Rashid Mehmood · Victor Alves · Isabel Praça ·
Jarosław Wikarek · Javier Parra-Domínguez ·
Roussanka Loukanova · Ignacio de Miguel ·
Tiago Pinto · Ricardo Nunes · Michela Ricca
Editors

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Editors
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Vila Real, Portugal

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Preface

The 20th International Symposium on Distributed Computing and Artificial Intelligence 2023 (DCAI 2023) is a forum for exchange of ideas between scientists and technicians from both academic and business areas. DCAI is essential to facilitate the development of systems that meet the demands of today's society. Research on Intelligent Distributed Systems has matured during the last decade, and many effective applications are now deployed. Nowadays, technologies such as Internet of Things (IoT), Industrial Internet of Things (IIoT), Big Data, Blockchain, and Distributed Computing, in general, are changing constantly because of the large research and technical effort being undertaken in both universities and businesses. Most computing systems from personal laptops to edge/fog/cloud computing systems are available for parallel and distributed computing. This conference is a forum in which to present application of innovative techniques to complex problems in all these fields.

This year's technical program will present both high quality and diversity, with contributions in well-established and evolving areas of research. Specifically, 108 papers were submitted, by authors from 31 different countries (Algeria, Angola, Austria, Brazil, Burkina Faso, Canada, Croatia, Czechia, Denmark, Ecuador, Egypt, France, Germany, Greece, India, Israel, Italy, Japan, Moldova, Netherlands, Nigeria, Norway, Poland, Portugal, Serbia, South Africa, Spain, Tunisia, Turkey, USA, and Zambia), representing a truly wide "area network" of research activity. The DCAI'23 technical program has selected 50 full papers in the special sessions, and as in past editions, there will be special issues in ranked journals such as Electronics, Sensors, Systems, and Advances in Distributed Computing and Artificial Intelligence Journal. DCAI'23 special sessions have been a very useful tool to complement the regular program with new or emerging topics of particular interest to the participating community.

This year, DCAI 2023 has especially encouraged and welcomed contributions on: Advances in Sustainable Economics and Technology (ASET); AI-Driven Methods for Multimodal Networks and Processes Modeling 2023 (AIMPM); Artificial Intelligence for Enhanced Cybersecurity (AI4CS); Computational Linguistics, Information, Reasoning, and AI 2023 (CLIRAI); New Perspectives and Solutions in Cultural Heritage (TECTONIC); Power System Optimization and Machine Learning Models (PSO-ML); Smart Factories of the Future (SmartFoF); and the Next Generation of IoT Infrastructures, Cybersecurity, and Applications (IoTalentum).

DCAI 2023 is organized by the LASI and Centro Algoritmi of the University of Minho (Portugal). We would like to thank all the contributing authors, National Associations (AEPIA, APPIA), the sponsors (AIR Institute), the funding supporting of the project "ActiveEdgeMobile, Reference: PDC2022-133161-C31, financed by MCIN /AEI/10.13039/501100011033 and NextGeneration EU/PRTR, UE", and finally, the

Local Organization members and the Program Committee members for their hard work, which was essential for the success of DCAI'23.

