AfCAI systems: Affective Computing with Context Awareness for Ambient Intelligence. Research proposal.

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1 Introduction

Context-aware systems gained huge popularity over the last decade. Rapid evolution of personal mobile devices such as smartphones, tablets, smartwatches and other types of wearables forced researchers and developers to work on efficient methods for modelling, and processing contextual information. The most recent research in the area of mobile context-aware systems identifies four challenges that should be met by the every context-aware system. These are [1]: intelligibility, efficiency, privacy and robustness. Assuring these requirements is a major challenge for systems that operate in dynamic environment, where contextual information is constantly delivered in a streaming manner. To address the four challenges, in our previous work we proposed a human-readable rule-language that is capable of modeling and processing uncertain knowledge with an efficient rule-engine under the soft real-time constraints. Moreover, knowledge discovery methods from uncertain streaming data were proposed [1].

Context in context-aware systems can be described as *any information that can be used to characterize the situation of an entity* [4]. Such a broad definition allows us to consider a variety of factors as the context: (a) physical, collected using a device's sensors, e.g. ambient light luminance and user location, (b) environmental, obtained via software services, e.g. weather and road traffic, (c) organizational, stored in electronic device, e.g. messages and events in a calendar. All of these values can be treated as a low-level context data. Based on them, a high-level context can be generated, on which some *semantics* is introduced, and a certain *interpretation occurs* e.g. location is understood as "user being at home" or "commuting to the university", also some activities like "giving the regular Wednesday lecture" are recognized.

We assert that a special case of a high-level context may be the *emotional state* of the user. In such a case, number of problems to be solved appear. The most serious are to determine if it is possible to build a high-level emotional state from low-level contextual data and how to do this. We believe, that Jesse Prinz's

Embodied Appraisal Theory [12] may be useful to answer the first question. According to it, emotions are build up by two parts: (a) *form* – bodily changes perception (as in the classical James-Lange theory of emotions [7]) and (b) *content* – relationship between agent and environment. As an example, faster heart rate (*form*) and perception of a loud sudden noise (*content*) build up a fear. The answer to the question of how these low-level blocks (*forms* and *contents*) state high-level emotions is among interests of Affective Computing [10] (AfC).

AfC is an interdisciplinary field of study, where two crucial elements are considered: modes of data collection and ways of interpreting them in correlation with affective states corresponding to emotions. Today most often harvested and processed information are about: speech (prosody: pitch variables, speech rate), body gestures and poses (3D mapping, motion capture techniques), facial expressions (visual analysis and electromyography), physiological monitoring (blood pressure, blood volume pulse, galvanic skin response).

2 Motivation for AfCAI Systems

Basically, we are aiming at developing a technology to detect, identify and interpret human emotional states. We believe, that it can be provided based on the integration of context-aware systems and affective computing paradigms. We are planning to identify and characterize affective context data, and provide knowledge-based models to identify and interpret affects based on this data. A working name for this technology is simply *AfCAI: Affective Computing with Context Awareness for Ambient Intelligence*.

The area of affective computing shares some characteristics with the area of mobile context-aware systems that we studied so far. The environment is highly dynamic in both types of systems, as the biomedical information like heart rate reading or blood pressure may change rapidly. There exist various factors that may have impact on the changes of the biomedical parameters. These factors may not always be observed, or may be delivered to the system with a degree of uncertainty that needs to be handled appropriately. Finally, the user has to be aware of what the system does with such sensitive data as biomedical information. He or she has to understand what is the goal of the system, and should have the ability to adjust the system to follow his or her goals.

We consider a certain hierarchy in interpreting affective context data. In the lowest level, we encounter readings including "physical" context that is delivered by the current mobile phone sensors (temperature, location coordinates), as well as physiological measurements from dedicated biomedical devices (heart rate, skin temperature, galvanic skin response measurement). This data can be considered as objective context. On a higher level, we provide certain conceptualization of this data, that we believe can be provided automatically. Examples include "being at home", or "resting heart rate of given person". Then, on the next level we would like to provide certain interpretation of that conceptualization, which in the case of the affective data could be "relaxed", "excited", or "anxious". In fact, an ultimate level could include identification of causal relations like explanations and prediction.

