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Data Management in Pervasive Systems

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Preface

1 Introduction

The adjective *pervasive* comes from the Latin verb *pervadere*, which literally means *to go through*. However, looking at modern dictionaries, we find wider definitions such as *to permeate* [5] or *to diffuse in order to modify and characterize the atmosphere or the physiognomy of a certain ambient* [3]. The last definition well characterizes modern pervasive information systems, which had a remarkable growth in recent years. Indeed, as shown in Fig. 1, we can find applications of pervasive systems in the most disparate domains, such as health care, archaeology, museums, pollution control, and others: domains which only a few years ago used computers only for administrative purposes and were alien to involve computers directly in their functionality. On the other hand, pervasive systems rest on, and integrate, many different technologies as far as sensing devices, transmission modalities, and networking techniques are concerned.

Back in 1991, Mark Weiser [6] set the essence of modern pervasive systems, stating that they must allow the computer to vanish in the background in the same way as happened with other facilities such as the electric grid or the telephone switching network: as a matter of fact, a typical car has more than a dozen computers and electric motors, but almost no driver is aware of that. This has a fundamental psychological effect, since only when we do not have to concentrate on the individual features of such utilities any more, and they become part of the infrastructure, is our mind free to focus on our goals.

The creation of intelligent pervasive spaces is one of the most interesting opportunities offered by pervasive systems: social and physical ambients can be created with the aid of information and communications technologies (ICT), providing enhanced capabilities for humans to interact with the surrounding environment [4]. These features are useful at home—for instance, for providing services for security, energy management, and water and pollution control or to create assisted-living ambients for impaired or elderly people—but also as proactive and intelligent supports to visiting museums and historical sites.

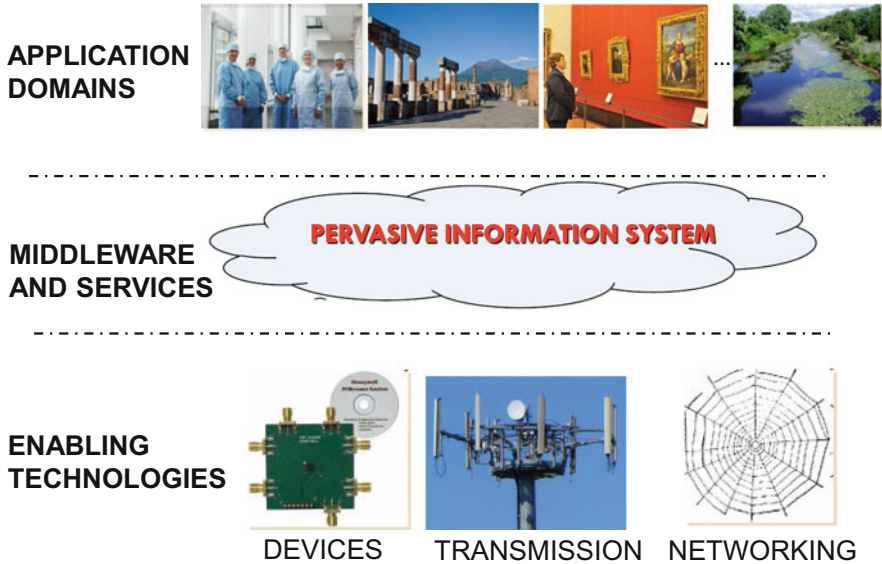


Fig. 1 The components of a pervasive system

Many of these solutions are made possible thanks to the adaptivity and context awareness of pervasive systems; by sensing the environmental conditions, the system dynamically recognizes the situation and context into which it currently operates and behaves accordingly. Adaptivity and context awareness are strictly related to each other and in many real situations are considered as interchangeable; however, while context awareness actually refers to the ability of the system to recognize the current context and to provide, at any time, the necessary contextual information and services [1], adaptivity refers to the execution of behavioral variations in response to changes of context or other parameters that can affect the behavior of the system, even the internal software itself [2]. Therefore, adaptivity and context awareness are complementary in building pervasive applications.

In Fig. 1, the pervasive information system is shown as a layer of middleware and services between the technological level and the application domains.

2 A Guide to Readers

The goal of this book is to provide a systematic description of the plethora of research issues related to the management of information in pervasive systems, illustrating the state of the art in this area. It can be used for a self-contained graduate

(PhD or master) course or for a series of seminars included in other courses on data management or distributed systems.

The book is divided into six parts with a final case study covered in the last part. Part I (Chaps. 1–3) covers very briefly the basic ideas underlying the economical, technological, social, and legal aspects of pervasive systems; Part II (Chaps. 4–7) describes several aspects of sensor networks and data stream processing; Part III (Chaps. 8–10) covers the main aspects of social networks with a special emphasis on cultural heritage applications; Part IV (Chaps. 11–13) describes the personalization and context awareness issues in pervasive environments; Part V (Chaps. 14–16) covers the multimedia aspects, again with a particular attention to the cultural heritage realm. Finally, a real case study is presented in Part VI (Chap. 17) with the description of an application within the DATABENC¹ project of the Campania region in Italy. Each part has its own foreword, guiding the reader through its chapters.

