IMPACT

# BUILDING SMART CONTEXT-AWARE MOBILE APPLICATIONS


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## Impact Objectives

- Research and develop activity recognition techniques targeting low energy and high accuracy
- Explore context aggregation approaches and algorithms to uncover human activity patterns
- Research and develop a middleware and domain-specific programming environment

# Building smart context-aware mobile applications

***Professors João Cardoso**, **Luís Veiga** and **João Moreira** discuss the emergence of context-aware applications and services that proactively respond to specific user activities or situations through their latest research project **CONTEXTWA***

*Professors João Cardoso, Luís Veiga and João Moreira*

**What exactly are context-aware applications?**

**JC:** Context-aware applications and services use properties of the environment and the context of one or more users and/or devices to runtime-adapt their behaviour, to provide richer user experiences, and/or to provide specialised services. For example, a user's context might be based on location and on the user activity being done.

**What are the aims of the CONTEXTWA project and what do you hope to achieve?**

**JM:** The CONTEXTWA project addresses key challenges and enabling techniques for developing context-aware mobile applications, focusing on rapid prototyping, low energy and high accuracy of human activity recognition, and the uncovering of user-activity patterns. The project intends to achieve techniques to efficiently classify many of the daily human-activities from sensing data.

**LV:** Specifically, CONTEXTWA is focused on three major aspects. Firstly, on researching and developing activity recognition techniques focusing on low energy and high accuracy. Secondly, on exploring context aggregation approaches and algorithms based on statistical classification to uncover human activity patterns. Lastly, on researching and developing a middleware and domain-specific programming environment for the rapid prototyping of context-aware applications. CONTEXTWA intends to improve the understanding of some of the actual limits for recognition of human-activities considering a limited set of sensors (typically the ones used in common smartphones) and the impact of using many wearable sensors on the recognition accuracy achieved by the techniques being proposed.

**What will the impact of this work be and who will benefit from this research?**

**JC:** CONTEXTWA will enable a new generation of context-aware applications and services that are fully responsive at the user's mobile devices and as well as seamlessly cloud-enabled. The actual beneficiaries are companies focused on mobile applications and services regarding recommendation systems. Some of the human-activities being automatically recognised in real-time would help to identify a sedentary user's life and to suggest the user becomes more active. Tracking human-activities can be also important in the context of children and the elderly as it can be used to identify uncommon patterns of behaviour.

**LV:** At the cloud level, the main impact of this project involves the enhancement of data processing platforms and deployments in order to increase their scalability, performance and flexibility from sensing activity from possibly thousands of users. Therefore, CONTEXTWA will directly benefit the developers of context-aware applications that are already in increasing demand, but it will also benefit the users (citizens) by providing them with enhanced and more widespread context-aware applications.

**How are you combining different research areas to deliver the outcomes?**

**LV:** In CONTEXTWA, we combine research on fundamental aspects of context-awareness (such as activity identification), distributed data processing systems (map-reduce, graph and stream processing in the cloud) and resource management to improve the performance and efficiency of Java big data processing platforms for faster replies, lower cloud costs and reduced energy footprint.

**JM:** We combine digital signal processing, machine learning, embedded, mobile and cloud computing to achieve the technical goals of the project. It is the interplay between the different areas that distinguishes this project from other projects dealing with human activity recognition.

# Prototyping context-aware applications

*The **CONTEXTWA** project is a unique partnership that provides a step ahead in terms of engineering context-aware applications and services based on human activity recognition*

The creation and design of applications and systems that are easy to use suggests that we should have a clear understanding regarding their context of use. Context is a very abstract notion that can be thought of as the information or circumstances that form the settings for an idea. Recent advances in sensing and automated means of interpreting physical environments allow for the collection of more information, and hence of more context.

Context-aware applications are often perceived merely as location-aware tools that integrate GPS information into user-friendly applications. Many users may in fact already have such applications in their own home, such as applications that prevent users from locking their car keys in their vehicles. However, context-aware applications are so much more than just a tool that is able to provide location services.

CONTEXTWA (middleware and context inference techniques from data-streams for the development of context-aware services using mobile devices) is a pioneering project that focuses on helping and supporting the development of context-aware mobile applications, including new techniques for user-activity detection. The CONTEXTWA project can be seen as a provider of new algorithms, techniques and technologies for mobile applications, advanced and complex engineering systems, contributing to electronic-based infrastructures and the promotion of the internet of the future.

At the core of these applications is the ability of mobile devices to accurately detect specific physical settings or user contexts, using either internal or external sensors such as accelerometers, GPS, light, image or sound. In other words, context-aware applications will become more about what we are doing at any given instant either in our professional environment or during a recreational or personal activity. CONTEXTWA aims to make prototypes with actual practical technology while considering a more medium-to long-term vision in which users may carry many wearable sensors and devices.

## PERFECTING MOBILE APPLICATIONS

Despite the fact that the topic of human activity recognition is widely studied by many researchers, the community continues to look for more advanced algorithms.

