

Pervasive Multi-Agent Programming in JaCaMo

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Abstract. JaCaMo is one of the main multi-agent programming platforms available in literature, widely adopted for teaching agent and multi-agent programming. In this demo, we show the recent advances in JaCaMo technologies, focusing in particular on the recent extensions that make it possible to exploit the same multi-agent programming model for developing pervasive multi-agent systems running not only on desktop computers, but also on mobile devices, wearable devices and embedded platforms. This makes it possible to use first-class agent, environment and organization programming languages and tools for prototyping systems for relevant application domains such as Pervasive Computing, Internet-of-Things, Augmented/Mixed Reality. During the demo, we will present some showcases about these extensions, showing and discussing the benefits and the current limits about adopting multi-agent programming.

1 JaCaMo Multi-Agent Programming Model

The key aspect of the JaCaMo programming model and platform is to integrate coherently three main first-class design and programming dimensions in Multi-Agent Systems [1]:

- the *agent* dimension, based on the BDI model and the Jason programming language [2];
- the *environment* dimension, based on the A&A model and the CArtaGO framework [7];
- the *organization* dimension, based on the MOISE model [3] and the ORA4MAS framework [4].

With JaCaMo, MAS designers and developers can choose the proper abstractions according to the aspect of the system that they are modeling/constructing and be sure that the composition and integration of such abstractions would be conceptually and semantically clear and well-defined. In particular, *agents* are used to model all the autonomous and task/goal oriented part of a system; *artifacts* – as building blocks of the environment – can be used to model every non-autonomous resource and tool used and possibly shared by agents to do their

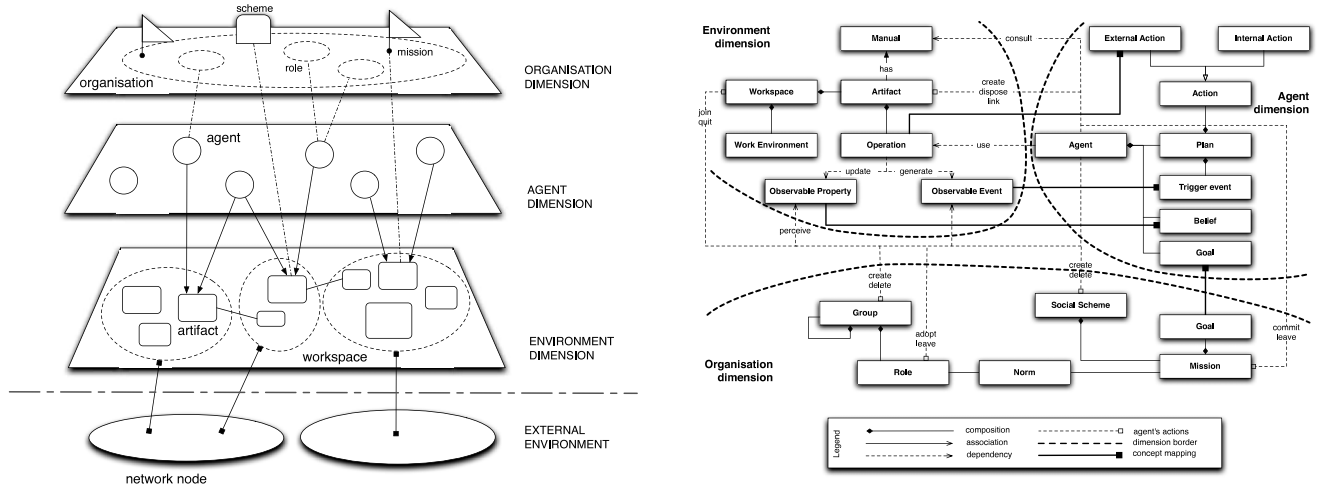


Fig. 1. JaCaMo levels overview (*left*) and meta-model (*right*).

job; *organization* (roles, groups, missions, etc.) can be used to specify macro-aspect of the system – concerning coordination, cooperation – from a structural, functional and normative point of view—in an open system perspective.

An overview of the three dimensions and of the meta-model on which JaCaMo is based is shown in Fig. 1. JaCaMo technology – including an Eclipse-based IDE and the runtime – is open-source and available at <http://jacamo.sourceforge.net>.

