# A context-aware middleware for ambient intelligence

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# A Context-aware Middleware for Ambient Intelligence

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## ABSTRACT
By the acronym MOCOCO we refer to our view of ambient intelligence (AmI), pointing out three main characteristics: Mobility, Contextualization and Collaboration. The ambient intelligence is a challenging research area focusing on ubiquitous computing, profiling practices, context awareness, and human-centric computing and interaction design. We are concretizing our approach in a platform called IMERA (French acronym for Computer Augmented Environment for Mobile Interaction). In order to make work together several sensors, actuators and mobile smart devices, the need of a context-aware middleware for this platform is obvious. In this paper, we present main objectives and solution principles concretized in a context-aware middleware based on hybrid reasoning engine (the ontology reasoning and the decision tree reasoning), which retrieves efficiently high-level contexts from raw data. This platform provides an environment for rapid prototyping of context aware services in Ambient Intelligent (AmI).

## Categories and Subject Descriptors
H.3.4 **[Information Storage and Retrieval]**: Systems and Software – *distributed systems.*

## General Terms
Design

## Keywords
Middleware, Context-aware, Ambient intelligence

## 1. INTRODUCTION
Ambient intelligence (AmI) refers to numerically augmented real environment that is sensitive and responsive to the presence of people [1]. AmI corresponds to a new vision of daily (or professional) life, consists of different kinds of sensors, actuators, communication objects and computing devices, which lead to pervasive intelligence in surrounding environment supporting the activities and interactions of the users. It means that computing technology will exist in everything that surrounds us (devices, appliances, objects, clothes, materials) and that everything will be interconnected by a ubiquitous network. The system formed by all these interconnected intelligent things (also called the Internet of Things) is interacting with humans by means of advanced interfaces, which are natural, flexible and adaptable to the needs and preferences of each user. The final goal is to have an adaptive and "intelligent" system that assists humans in their daily (or professional) activities.

To reach AmI, first, we need to integrate all sensors, actuators, communication objects and computing devices to the system. Low level mechanisms and drivers are necessary but they must be encapsulated to more common and higher level view allowing to collect, treat and propagate the information between these components in an appropriate manner, i.e. take into account the changes in the context, and propagate appropriate decisions. In computing, this kind of concern is known as “context-aware computing” [2]. This class of mobile systems that are related with their physical environment needs to adapt their behaviors accordingly to context management and adaptation to deal with the different resources present in the environments [3]. Overall middleware characteristics (multiple sources and destination information management) are to be adapted to the problematic of context-aware computing in order to create an appropriate and efficient environment. To find a solution for our AmI approach expressed by MOCOCO for Mobility, Contextualization and Cooperation [4] and concretized by a platform called IMERA for Mobile Interaction in Real Augmented Environment [5], we are proposing a context-aware middleware to support AmI [6]. Our context-aware middleware allows a rapid developing of new applications on IMERA platform.

## 2. PLATFORM ARCHITECTURE
In our context-aware middleware architecture, showed in fig.1, we are distinguishing 5 parts: at the lowest layer we have access to different computational entities (Smart phone, wearable computer, and tablet) and diverse sensors and actuators devices (RFID, camera, and marker). Next layer is an interface allowing two ways exchange between devices and middleware management layer. Third layer is middleware management layer which is based on sensors data fusion, a reasoning engine, a context knowledge base (KB), a context database and a context query engine. Next layer is a high level interface between the middleware and the application layer. We propose to describe more precisely the management layer in which the reasoning engine is the brain of the context-aware middleware.

**Sensors data fusion:** collects and transforms the information from the sensors and send appropriate information the actuators; **Context database:** stores the context data (low level context) from sensors; **Context query engine:** handles the query from the application; **Context knowledge base:** stores the context model (environment context and users’ context) by the ontology based


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model. **Reasoning Engine:** checks the context consistency and deduces the high-level context from low-level context (fig.2(a)). We propose a hybrid reasoning engine, which is organized as hybrid two level engine: a strategy reasoning engine based on ontology reasoning and the detail reasoning engine based on decision tree reasoning (fig.2(b)).

