Multi Sensor Context Awareness

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Abstract – Context awareness is one of the holy grails in ubiquitous computing, envisioning many embedded computing devices that serve their user while being perceptive enough of events and situations around them. This extended abstract will give a brief overview of an approach for resolving this key concern in ubiquitous and wearable computing, which uses techniques and ideas from statistics, machine learning, and signal processing. The issue of context awareness is treated as a traditional classification problem where raw sensor signals have to be fused and converted into a description that makes sense for both application and user.

Key words – multi-sensor fusion, distributed sensing, on-line context awareness, ubiquitous computing, wearable computing

I. Introduction

The objective of the research described in this abstract is to explore self-learning computer systems that make observations with low-level sensors so they can learn, perceive, and anticipate what their user is doing. The technological aim is to build a bridge between the available sensing infrastructure and applications in ubiquitous and wearable computing.

The ability of an algorithm or application to calculate descriptions of the world around it, based on sensor data, has generally been referred to as context awareness, situational awareness, or sensor-based perception. If a device can register concepts such as its location or its user's task at hand, it can anticipate and adjust its behaviour to avoid redundant user-interaction.

The next three sections will introduce three relevant established concepts that serve as a foundation framework.

II. Multi-Sensor Fusion

Multi-sensor fusion, or distributed sensing, is a methodology that has evolved a lot during the last decades in a number of research areas. It is applied in systems where multiple, diverse sensors are combined to make inferences about events, activities, situations, or more general: about their contexts.

The advantages of having many sensors distributed over an area have been appreciated by a variety of fields, such as military observation systems and environmental sensing, where sensor nodes may fail at any time and local events may distort sensor readings. Having in addition various types of sensors has the potential to increase the information gain while keeping the overall bandwidth low. Properties like an inherent redundancy in the sensed data, a distributed deployment of the sensors, and the uniform configuration over all devices, guarantee a certain degree of robustness, cost-effectiveness and allow graceful degradation in its performance (see Figure 1 for a comparison diagram with a single-sensor approach).

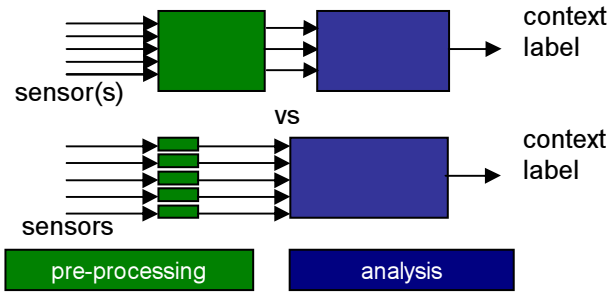

Figure 1. One sensor specifically tuned to the application versus many simple, distributed sensors.

Multi-sensor systems were initially inspired by the human cognitive process where the brain fuses sensory information from the various sensory organs and links these signals to a concept. They since then have outgrown the disciplines of artificial intelligence, statistics, cognitive psychology and machine learning, and can be found in a wide range of applications from product manufacturing to medical diagnosis.

III. Context Awareness

Context awareness is mainly an application-specific trait: it indicates that a computing element is able to acquire information about the context of both the user and itself. It especially has become an integral part in human-computer interaction research, based on findings that any dialog is heavily based on common context.

The notion of context has been interpreted in many ways, including (subsets of): location, situation, activity, the state of the environment, and the user's state. This has lead to a large number of applications that claimed to be context aware, and a great deal of confusion concerning the definition of context awareness. Since this abstract tries to cover context awareness in general, without any specific application in mind, its focus is mainly on the mapping process between raw sensor data and a

context description and thus treats context awareness as a typical machine learning classification problem.

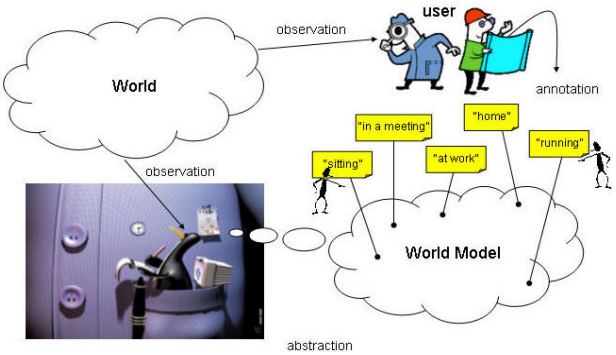

Figure 2. Context Awareness as an adaptive process where the system incrementally creates a model of the world it observes.

Additionally, the user of a device can be taken into the loop to train and detect contexts on the spot; the device learns new situations by example, with its user as the teacher. This flexible learning scheme is often referred to as incremental learning: new classes can be trained without having to retrain the ones that were already trained, and old classes can be re-trained should they have changed or become obsolete (see Figure 2 for an impression).

IV. Ubiquitous and Wearable Computing

Ubiquitous computing is originally dubbed by Mark Weiser, who positioned it as an opposite of virtual reality, where computers are integrated in the real world (instead of putting people in computer-generated environments): "*First were mainframes, each shared by lots of people. Now we are in the personal computing era, person and machine staring uneasily at each other across the desktop. Next comes ubiquitous computing, or the age of calm technology, when technology recedes into the background of our lives. Alan Kay of Apple calls this 'Third Paradigm' computing*" (Mark Weiser). Ubiquitous Computing could be seen as an approach to human-computer interaction, but is also about distributing computation in the environment, as opposed to keeping it bottled in a desktop-bound personal computer.

V. The Combination: Multi Sensor Context Awareness

Multi-sensor fusion, context awareness, and ubiquitous and wearable computing combined, aim at realizing a practical approach where a large number of different and distributed sensors are used to predict a context description. In the presentation, particular attention is given to the methods for achieving multi-sensor fusion with these constraints, and a list of past and current research projects in mobile and wearable computing will be given as specific examples.