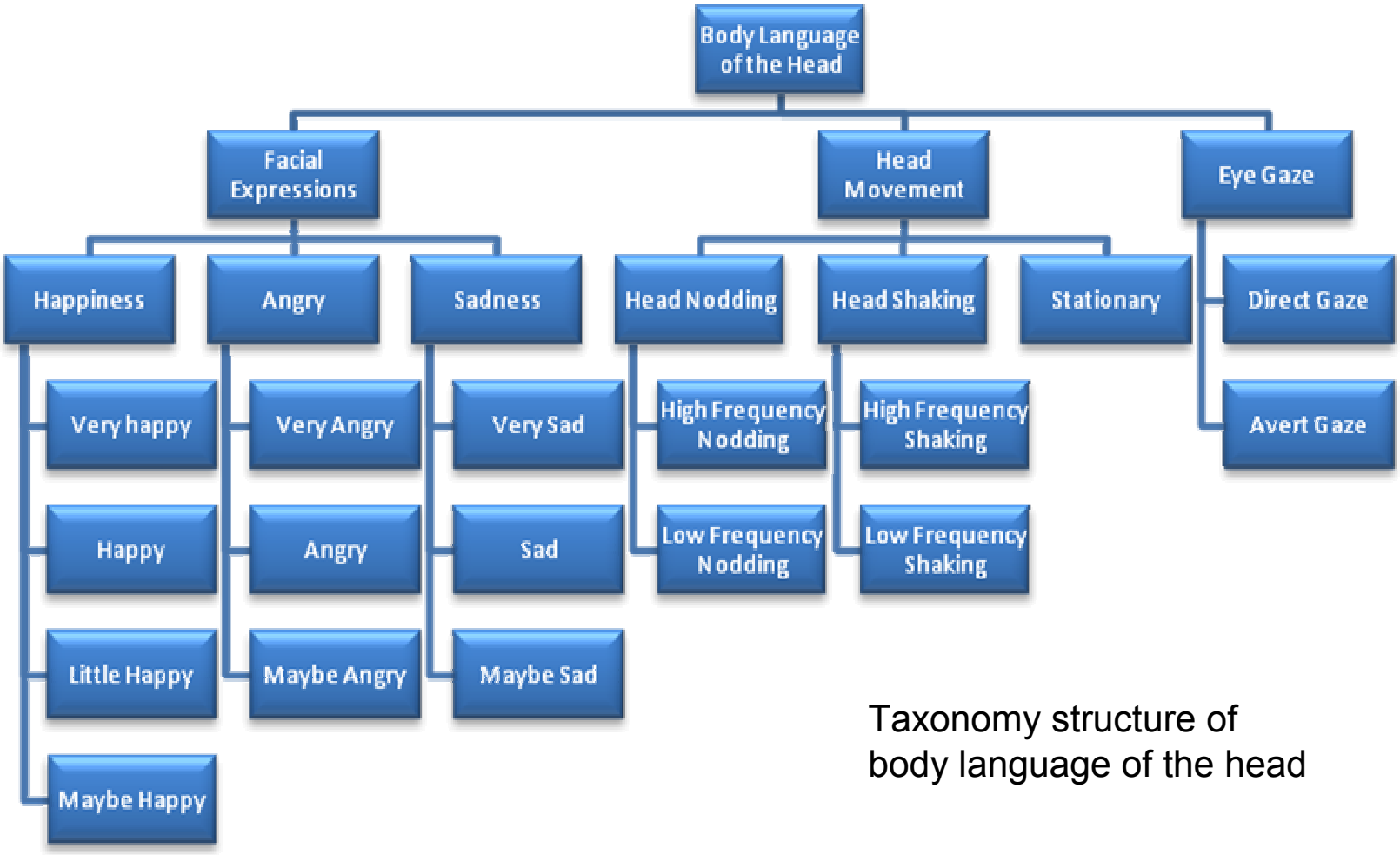


Examples of nostril detection results using Webcam images

Video interpretation of human face expression and eye gaze in combination with hand gesture and body posture