June 2023

Rashid Mehmood
Victor Alves
Isabel Praça
Jarosław Wikarek
Javier Parra
Roussanka Loukanova
Ignacio de Miguel
Tiago Pinto
Ricardo Nunes
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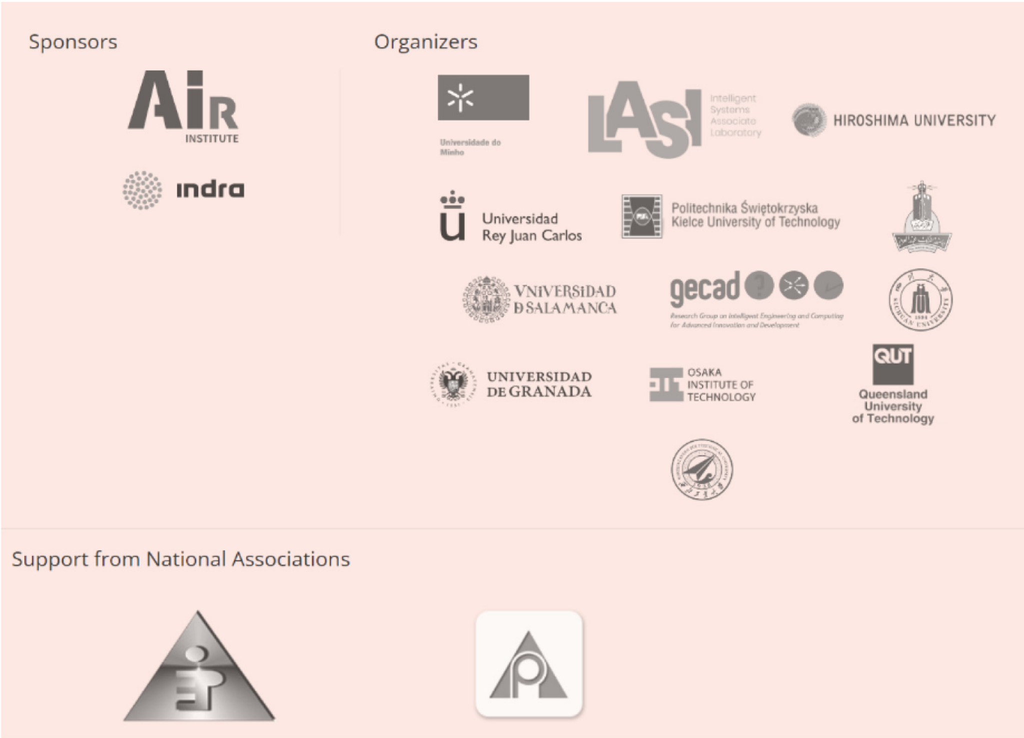

Contents

Session on New Perspectives and Solutions in Cultural Heritage (TECTONIC)

Special Session on Power System Optimization and Machine Learning Models (PSO-ML)

Design of Context-Aware Information Systems in manufacturing industries: overview and challenges

Arlindo Santos[1[0000-0002-7531-9070]], Claudio Lima[2[0000-0003-0762-9680]], Arsénio Reis[2[0000-0002-9818-7090]], Tiago Pinto[2[0000-0001-8248-080X]], Paulo Nogueira[3] and João Barroso[2[0000-0003-4847-5104]]

[1] Polytechnic Institute of Bragança, Campus de Santa Apolónia, 5300-253 Bragança, Portugal
acsantos@ipb.pt
[2] University of Trás-os-Montes and Alto Douro, Quinta de Prados, 5000-801 Vila Real, Portugal
{claudiol, ars, tiagopinto, jbarroso}@utad.pt
[3] Continental Advanced Antenna, Zona Industrial de Constantim, 5000-082 Vila Real, Portugal
paulo.nogueira@continental-corporation.com

Abstract. In the last 30 years, several academic and commercial projects have explored the context-awareness concept in multiple domains. The concepts of ubiquitous computing and ambient intelligence are features associated with the fourth generation industry empowering space with the ability to interact and respond appropriately according to context. In the scope of Industry 4.0, context-aware systems aim to improve productivity in smart factories and offer assistance to workers through services, applications, and devices, delivering functionalities and contextualized content. This article, through descriptive research, discusses the concepts related to context, presents and analyses projects related to ubiquitous computing and associated with Industry 4.0, and discusses the main challenges in systems and applications development to support intelligent environments for increased productivity, supporting informed decision-making in the factories of the future. The study results indicate that many research questions regarding the analysed projects remain the same, leading the research in the context-ware systems area to minimize issues related to context-aware features, improving the incorporation of Industry 4.0 paradigm concepts.

Keywords: context-aware, *context-aware systems, manufacturing industries, ubiquitous computing*

1 Introduction

In 1970 the mainframe was a resource shared by several people, but in 1980 this concept changed, and the era of the personal computer began. In the 1990 decade, computational advances such as increased processing power and storage, size reduction, interconnectivity, increasing battery capacity, wireless networking, and software technologies allowed the computer to become an integrated part of everyday life. It led to an era where technology is present and seamlessly integrated into the performance of the most diverse tasks. Weiser [1] called this new paradigm ubiquitous computing and the author believed that "*the most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are in*".

