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Activity Recognition in Opportunistic Sensor Environments

Daniel Roggen [1], Alberto Calatroni [1], Kilian Förster [1], Gerhard Tröster [1], Paul Lukowicz [2], David Bannach [2], Alois Ferscha [3], Marc Kurz [3], Gerold Hölzl [3], Hesam Sagha [4], Hamidreza Bayati [4], José del R. Millán [4], Ricardo Chavarriaga [4]

[a] *Wearable Computing Laboratory, ETH Zurich*
[b] *Embedded Systems Laboratory, University of Passau*
[c] *Institute for Pervasive Computing, Johannes Kepler University Linz*
[d] *Defitech Foundation Chair in Non-Invasive Brain-Machine Interface, Ecole Polytechnique Fédérale de Lausanne*

Abstract

OPPORTUNITY is project under the EU FET-Open funding[1] in which we develop mobile systems to recognize human activity in dynamically varying sensor setups [1,2]. The system autonomously discovers available sensors around the user and self-configures to recognize desired activities. It reconfigures itself as the environment changes, and encompasses principles supporting autonomous operation in open-ended environments. OPPORTUNITY mainstreams ambient intelligence and improves user acceptance by relaxing constraints on body-worn sensor characteristics, and eases the deployment in real-world environments. We summarize key achievements of the project so far. The project outcomes are robust activity recognition systems. This may enable smarter activity-aware energy-management in buildings, and advanced activity-aware health assistants.

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Keywords: Activity recognition; pervasive computing; adaptive systems; machine learning; context framework

1. Resilience and adaptation with opportunistic sensing

Activity recognition systems must be robust against possible changes and failures in the sensor network which are typical in open-ended environments. We developed machine learning techniques and heuristics that provide these capabilities. We have proposed a method for detecting sensors that fail or degrade [3] based on discrepancy between classifier outputs in an ensemble classifier architecture. Anomalous sensors can be automatically removed yielding a graceful performance degradation upon sensor failures. Probabilistic approaches have been developed to handle missing data (e.g. due to transmission problems in wireless networks) [4] by inferring missing samples from the conditional distribution between available and missing data sources. This inference can be performed at the raw data level or at the fusion level. These methods increase the tolerance to sensor failure without the need for re-calibration or external intervention.

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2. Use of unknown new resources

As the environment is upgraded or as the user buys a sensorized gadget, new, unforeseen, resources can be discovered at run-time. We devised novel approaches to exploit such unknown new resources without design-time training nor user intervention. This supports the "growth" of an activity recognition onto new resources. We devised a variation of transfer learning to autonomously transfer the activity recognition capabilities of one sensor node to another, regardless of the modality and placement of the new node. We devised a form of multi-task learning that allows to exploit new sensors to improve the recognition accuracy of an existing system. The approach works by exploing the natural tendency of relevant activities to form clusters in the feature space.

3. Tools and datasets

The development of context aware systems involves the collection and management of a sample data set. For non trivial data sets such management can be extremely time consuming. Thus, we have developed an integrated tool chain to support this. It comprises (1) a GUI based tool for dynamic monitoring of data acquisition and to ensure data integrity, (2) a data base system in order to allow sensor data, annotations and accompanying videos to be stored and accessed in an organized way, (3) a GUI based labeling tool for the inspection, annotation, and manual resynchronization of data, (4) a trace generation tool to retrieve data for system training, testing or demonstration.

4. The OPPORTUNITY Framework

The OPPORTUNITY framework allows to state a human activity recognition goal, without specifying the set of sensors used for that purpose [5]. Thus, the framework provides an abstraction layer between the application goal and the physical world. It combines knowledge obtained from self-describing sensors and a rich domain-knowledge in form of an ontology to match at run-time sensors and machine learning components (e.g. classification, fusion, feature-extraction, anomaly detection, . . .) to achieve the desired recognition goal. Neither the recognition goal, nor the available sensing devices have to be pre-defined. The system reacts at runtime on (i) recognition requests (by translating this request to a machine-readable format - *the goal description language*), and (ii) on changes in the sensing infrastructure by re-configuration of configured sensing ensembles. The framework is implemented using Java and the OSGi module system and acts as a runtime environment together with a code base and libraries, able to execute autonomously on a target platform.

5. Conclusion

The highly diverse way in which identical goals unfold in terms of motor actions remains challenging to current activity recognition systems. Ongoing work aims at further method improvement and also seeks an interdisciplinar view on action perception. For instance, understanding the evolved cognitive processes may be key to more robust recognition systems. We welcome community input along these lines.

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