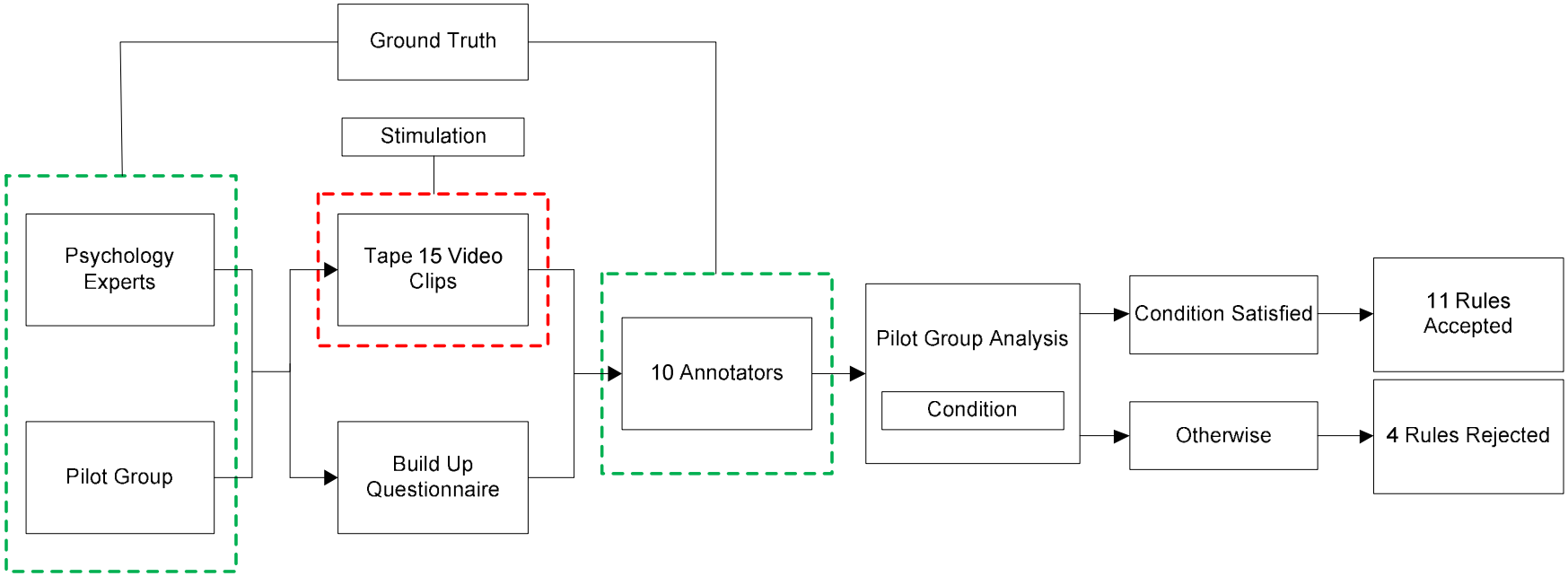


Video interpretation of human face expression and eye gaze in combination with hand gesture and body posture



Taxonomy structure of body language of the head

Video interpretation of human face expression and eye gaze in combination with hand gesture and body posture



Procedure for creating fuzzy rules

Video interpretation of human face expression and eye gaze in combination with hand gesture and body posture

Rule 1: IF (*Happiness* is *Very-Happy*) AND (*Head-Movement* is *High-Frequency-Nodding*) AND (*Eye-Gaze* is *Direct-Gaze*) THEN (*Emotion-Set-A* is *Agree*)
Rule 2: IF (*Happiness* is *Happy*) AND (*Head-Movement* is *Low-Frequency-Nodding*) AND (*Eye-Gaze* is *Direct-Gaze*) THEN (*Emotion-Set-A* is *Admire*)
Rule 3: IF (*Happiness* is *Little-Happy*) AND (*Head-Movement* is *Low-Frequency-Shaking*) AND (*Eye-Gaze* is *Direct-Gaze*) THEN (*Emotion-Set-A* is *Decline*)
Rule 4: IF (*Happiness* is *Maybe-Happy*) AND (*Head-Movement* is *Low-Frequency-Nodding*) AND (*Eye-Gaze* is *Avert-Gaze*) THEN (*Emotion-Set-A* is *Thinking*)
Rule 5: IF (*Happiness* is *Maybe-Happy*) AND (*Head-Movement* is *Stationary*) AND (*Eye-Gaze* is *Avert-Gaze*) THEN (*Emotion-Set-A* is *Thinking*)
Rule 6: IF (*Angry* is *Very-Angry*) AND (*Head-Movement* is *Low-Frequency-Shaking*) AND (*Eye-Gaze* is *Direct-Gaze*) THEN (*Emotion-Set-B* is *Resentment*)
Rule 7: IF (*Angry* is *Maybe-Angry*) AND (*Head-Movement* is *High-Frequency-Shaking*) AND (*Eye-Gaze* is *Direct-Gaze*) THEN (*Emotion-Set-B* is *Disagree*)
Rule 8: IF (*Sadness* is *Very-Sad*) AND (*Head-Movement* is *Low-Frequency-Shaking*) AND (*Eye-Gaze* is *Avert-Gaze*) THEN (*Emotion-Set-C* is *Distressed*)
Rule 9: IF (*Sadness* is *Sad*) AND (*Head-Movement* is *High-Frequency-Nodding*) AND (*Eye-Gaze* is *Avert-Gaze*) THEN (*Emotion-Set-C* is *Guilty*)
Rule 10: IF (*Sadness* is *Maybe-Sad*) AND (*Head-Movement* is *Low-Frequency-Shaking*) AND (*Eye-Gaze* is *Direct-Gaze*) THEN (*Emotion-Set-C* is *Disappointed*)
Rule 11: IF (*Angry* is *Angry*) AND (*Head-Movement* is *High-Frequency-Shaking*) AND (*Eye-Gaze* is *Avert-Gaze*) THEN (*Emotion-Set-B* is Annoyed)