Later, Lyytinen and Yoo [2] state that computing devices can obtain information from the environment and use it dynamically. In this sense, the environment becomes "smart" as it acquires the ability to detect other devices. Thus, the ubiquitous computing paradigm presents interesting concepts from which the industrial community and visions of the factory of the future can benefit [3]. As a consequence of technological advances in the area of ubiquitous computing, semantic and soft computing, Thaduri et al. [4] report an increasing demand in the research of context-aware applications, such as medical applications, smart homes, smart cities, e-commerce, web services, and industrial applications. Within industrial environments, spaces incorporate the context-aware concept to assist people and machines in performing their tasks, and Mark Weiser's approach is visible in the factory environment [5].

Considering the increasing presence of context-aware systems in the industry, this paper reviews the context concept, by exploring projects related to ubiquitous computing and associated with Industry 4.0. Consequently, the main challenges in systems and applications development to support intelligent environments for increased productivity are identified, highlighting promising paths for future research and development.

2 Background

The term context was firstly used by Schilit et al. [6] to refer to the location and identity of people or objects in the surroundings, as well as changes in these objects. These authors define three aspects of context as essential: where you are, who you are with, and what resources are available in the surroundings. Other definitions emphasize the context information used to provide relevant services, which depend on the user characteristics, and the tasks being performed [7].

According to Dey [8], context is any information that can be used to characterize the situation of an entity (person, place, or object) and that is considered relevant to the interaction. To differentiate and capture the various types of context information, Dey [9] suggests finding answers to five basic questions: who? related to the user identification; where? related to the user location; when? related to the temporal context; what? related to the identification of the user's activities; and why? related to the information that provokes certain user actions.

The diversity of definitions is so complex that researchers Bazire and Brézillon [10] examined 150 definitions of the word "context", from a wide variety of research areas, concluding their analysis by stating that creating a unified definition of context is an arduous and probably impossible endeavour. The context definition depends mainly on the field in which it is applied and, in general, context is a set of constraints that influences behaviour relative to a given task.

Nowadays, the availability of sensors and the extensive use of intelligent devices allow the development of systems that can "feel" the environment and recognize specific contexts. In recent years, context-aware systems have gained increasing popularity, as they can provide contextual assistance and automate processes. According to Rosenberger et al. [11], despite the advantages of context-aware systems, they still play a minor role in industrial applications. When compared to the personal domain, their use is incipient in the industrial environment [12] due to the absence of methods and techniques to support context documentation, analysis, and optimization, hindering the more intensive development of context-aware systems [13].

3 Methodology

In this study, we adopt the qualitative approach. Within exploratory research, descriptive research was applied as a study methodology aiming to describe facts and phenomena of a given reality - namely, here, the development of context-aware systems in Industry 4.0 (I4.0). In addressing issues in a permanent change process, descriptive research searches, records and analyses the obtained data, seeking to present an accurate description of the studied phenomenon, through a critical examination of the information [14].

By analysing the literature on the development of context-aware information systems for I4.0 between the years 2001 and 2020, 7 projects were selected, for presenting the characteristics related to the researched theme, being the same as described in section 4, analysed, and discussed in section 5, making it possible to reach the conclusions of the research, in the section 6.

4 Related projects

Pradeep and Krishnamoorthy [15] performed a literature review and listed about 50 projects related to context-aware systems between 2001 and 2017. We conduct descriptive research of systems associated with the ubiquitous computing concept and oriented to the industry domain, considering that industrial spaces incorporate properties of ubiquitous computing and act as smart spaces that aggregate smart objects [3]. These projects provide relevant insights for thinking about architecture that incorporates the context-aware concept and facilitates rapid applications development.

4.1 Context ToolKit

Dey et al. [16] presented the Context Toolkit, which provides tools that facilitate the development of context-aware applications and contribute to the standardization of the way context data is accessed, by the fact that sensors and actuators are encapsulated by a set of common access methods, regardless of type, and data can be accessed and shared transparently by applications. In this approach, context is understood as information that applications can use and that is part of the space. The strategy of infrastructure development aimed to meet some requirements for handling context and contextual information [8, 16], facilitating application development.