Readers of two different categories can take advantage from reading this book: on one hand, humanities and cultural heritage experts and enthusiasts can be introduced to the enabling technologies that are so promising for their application domain; on the other hand, ICT researchers and professionals can familiarize themselves with the issues of the cultural heritage realm while gaining new knowledge on the advances of pervasive technologies.

As shown in Fig. 2, we suggest the following path to cultural heritage experts. Chapter 1 analyzes and illustrates how new technologies have radically changed cultural and economic models, while Chap. 2 explains the essential technological aspects involved in the implementation and deployment of pervasive information systems. Chapter 3 surveys the main issues related to privacy in emerging pervasive scenarios and discusses some approaches toward their solution. In order to avoid overwhelming non-ICT readers with too many technicalities, we propose to skip some details and sometimes whole chapters: from Chaps. 4, 5, and 7, we recommend to extract only the first two sections. Chapters 8, 10, 11, 12, 13, and 14 are more descriptive and thus can be profitably read by a nontechnologist, while we advise the reader to jump from here directly to Chap. 17, which contains an overall description of the pervasive technologies applied to DATABENC.

The reading path for ICT experts is depicted in Fig. 3. Chapters 1 and 3 provide the readers with the economical, social, and legal aspects raised by the introduction of pervasive technologies, especially in the cultural heritage domain. From here, the readers can probe deeper into one or more technological aspects covering their interests: Part II (sensors, data stream, and storage), Part III (social networks), Part IV (context awareness and personalization), and Part V (multimedia information management). Also the technologists will be interested in the application of all the discussed technologies to the real case of the DATABENC project described in Chap. 17.

¹High Technology District for Cultural Heritage.

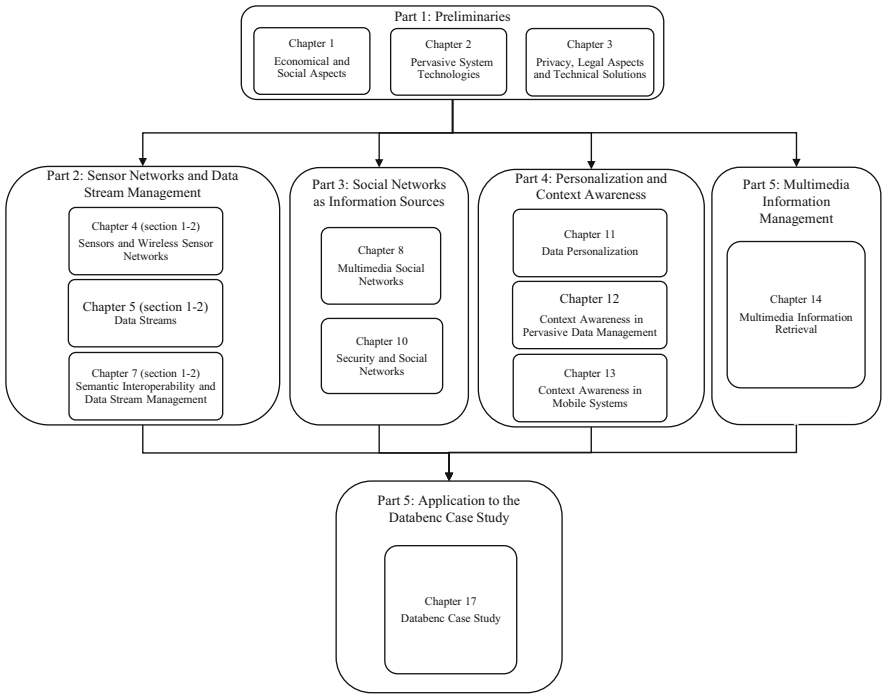


Fig. 2 Reading path for humanities and cultural heritage experts

3 Presentation of the Case Study

The DATABENC project is a high-technology district for the management of cultural heritage, recently funded by the Campania region in Italy. Campania boasts one of the largest and most precious cultural heritages in the world: valorizing and promoting such a patrimony, by the adoption of information and communications technologies, is nowadays of paramount importance also at the international level, with a large variety of potential applications.

In particular, DATABENC aims at designing and developing a general framework that provides each cultural site (indoor museums, archaeological sites, historical archives, old town centers, etc.) with several context-aware services for seamlessly assisting users (e.g., visitors or staff personnel) in the exploration and management of the related environment. As in a typical smart-city scenario characterized by the use of Internet-of-Things technologies, the physical sites as well as the users are equipped with all sorts of smart devices and appliances against which the topics of sensor data management, user-originated data operation and reasoning, multimedia and social data management, data analytics and reasoning for event detection and decision making, context modeling and control, automatic data, and service tailoring for personalization and recommendation have to be challenged.

