OPPORTUNITY: activity and context awareness in opportunistic open-ended sensor environments

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ABSTRACT

We introduce the newly started EU project OPPORTUNITY where we develop *opportunistic activity and context recognition systems* in ambient intelligence (AmI) environments. They are mobile systems that recognize context from opportunistically discovered sensors. They encompass principles supporting their autonomous operation in open-ended environments, such as self-configuration, autonomous evolution, and self-improvement, that are key to large-scale AmI. We outline the project scope and emphasize autonomous evolution and self-improvement aspects supported by late breaking results.

1. INTRODUCTION

Recognizing human activities and gestures - and in a broader sense the user's *context* - is used in wearable and pervasive computing and in human computer interaction. Activity and context recognition is an *adaptive* mechanism allowing a wearable computer to become uniquely *personalized* to the specific needs of a user. Applications include gestural interfaces, industrial worker's assistance, or elderly assistance.

Action perception is key to social behavior. It is studied from multiple perspectives. Behavioral studies and psychology seek to identify units of actions. Cognitive sciences show that brain processes linked to action generation and perception are related, with the discovery of mirror neurons. Evolutionary and neurophysiological views indicate that production of speech and gestures share common underlying brain mechanisms and may have co-evolved. Thus, linguistical description is closely linked to action production. Computational approaches are used to test biological hypotheses and model brain mechanisms.

Eventually, in wearable and pervasive computing, machine-learning and pattern recognition techniques are used to map typical on-body or ambient sensor signals (e.g. limb motion sensed from on-body accelerometer) into activity classes (e.g. grasping gesture, manipulating object). Current approaches usually require a specific deployed infrastructure for a specific recognition task. This is not desireable for a widespread use of context-aware systems. Users are at times in highly instrumented environments and at other times in places with little sensor infrastructure. Users carry various sensor enabled devices, such as mobile phones, watches, or smart garments. As the user leaves devices behind, picks up new ones and changes his outfit, the type and location of on-body sensors varies, and the sensing environment changes. Thus, a more flexible *opportunistic* approach to activity and context recognition is desired.

2. OPPORTUNITY

OPPORTUNITY is a 3-year long (February 2009-February 2011) EU FP7 project under FET-Open funding with four partners collaborating to develop mobile systems to recognize human activity and context in dynamically varying sensor setups. We envision a mobile system that autonomously discovers available sensors around the user and self-configures to recognize desired activities. It autonomously evolves and reconfigures as the environment changes. It self-improves by exploiting re-occuring contexts typical of human behavior and human generated signals related to cognitive states.

OPPORTUNITY thus addresses the limitations of application specific deployed infrastructure. This may mainstream ambient intelligence and improve user acceptance by relaxing constraints on body-worn sensor characteristics. Overall, it encompasses principles supporting autonomous operation in open-ended environments.

We combine opportunistic sensing, opportunistic context recognition, and autonomous evolution and adaptation. The user carries a mobile device that discovers sensor nodes on the body and in the environment. Each sensor node is an autonomous unit that senses information related to the user's context (e.g. with a motion or location sensor). It updates its local probabilistic context representation and shares it with the mobile device with additional self-description information. Through interactions of multiple sensors mediated by the mobile device, the picture of the user's context emerges from the fusion of multiple sensors.

The OPPORTUNITY methods are demonstrated on the recognition of activity primitives, and on robust adaptive Brain-Computer Interface (BCI) systems, as an example of complex cognitive context recognition.

Opportunistic sensing relies on an abstract goal formulation that is diffused through the sensor nodes surrounding the user's mobile device. By interpreting and differentiating this information, the sensors autonomously form a goal-oriented sensor ensemble that provides the information relevant to the recognition goal. The key mechanisms underlying this are the capability of sensor nodes to self-organize, self-describe their key characteristics (e.g. modality, location), and to self-characterize dynamic parameters (e.g. the on-body position of a wearable sensor). The main research efforts address the components for an infrastructure-free opportunistic sensing system, optimized for human activity and context recognition.

Opportunistic recognitition interprets sensor signals in terms of activites, gestures or location. Since there is not necessarily a static mapping between signal patterns and context we investigate signal conditioning methods to redefine commonly used features in a way as to make them less sensitive to variations (e.g. placement, orientation) and sensor combinations immune to variations. We investigate sensor independent features that allow to use different sensor modalities with an identical underlying representation. Finally, we investigate machine learning techniques operating on sensor ensembles that ensure graceful degradation in case of environmental changes, and have the ability to dynamically exploit additional or improved sources.

Autonomous evolution and adaptation The sensing infrastructure changes over time as sensors fail or the AmI infrastructure is upgraded. Autonomous evolution relies on the local communication between nodes and mobile devices to autonomously discover correlations between sensor information and to share information about recognized context occurences. Thus, it is possible to identify at run-time correlated sensors that can substitute each other. The current opportunistic system can also provide estimated ground truth labels for the training of the classifiers operating on newly recruited nodes. In recent result we show that it is possible to recruit and loose sensors in this way with little performance drop in even small sized sensor ensembles.

Long-term changes in signal characteristics (e.g. sensors degradation in harsh environments) and user activity patterns (e.g. due to change of habits, ageing) lead to changes in the mapping between sensor signals and context. The classifier parameters can be adjusted by taking advantage of many repetitive occurences of context in daily life by monitoring drift over time. In recent results we show that with only slightly better than chance probability of recognizing the correct context, there is a high likelihood of improving the classification accuracy upon context reoccurences.

In the ubiquitous computing vision there is a symbiosis between man and AmI. An opportunistic system may take advantage of this tight coupling by collecting error statistics during occasional user feedback to adjust its behavior. Methods such as semi-supervised learning can efficiently exploit small proportions of opportunistically labelled data. However, more promising is the use of human generated signals related to cognitive states to provide learning signals to artificial systems. Error-related EEG correlates are signal patterns that occur when a system deviates from expected behavior. We showed they are promising to derive an endogenous measure of system performance and guide adaptation in static setups. Electro-oculography may also allow to gain insight into similar cognitive processes. We speculate this may eventually allow an opportunistic system to turn into an autonomic system capable of self-improvement.

3. CONCLUSION

We presented the newly started project OPPORTUNITY and outlined preliminary results and potentials along autonomous evolution and self-improvement using reoccuring contexts, self-supervision, and human generated signals related to cognitive states.

Recognizing and understanding activities in others is a key component of human behavior. It is also essential to devise AmI environments. Insights from psychology and linguistics may help outline meaningful "units of actions" thus allowing scalable recognition of complex human behaviors from simpler building blocks. The highly diverse way in which identical goals unfold in terms of motor actions remains challenging to current activity recognition systems. Understanding the evolved cognitive processes of action perception may be key to more robust recognition systems. Thus, OPPORTUNITY will benefit from, and contribute to, an interdisciplinary perspective on action perception.

More information about the project is available at `www.opportunity-project.eu`.

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