The architecture introduces the widget component, which executes the mediation between the user and the environment and provides a common interface for applications that use the context independently of the sensors used to capture the information. Aggregators are responsible for gathering the context information associated with a real-world entity, such as a person or a place, while interpreters are responsible for transforming one form of context into another. The services embedded in widgets can execute determined actions according to the interest and needs of a given application, i.e., when a specific combination of conditions occurs, any predefined action must be taken at the request of the application. Finally, the discoverers are responsible for keeping track of all the components' information and what each one can accomplish.

4.2 Aura

Garlan et al. [17] present a framework for supporting user mobility in ubiquitous computing environments and facilitating the task of developing context-oriented applications. The base of this system relies on the concept that the most precious resource in a computing system is no longer the processor, memory, disk, or network, but human attention, i.e., the ability of a user to dedicate himself to primary tasks is a priority.

The framework monitors the actors in the context and acts to be proactive and anticipate needs, adapting to the resources available and to the requests made. In this way, it provides opportunities for adaptation to changing resources, user mobility, changes in user needs, and system failures [18]. The proposal supports applications that benefit from the co-knowledge of available computing resources.

In the lower layers of the architecture are the components that monitor the network conditions or determine the user's location. Above the operating system layer are the components which allow access to remote files considering the network state and the monitoring and adaptation of resources and applications: the Spectra, which, based on context, determines the best mechanism for the execution of remote procedure calls and, at the highest level of the architecture, the Prism that supports task execution, is context-sensitive, allows adaptation to the environment, and detects the user's intentions, assisting before any need is declared.

4.3 GAIA

Román and Campbel [19] proposed a distributed software infrastructure for ubiquitous applications development and publishing. Related to an operating system, the project abstracts access to physical resources, and several the concepts, such as events, file systems, processes, and others. The result culminated in a middleware and framework development, aiming to support the creation of user-centric, resource-aware, multi-device, and context-sensitive applications for active spaces, performing resource and service management and offering services related to context, events, and localization.

The architecture has three main layers: kernel, application framework, and applications. The kernel provides basic services such as events, presence of entities, context notification, discovery, and others. The Application Framework provides mechanisms to build, run and adapt the Applications, executed over the third layer. The great advantage is the ease of generating scripts to create distributed applications through the instantiation of components present in the space, while allowing rapid application development.

4.4 CIConAInd

Thaduri et al. [4] propose a meta-database generated by contextual information and use a rule-based approach, thus providing decision-making using various soft computing algorithms. In the industrial application setting, context often considers users, machines, the environment, as well their interactions that cumulatively affect performance.

The users have interests, qualifications, education, and others, while the environment has variables such as weather information, location, and temperature, among others, and the machine is an abstraction of devices, resources, and events. The implementation of context-aware systems depends on requirements, availability, cost, and business objectives. The proposed framework consists of module integration like as data acquisition, pre-processing, network, data storage, and user interface layer.

4.5 Three-tier architecture

Alexopoulos et al. [20] proposed a system designed according to the requirements of the shop floor, thus offering a context-aware solution to support operators and activities. The architecture has in three levels: Edge tier, Platform tier, and Enterprise tier. In the Edge tier, data is obtained from the devices in the physical environment (assets) and pre-processed. In the Integration layer, and according to pre-configuration rules, audio and visual alerts can be generated. Subsequently, the low-level information is sent to the Platform tier, where contextual information is extracted (context engine) to make it available to services (Services layer) and applications embedded in the Enterprise tier.

The proposed approach was validated by the shop floor actors and allows the development of applications independent of heterogeneous data sources (assets), which can be easily reconfigured without additional development effort.

4.6 Context-Aware Programming (CAP)

Gaur et al. [21] propose a declarative approach for application development called Context-Aware Programming (CAP), allowing the developer to write autonomous blocks of code promoting abstraction, modularity, and mobility. Low-level issues are discarded, ignoring heterogeneity issues, and code reuse and availability is promoted on different devices and in different execution contexts.