Detecting changes in emotional context and explaining it with changes in physiological context could be used to build complex profiles of user emotions. Such profiles could be further used by a computer system to better fit the user preferences, or to react on some alarming changes both in emotional and in biomedical contexts. Furthermore, existence of complex profiles of user emotions may lead to creation of general profiles for emotions at all or at specific context which could be used for diversity of cases. Awareness of variation in user emotion in relation to general profile could be then classified as another variable for objective context (weather, location, activity etc.). This general information could be then used for better understanding of user emotions in real situations and better reaction to them. Another case is an introduction of user emotions' awareness into personal artificial assistants, suggestions systems or non-invasive advertisement. It is also valid to discover shortcomings of current generation mobile devices for gathering biomedical context, to be aware and ready to develop tools and methods for future validation and accuracy increase inside framework.

3 Methods and Tools

In our most recent research [2,3] in the area of mobile context-aware systems we aimed at providing methods for uncertain knowledge modelling and mediation, to support user in adjusting the system to his or her personal preferences and habits. Moreover we wanted to improve management of uncertain and incomplete knowledge management in order to enhance the self-adaptation capabilities of the system. In particular we proposed:

1. **Uncertainty handling** – Improvement of knowledge management methods for imperfect or incomplete context that allow for modelling dynamics of the uncertainty and provide efficient reasoning under incomplete or missing data.
2. **Adaptability** – Proposal of new modelling and context processing methods that improves the system capabilities to self-adaptability in dynamic mobile environments.
3. **Mediation** – Formulation of mediation techniques for improving system intelligibility and adaptability, and help in resolving uncertainty in data.

Both the rapidly changing and uncertain nature of the physiological context, and the need to explain to the user the system behaviour makes the deliverables of our previous research fit perfectly the AfCAI motivations.

The first aim of our research is to provide:

1. an integrated sensory framework which will use wearable physiological and biomedical hardware sensors for detection of user affects.
2. computational models for affect identification and interpretation

Our aim is to provide an integrated sensory framework which will use wearable physiological and biomedical hardware sensors for detection of user affects.

We are also oriented to feed mobile context-aware systems with this data. These assumptions lead us to the conclusion that we need to use some small mobile devices to acquire sensory data. Based on our experience with various hardware, four devices were selected as the most promising ones:

Empatica E4. An advanced sensory wristband based on the technologies previously developed in the Affective Computing division of MIT Media Lab 1. Blood volume pulse and galvanic skin response sensors, as well as infrared thermopile and accelerometer are on board. It has already been used in number of research projects [5,6,8,9,11,13,14].

Microsoft Band 2. Band developed mainly for tracking fitness goals. Equipped with optical heart rate, skin temperature and galvanic skin response (GSR) sensors as well as accelerometer, available through well documented Software Development Kit (SDK).

e-Health Sensor Platform. An open medical monitoring platform supervised by the Cooking Hacks. It is a shield for Arduino/Raspberry Pi and the set of sensors that can be plugged in: pulse, oxygen in blood (SPO2), airflow (breathing), body temperature, electrocardiogram (ECG), glucometer, galvanic skin response (GSR), blood pressure (sphygmomanometer), patient position (accelerometer) and muscle/electromyography sensor (EMG). Thanks to build on Arduino, this solution can be combined with various devices and installations.

Jawbone UP3. Is an advanced "fitness band". While it sensory capabilities are limited compared to the above ones, it is ultra portable and non invasive, thus increasing opportunities for all day person monitoring.

What is also important, besides basic sensor reading we want to capture user reports on their emotional state. Ultimately, information on these states should be acquired semi-automatically by dedicated mobile applications in the form of recommendation and mediation[1]. However, at the basic stage at which we are now, sensor recordings are compiled with user surveys prepared to determine which emotions were experienced during each stage of a prepared experiment.