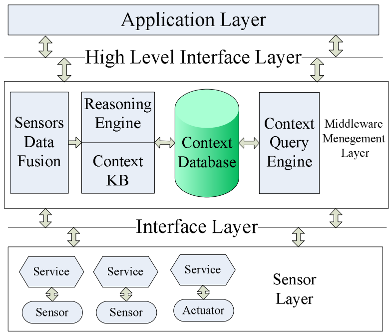


Fig.1 The architecture of the context-aware system

According to the collected raw data from sensors, reasoning engine exploring environment context and user context is able to take strategic appropriate decision. Then more precise reasoning can occur based on context decision tree. Here, a number of nodes can be combined to provide different decision paths based on information supplied by the sensors and context database. These nodes can communicate with context database, allowing up-to-date information to be retrieved. The users can define different reasoning rules depending on different working or living situations. In this way we obtain a more flexible, robust, and efficient problem resolution in complex ambient intelligence situations.

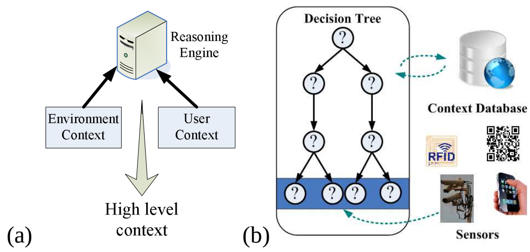


Fig.2 The decision tree reasoning engine

## 3. SCENARIOS

Bus stop application (fig.3(a)) is a typical application of Smart City [6]. To explain better how the context-aware middleware works, we present a scenario: After a conference, Mr. XU Tao is taking the bus back to his hotel. He is tired, hungry and only wishes to have his most favourite meal of grilled chicken. However, he knows nothing about providing this meal in this city. When he is lost in fantasy of the food, the bus arrives at the bus stop. "Oh-la-la!" Tao shouts out with excitement. An avatar, recognizing him (by the collection of his identification data) in the large public screen speaks in Chinese to him with the subtitles popping up: "Welcome! The grilled chicken restaurant is about 300m far from this bus stop. If you want to book the meal, please wave yours hands to me… The process of context-aware system for this scenario is as follows: When Tao gets on the bus with his traffic card (RFID card), his public profile is transferred to the bus stop via internet. Then the server checks Tao's schedule (context: time), searches all the restaurants near the bus stop (context: location). The strategic reasoning engine (the ontology reasoning) deduces Tao's next activity from these contexts: Dinner (context: activity). The detailed reasoning engine (decision tree reasoning) constructs the decision tree (Fig.3(b)) on Tao's profile. With the analysis of the nearby restaurants' menus, this reasoning engine infers Tao's probable favourite restaurant (context: profile: favourite food). The camera fixed in Bus stop distinguishes Tao from the other passengers (face recognition techniques allowed by Tao's profile), and then confirm the reservation by Tao's hand gestures (gesture recognition techniques).

The context-aware middleware plays an important role in this scenario, which collects contextual information from various interaction devices (camera, etc.), techniques (gesture recognition, markers or face recognition, etc.) and sensors (RFID, QR codes, etc.), and provides the user relevant information and/or services in the context [7].

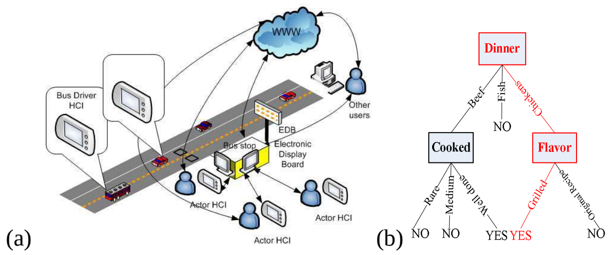


Fig.3 Bus shelter scenario

## 4. CONCLUSION

In this paper, we presented a context-aware middleware platform and a hybrid reasoning engine based on the ontology reasoning and decision tree reasoning technology, which makes the context-aware middleware platform more flexible, robust, and efficient. This platform provides the ways to solve the issues covering service discovery, mobility, and environmental changes. In addition, it also provides a rapid prototyping of new interaction techniques in AmI.

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