The proposal provides a component called Context Manager that keeps a complete record of each context and the applications associated with each context. And for an application to be associated with a context, it must already have been created using the Applications Manager component. The Resource Administrator provides automated CoAP operations (such as pull, push, get, and observe) to maintain the state of available devices and the resources provided by those devices.

4.7 Digital Factory Assistant

Belkadi et al. [3] designed a contextual knowledge-based system dedicated to supporting the factory actors with the correct information at the right time and in the appropriate format according to their work context and level of expertise for machine configuration and manufacturing operations. They present a matrix of comparison of this system with 5 other systems based on each system's ability to understand the situation, assist the user in real-time, integrate the ability to provide collaboration, support human-machine interaction, access context, provide interoperability of legacy tools, and mapping to different application domains.

The authors proposed a context model with organizational, operational, and user-centric dimensions, as well as the relationship between them for intensive knowledge reuse. The model aims to help shop floor workers in their daily activities and improve the efficiency and effectiveness of the operational process in assisting decision-making.

5 Analysis and Discussion

Although society has permanent contact with solutions that take advantage of different context variables, the definition of the concept is still superficial and with some limitations [13], and the development of applications that use simple con-text data, with a minimum of variables and without any complexity, is "trivial". The issue arises when the objective is to develop computational systems with the skill to comprehend contexts beyond the scope of simplicity and encompassing a high degree of complexity. In industrial settings, particularly within the manufacturing industry, computational systems traditionally incorporate cloud computing and edge computing technologies. More recently, the discourse has arisen regarding the application of fog computing in such contexts [22]. At the extreme, we can design multiple layers of context storage and computation, for subsequent decision-making (supervised, semi-supervised, or unsupervised). Under such circumstances, complexity escalates and responses to the 5W inquiries posed by Dey [9] do not remain facile.

The discussion initiated by Dey et al. [16], concerning the topic of minimizing development is related to the development process of applications that use contextual information. The authors identified a set of system requirements to facilitate the developer's task, shifting to the system the responsibility of managing the contextual life cycle: acquisition, interpretation, storage, dissemination, as well as resource discovery in the environment. And this approach is followed in some previously presented works and in literature review articles [23, 24], where the focus is on creating an architecture that hides the complexity of the context and provides access interfaces for applications. According to Gaur et al. [21], the facilitation of contextual understanding necessitates the provision of suitable tools for application development and the concealment of knowledge pertaining to specific resources.

According to Baldauf et al. [24], the design of context-aware systems should consider two principles: the architecture and the context model. However, in the industry domain, there are available software system architectures specifically targetting the application environment in I4.0, where every physical object will always be connected with its digital twin [20]. Alexopoulos et al. [20] consider that IIoT (Industrial Internet of Things) architectures oriented to industrial and context-aware environments, should privilege a layered approach to simplify the development of a complex system, isolating functionalities, as well as an event-driven approach and the use of ontologies or semantics in the context specification in a dynamic environment.

Another challenge that adds complexity is related to the interactions of the environment's actors, be they people, applications, machines, robots, etc. Instead of the traditional model, where the computer is the center of the interactions, the new ambiances allow users to interact with the system at any time, in any space, and from any device. Kymäläinen et l. [25] contend that forthcoming control operatives must oversee intelligent systems via novel modes of interaction and that tasks will be distributed flexibly between human workers and systems. And the interaction between humans and machines is still underestimated by developers, which makes it difficult to design a system that can interact with multiple users and support their daily activities [3]. More, in the smart factory context that aims to build the "Factory of Things" concept, the factory incorporates smart objects (physical and/or virtual) that interact together to exchange information [26] in the framework of the Cyber-Physical System (CPS) concept.

The Aura project [17] privileges the focus on the user and the system's ability to prevent this actor from being disturbed in his activities. For proactivity to be effective, a system must track the user's intent to determine which system actions will help [27]. This is, i.e., the concern of World Wide Web search engines such as Google Search that "guesses" the user's intent when they type a term into the search bar. Extending to an industrial environment populated by other actors, and each with intelligence capabilities, the challenges increase. Conversely, the ability to forecast the intentions of actors within a given environment engenders several significant research inquiries. And according to Gaur et al [21], the context-aware concept can anticipate the needs of a user/environment and act accordingly, to support context-aware, it is important to provide the user with the appropriate tools to write applications. The main goal of such a programming approach should be to let the user express the desired goals without requiring knowledge about specific resources, and yet we only visualize the concept of usability as addressed by Alexopoulos et al. [20] intakes at the stage of the project evaluation.