Video interpretation of human face expression and eye gaze in combination with hand gesture and body posture

Example of an image sequence for “Admire” emotion

Head movement = Nodding, 0.8 cycle/sec / Fuzzy variable = 0. 633;
Eye gaze = Direct / Fuzzy variable = 0.887;
Facial expression = Happy / Fuzzy variable = 0.6;

Emotion = Fuzzy output A=0.6, B=n.a., C=n.a. / Emotion = Admire

Publications related to our work undertaken as a direct result of the hSITE technical agenda

[Zhao12b] Y. Zhao, X. Wang, M. Goubran, T.E. Whalen E. M. Petriu, "Human Emotion and Cognition Recognition from Body Language of the Head Using Soft Computing Techniques," (in press), *Journal of Ambient Intelligence and Humanized Computing*, Springer Berlin / Heidelberg.

[Zhao12a] Y. Zhao, M.D. Cordea, E.M. Petriu, T.E. Whalen, "Multimedia-Based Affective Human-Computer Interaction," in *Multimedia Image and Video Processing* (2nd edition), (L.Guan, Y. He, S.-Y. Kung Edit.), pp. 173-196, CRC Press, 2012,

[Prec12] R.-E. Precup, R.-C. David, E.M. Petriu, S. Preitl, M.-B. Radac, "Fuzzy Control Systems with Reduced Parametric Sensitivity Based on Simulated Annealing," *IEEE Tr. Industrial Electronics*, Vol. 59, No. 8, pp. 3049 – 3061, 2012.

[Maam11] H. R. Maamar, G. R. Alonso, A. Boukerche, E. Petriu, "Energy Management Control for Supplying Partner Selection Protocol in Mobile P2P 3D Streaming," *Concurrency and Computation: Practice and Experience*, Wiley, 2011.

[Foua11] M. Fouad, F. Alsulaiman, A. El Saddik, E.M. Petriu, "Revocable Handwritten Signatures with Haptic Information," *Proc. HAVE 2011 - IEEE Int. Symp. Haptic Audio Visual Environments and Games*, pp. 108 - 111, Qinhuangdao, China, Oct. 2011.

[Shi11] F. Shi, E.M. Petriu, A. Cordeiro, "Human Action Recognition from Local Part Model," *Proc. HAVE 2011 - IEEE Int. Symp. Haptic Audio Visual Environments and Games*, pp. 35 - 38, Qinhuangdao, Hebei, China, Oct. 2011.

[Zhao11] Y. Zhao, X. Wang, E.M. Petriu, "Facial Expression Anlysis using Eye Gaze Information," *Proc. CIMSA 2011 IEEE Int. Conf. on Computational Intelligence for Measurement Systems and Applications,* pp. 7-10, Ottawa, Sep. 2011.

[Dard11] N. Dardas, E.M. Petriu, "Hand Gesture Detection and Recognition Using Principal Component Analysis," *Proc. CIMSA 2011 IEEE Int. Conf. on Computational Intelligence for Measurement Systems and Applications,* pp. 11-16, Ottawa, Sep. 2011.

[Petr11] E.M. Petriu, "Biology-Inspired Multimodal Tactile Sensor System," *Proc. ROSE 2011, IEEE Int. Symp. Robotic and Sensor Environments*, pp. 54-59, Montreal, Sep. 2011.

[Stat11] A.Stathakis, E.M. Petriu, "Robust Pseudo-Random Fiducial Marker for Indoor Localization," *Proc. ROSE 2011, IEEE Int. Symp. Robotic and Sensor Environments*, pp. 19-24, Montreal, Sep. 2011.

[Toru11] E. Torunski, A. El Saddik, E.M. Petriu, "Gesture Recognition on a Mobile Device for Remote Event Generation," *Proc. ICME'2011 Int. Conf. Multimedia and Expo*, pp. 1-6, Barcelona, Spain, July 2011

[Drag11] C.-A. Dragos, S. Preitl, R.-E. Precup, E. M. Petriu, A.-I. Stinean, "A Comparative Case Study of Position Control Solutions for a Mechatronics Application," *Proc. AIM 2011*, *IEEE/ASME Int. Conf. Advanced Intelligent Mechatronics* - pp. 814-819, Budapest, Hungary, 2011.

Thank You !