Professor João Cardoso from the Institute for Systems and Computer Engineering, Technology and Science (INESC TEC) and the Faculty of Engineering (FEUP) of University of Porto, Portugal, explains that this is important, 'especially given the importance of saving energy consumption, the real-time requirements of recognition systems, the constraints imposed by the embedded devices used, the different characteristics and hardware resources in each device, the need to consider different users (with different activity behaviours), and the large number of daily life human activities one can consider and the human activities that are impossible to cover from the very beginning'. For instance, context-aware applications based on user-activities can recommend related TV shows. For example TV shows about cooking can be suggested to users who dedicate regular time to cooking. On the other hand, context-aware applications can also identify an anomalous situation with an elderly person at home, for example alerting carers to the occurrence of a fall.

According to the accuracy needed, human activity recognition systems can use less computationally intensive and more

energy-efficient algorithms. Each activity requires different attributes for an adequate classification. Hence, a major objective of the project is to minimise the classification error using energy-aware algorithms for the detection of physical activities based on accelerometer and other sensor data. The outcome of these algorithms will be integrated with a high-level algorithm for the detection of high-level user contexts and related activities. Therefore, it is important to highlight the ability to select the right features depending on the sensors being used. 'Moreover, the ability to recognise unseen activities implies the use and development of online novelty detection algorithms, an additional research topic that is being investigated' says Professor João Moreira, also from INESC TEC and FEUP.

An Android application is being developed in order to collect sensing data for offline studies as part of the CONTEXTWA project. This application is flexible enough to be aware of the actual sensors in a specific smartphone while at the same time the measurements for each activity obey previously defined protocols. The group intends to have a prototype of the human activity recognition system for Android smartphones as well as a prototype of the recommendation system executing at the cloud. These prototypes use middleware and rapid prototyping developing techniques, taking advantage of domain-specific languages (DSLs). An important Application Programming Interface (API) is being developed to provide runtime adaptive schemes that can be integrated into handheld human activity recognition devices to dynamically adapt software components to specific runtime characteristics. In addition, CONTEXTWA will provide datasets of sensing data for many human activities, considering sensors from typical smartphones as well as those from the CONTEXTWA wearable system, which includes several sensors located at different places around the human body.

## ADDRESSING THE CHALLENGES

There are many challenges with engineering context-aware applications and services based on human activity recognition using smartphones and other handheld and wearable devices. In order to deliver successful systems, the project needs to deal with challenges related to the accuracy of the human-activity recognition system due to the number of activities being recorded. It is vital to be aware that the sensors found in smartphones are not always of the same type nor are they located in the same locations. It is also important to question how efficient smartphone-based human activity recognition systems can be in terms of accuracy, computing power, and energy consumption, says Cardoso: It is vital to successfully deal with the activities provided by user-devices in the context of recommendation systems, how to optimise computations needed for human activity recognition when considering a vast number of sensors and to identify the impact of using sensing data from tens of sensors located in different parts of a human to recognise representative human daily life activities.'

With current technologies, context-aware applications running on mobile devices have to face a multi-faceted challenge that is intertwined with poor usability, poor performance, and poor resource-efficiency. 'Designing them to run exclusively on the mobile device introduces big limitations to applications features, data processing and data storage. By feeding all the sensory data to remote cloud-powered application servers, there is simply too much data being sent that increase the cost, the latency, and also the respective battery drain,' explains Cardoso. Furthermore, executing backend data processing tasks repetitively at the cloud as new data arrives, without taking into consideration the application relevance of the new data, is bound to waste a lot of resources and it also increases costs with acquiring them in the cloud.

> *'It is the expertise synergistically provided by the different teams involved in CONTEXTWA that, we believe, will provide outstanding achievements'*

## SUCCESSFUL COLLABORATION

Partnership and collaboration are essential for the realisation of this project. Project partners include the INESC TEC in Porto, the Instituto de Engenharia de Sistemas e Computadores - Investigação e Desenvolvimento (INESC-ID) in Lisbon and Altice Labs in Aveiro. INESC TEC has several centres that participate in this research and which bring in the expertise in embedded and mobile computing, energy efficiency, classification algorithms from data-streams (especially in human activity recognition), and techniques for recommendation systems. This expertise is provided by the Information Systems and Computer Graphics (CSIG), the Laboratory of Artificial Intelligence and Decision Support (LIAAD), the Centre for Enterprise Systems Engineering (CESE), Telecommunications and Multimedia (UTM) and the Centre for Robotics and Autonomous System (CRAS). 'It is the expertise synergistically provided by the different teams involved in CONTEXTWA that, we believe, will provide outstanding achievements,' says Cardoso.

# Project Insights


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## PROJECT COORDINATOR BIO

**Professor João M. P. Cardoso** completed his five year Electronics Engineering degree from the University of Aveiro in 1993, an MSc in Electrical and Computer Engineering from the Technical University of Lisbon (IST/UTL), in 1997 and a PhD, also from IST/UTL in 2001. He is Full Professor at the Department of Informatics Engineering, Faculty of Engineering (FEUP) of the University of Porto and a researcher at INESC TEC. Cardoso has served on committees of various international conferences, such as FPL, IEEE/IFIP EUC, IEEE CSE, ARC, ARCS and DASIP. He is a member of professional societies such as IEEE and ACM. Cardoso's research interests include compilation techniques, domain-specific languages, high-performance (embedded) computing, pervasive systems, and reconfigurable computing.