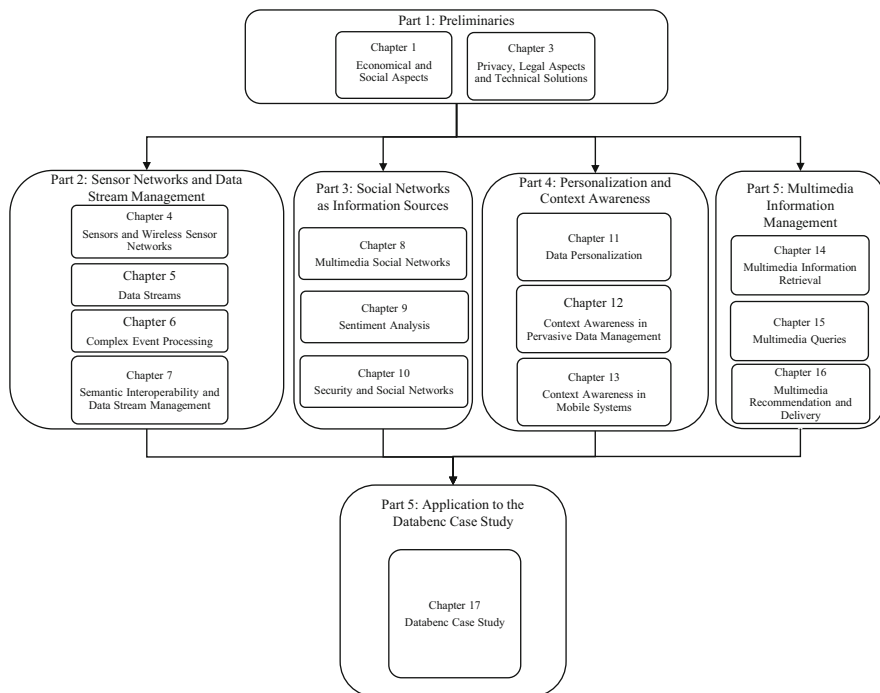


Fig. 3 Reading path for ICT experts

As a first motivating example, we can consider tourists who, during their vacation, want to visit a special exhibition of paintings and sculptures offered by a given indoor museum (e.g., the national museum of Capodimonte in Naples). To be considered *smart*, the museum environment should provide users with a set of functionalities for:

- Booking a visit for a specific date and time and buying the related ticket, managing, and user accounting/registration
- During the exhibition visit, accessing appropriate guides which describe the artworks by means of information coming from multiple and heterogeneous multimedia repositories (e.g., Flickr, Panoramio)
- Enabling the objects of the exhibition to “talk,” when a user is sufficiently close to them, automatically telling their story by means of multimedia facilities, again according to user preferences and needs
- Analyzing feedbacks, reviews, and comments of other users or experts coming from the most common social networks (Twitter, Facebook, etc.) to have a more detailed vision or an opinion about artworks
- Monitoring the environmental condition of each room by means of sensor networks (e.g., a Wireless Sensor Network (WSN)), for example, detecting some danger and showing the exit in the case of an emergency

- Saving the users' visit experiences in a digital format for future memory, which also allows them to post their comments on social network web sites

As a second example, we can imagine tourists visiting an archaeological outdoor site (e.g., Paestum or Pompeii ruins), endowed with an app which guides and supports them in their visit. In this case, to be considered smart, the environment should provide a set of functionalities for:

- Suggesting useful data and services tailored according to the current user context (user location, user preferences and needs, cultural level, environmental conditions, etc.); as an example, the information can be tailored differently according to the different levels of detail required by an archaeologist or by a nonexpert user
- Dynamically recommending visit paths, using the multimedia description of the cultural attractions or other support information, possibly enabling the publication of comments about user experience on social networks
- Allowing the 3D reconstruction of objects and the interaction between physical and virtual space by means of Virtual Reality technologies
- Monitoring environmental conditions, buildings' state, and users' behavior for security aims

Summarizing, the aim of the DATABENC project is the design and implementation of a Cultural Heritage Pervasive Information System based on the adoption of the future Internet architectural models and technological standards, capable of managing, in an integrated way, sensor-originated data and user-generated content in a pervasive context. Therefore, according to the most recent methodological and technological research on pervasive data management, the system should have the following features:

- It must manage the communication with any kind of sensor that can be deployed in the cultural site of interest (WSN, Radio Frequency Identification (RFID), video cameras, etc.).
- It must provide a set of primitives for the access, retrieval, integration, and analysis of information coming from the different data sources (multimedia repositories, social networks, sensors' database, etc.), managing the correlation with spatial information.
- While supporting data management, it must implement the transformation of the captured data into usable knowledge.
- It must be able to discover and track users within a site using heterogeneous technologies (GPS, Bluetooth, WiFi positioning, etc.).
- It must provide intelligent and personalized access to the knowledge base on the user profile, context state, and applications using context-aware and recommendation facilities.
- It must provide basic primitives for data analytics and reasoning, with the aim of supporting dynamic, on-the-fly personalization and social network analysis applications.

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