In fact in our initial phase of research we prepared and conducted several in lab experiments to verify our assumptions. The studies were conducted with the use of Virtual Reality (VR) via Oculus headset to provide emotional stimuli for more immersive user experience. Three experiments were conducted to collect the data for preliminary analysis as well as for the comparison of the signals collected by different devices.

All of these experiments were prepared with a close collaboration with Dr Jan Argasinski from Jagiellonian University and were conducted with him in the Department of Games Technology at Jagiellonian. They are described in the second paper submitted to the AfCAI workshop.

Based on the data from the experiments we are aiming at building knowledge-based computational models for affect identification and interpretation.

[1] An example of such an approach is in Jawbone UP Coach, where the user is asked interactively about his past activities.

4 Summary

During the AfCAI workshop in Murcia we elaborated on the issues introduced above. In particular we discussed in more detail our: vision of AfCAI systems, ideas about emotion detection and identification based on Prinz's theory, works in the area of context aware systems, proposal of affective context aware architecture, outlook at building knowledge-based computational models for affect identification and interpretation.

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References

1. Bobek, S.: Methods for modeling self-adaptive mobile context-aware sytems. Ph.D. thesis, AGH University of Science and Technology (April 2016), Supervisor: Grzegorz J. Nalepa
2. Bobek, S., Nalepa, G.J.: Uncertainty handling in rule-based mobile context-aware systems. Pervasive and Mobile Computing pp. – (2016), `http://www.sciencedirect.com/science/article/pii/S1574119216302115`
3. Bobek, S., Nalepa, G.J.: Uncertain context data management in dynamic mobile environments. Future Generation Computer Systems 66, 110 – 124 (2017), `http://www.sciencedirect.com/science/article/pii/S0167739X1630187X`
4. Dey, A.K.: Providing architectural support for building context-aware applications. Ph.D. thesis, Atlanta, GA, USA (2000), aAI9994400
5. Doty, T.J., Kellihan, B., Jung, T.P., Zao, J.K., Litvan, I.: The wearable multimodal monitoring system: A platform to study falls and near-falls in the real-world. In: International Conference on Human Aspects of IT for the Aged Population. pp. 412–422. Springer (2015)
6. Hernandez, J., McDuff, D.J., Picard, R.W.: Bioinsights: Extracting personal data from "still" wearable motion sensors. In: 2015 IEEE 12th International Conference on Wearable and Implantable Body Sensor Networks (BSN). pp. 1–6. IEEE (2015)
7. James, W.: What is an emotion? Mind (34), 188–205 (1884)
8. Muaremi, A., Arnrich, B., Tröster, G.: Towards measuring stress with smartphones and wearable devices during workday and sleep. BioNanoScience 3(2), 172–183 (2013)
9. Müller, S.C., Fritz, T.: Stuck and frustrated or in flow and happy: Sensing developers' emotions and progress. In: Proceedings of the 37th International Conference on Software Engineering-Volume 1. pp. 688–699. IEEE Press (2015)
10. Picard, R.W.: Affective Computing. MIT Press (1997)
11. Picard, R.W.: Recognizing stress, engagement, and positive emotion. In: Proceedings of the 20th International Conference on Intelligent User Interfaces. pp. 3–4. ACM (2015)
12. Prinz, J.: Which emotions are basic? In: Evans, D., Cruse, P. (eds.) Emotion, evolution, and rationality, pp. 69–88. Oxford University Press New York (2004)

13. Sano, A., Picard, R.W.: Stress recognition using wearable sensors and mobile phones. In: Affective Computing and Intelligent Interaction (ACII), 2013 Humaine Association Conference on. pp. 671–676. IEEE (2013)
14. Song, M., DiPaola, S.: Exploring different ways of navigating emotionally-responsive artwork in immersive virtual environments. In: Proceedings of the Conference on Electronic Visualisation and the Arts. pp. 232–239. British Computer Society (2015)