Recovering the concept of Active Spaces [28] as a collection of dynamic components installed and distributed to meet the requirements of a user or a group of users. Dynamism is arguably the most critical aspect of an application, thereby necessitating a flexible, component-based application architecture capable of modifying its composition during runtime. Dynamism presupposes that the mobility of entities is a constant requirement [17], and the challenge focuses on capturing the attention of the interaction actors.

Undoubtedly, the advent of the Internet and mobile technologies has transformed the manner in which users acquire and engage with information. It is crucial to recognize that users transition between physical or virtual spaces, just as sensors and actuators themselves may move within space, potentially persevering or relinquishing connection to the same environment. Besides these, we have the mobility of applications and activities between spaces, devices, and users.

The emergence of the Internet and mobile technologies has brought about a shift in the means through which users retrieve and interact with information. It is imperative to recognize that users navigate between both physical and virtual spaces, in a similar manner to how sensors and actuators may move within a given environment and maintain, or sever, their connection. Besides these, we have the mobility of applications and activities between spaces, devices, and users.

With the merging of wireless communication and device functionality, devices can be employed in highly mobile situations. Thus, entities must be able to operate in different and dynamic communication characteristics, possibly changing service access providers. Furthermore, the incorporation of new entities may lead to a surge in the volume of data that necessitates effective data management. Considering that context is dynamic and multi-variant, working with the complexity, heterogeneity, and data management of context-aware systems requires the adoption of sophisticated hardware and software computing, and with the emergence of the soft computing concept, in contrast to traditional computing, may be an opportunity [4]. Nevertheless, in industrial settings characterized by dynamic and semi-structured conditions, where job responsibilities are subject to change and workers are mobile, the utilization of context-aware information is deemed even more pertinent [20].

Applying Weiser's vision [1] to secure an increased degree of availability and proactivity is a concept that could enhance the capacity to provide real-time assistance to users. Belkadi et al. [26] contend that, although the notion of ubiquitous computing is not novel, it nevertheless presents an intriguing scientific challenge that has yet to be comprehensively explored by industrial engineering research communities. Incorporating such concepts may offer significant advantages to these communities and facilitate the realization of visions pertaining to the factory of the future.

6 Conclusions

Currently, many commercial companies offer assistance to the user by delivering context-aware content and functionality through services, applications, and devices. Since the start of XXI century, several academic projects have demonstrated the efficacy of implementing context awareness, resulting in the term "context" proliferating over the years. However, the generalized and unique definition of the context concept does not exist and differs from domain to domain. Projects embodying this concept within industrial spaces are reduced, but the encouragement in development of applications is an option to meet the challenges of the market.

In this sense, this article has analyzed and presented a set of discussion topics related to the meaning of the word context and its challenges in industrial systems, as well as enumerating academic projects, and from this leverage a set of challenges for the development of context-aware systems and applications to support decision making in manufacturing industries. The advances in digital technologies and systems have opened new opportunities in the soft computing field, where industry practices have incorporated no-code and low-code development strategies. With the ability to design systems capable of facilitating real-time decision-making and reducing the application development process, we can surmount new challenges in the soft computing domain.

While the early analyzed projects did not address the concepts of cloud computing, fog computing, and edge computing, in recent projects these concepts are part of the discussion in the smart factories design solution. In the context of Industry 4.0 and the production domain, it is crucial to acknowledge that the underlying assumptions differ from those of other knowledge domains. The final analysis indicates that many issues addressed by projects in the first two decades of the 21st century remain relevant in the current literature, such as mobility, heterogeneity, interoperability, resource discovery, and system integration. Therefore, future system development and improvements should minimize issues related to context-sensitive features, improving the speed of incorporating Industry 4.0 paradigm concepts into these systems.

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