2 Pervasive Extensions

A main application domain where agents and multi-agent systems can be fruitfully used is given by smart systems in the context of pervasive/ubiquitous computing [9]. Pervasive computing is becoming mainstream today thanks to the technology advances in mobile computing and wearable computing, and, more generally, to technologies related to the *Internet-of-Things*. In these systems, software is embedded *everywhere*, from traditional desktops/servers and mobile computing devices (such as smartphones and tablet), to wearable devices (such as smart glasses and wrists), to smart objects spread in the physical environment where people live and work. Programs run everywhere, anytime and interact, mainly through the Internet.

JaCaMo pervasive extensions are a set of libraries that make it possible to exploit uniformly the JaCaMo programming model to develop multi-agent systems for such pervasive computing scenarios. In this demo, we are going to show the most recent advances and work-in-progress about these extensions, that are identified by the prefix JCaM—which stands for JaCaMo. In particular we are going to show some concrete examples about:

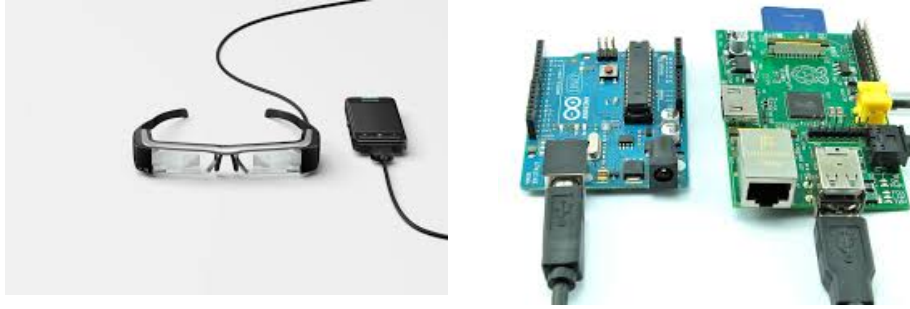


Fig. 2. Moverio BT-200 Smart glasses (*left*), and Arduino and Raspberry Pi (*right*).

- JCaM-mobile – this is an evolution of the JaCa-Android project [8] and makes it possible to develop full JaCaMo systems running on Android-based smartphones and tablets.
- JCaM-wearable – this extension allows the development of multi-agent programs running on wearable technologies, in particular on systems adopting *smart-glasses* as a main user interface devices.
- JCaM-IoT – this extension makes it possible to develop multi-agent programs controlling embedded devices – equipped with proper sensors and actuators – and eventually interacting through the Internet by means of IoT-oriented communication protocols and technologies (such as HTTP, MQTT, UPnP, XMPP, CoAP).
- JCaM-AR – this extension provides an enabling support for developing agent-based *augmented* and *mixed reality* applications, either on mobile devices (exploiting JCaM-mobile) or smart glasses (exploiting JCaM-wearable).

It is worth remarking that such extensions do not concern simply *porting* the technology on the target devices, but the definition of an effective and uniform multi-agent oriented abstraction layer useful to exploit and control all the functionalities of the specific target environment. In particular, this layer is given by a carefully designed set of artifacts encapsulating the main functionalities, hiding the interaction with low-level enabling libraries and services provided by the hosting device/framework. There is no need to extend neither the agent model/architecture, nor the organization.

During the demo, we will show the on-the-fly programming of simple JaCaMo multi-agent programs based on these extensions and deployed on a variety of devices, that include a number of Android smartphones, Epson Moverio BT-200 smart-glasses (see Fig. 2, left) and some Arduino and Raspberry Pi 2 based embedded systems (see Fig. 2, right)—eventually interacting altogether. Besides, we will show some work-in-progress about more comprehensive applications that exploit all these extensions together—a main one is given by a first platform for developing and running *mirror worlds* [6, 5].

3 Conclusion

The JaCaMo extensions presented in this demo allow to exploit the expressive power of multi-agent oriented abstractions and languages to conceive, design and program pervasive computing applications, shielding the MAS developer from the complexity of low-level heterogeneous enabling technologies. We believe that this is useful both for making it easier for agent/MAS researchers to explore and stress the adoption of agent/MAS technologies to develop innovative systems – such as smart environment and Ambient Intelligence ones – and for fostering the exploration and adoption of the agent and MAS paradigm for pervasive computing and related communities.

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