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HABILITATION THESIS

SUMMARY

Title: Distributed Applications for Ambient Assisted Living

Domain: Computers and Information Technology

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This thesis succinctly and selectively presents the author's research and achievements in the vast field of distributed applications. The case studies framed into the domain's theme are limited to applications made in the context of *Ambient Assisted Living* (AAL) systems.

Ambient Assisted Living is an innovative field that uses distributed applications to enhance the independence and quality of life for elderly and disabled individuals. By leveraging cloud technologies, sensor networks, and *Internet of Things* (IoT) devices, AAL provides comprehensive support that can be integrated into daily activities. These technologies enable continuous monitoring and real-time data processing, ensuring effective assistance and promoting an environment of autonomy and safety for its users.

Chapter 1 of the paper presents the theoretical foundations of distributed applications and includes brief descriptions of the projects used as case studies in this work. Thus, the main architectural models used in designing distributed applications and the technologies that facilitate their development are presented.

The architecture of distributed applications is very important for implementing efficient and scalable systems. Among the basic architectures are the client-server model, which involves the interaction of multiple clients with a central server, and peer-to-peer (P2P) networks, where nodes function both as clients and servers, improving resilience and resource distribution. More complex architectural models, such as multi-tier and microservices architectures, allow for the separation of concerns across different layers, facilitating easier maintenance and better scalability.

Distributed applications for AAL integrate a variety of advanced technologies to manage and analyse data collected from various sources. Cloud computing platforms play a vital role in data storage and processing, allowing scalability and accessibility across different devices.

Chapter 2 develops the topic of *Service-Oriented Architecture* (SOA), which is a design approach that facilitates system development and integration by defining services as well-defined business functionalities accessible through a network. These services allow organizations to build flexible applications capable of interacting with other applications across various networks through a set protocol. Service-Oriented Architecture emphasizes principles such as reusability, modularity, and interoperability, which help in reducing development costs by minimizing redundancy and allowing services to be loosely coupled for easier modifications and replacements.

The chapter highlights how this type of architecture was used in the implementation of the FOOD project (*Framework for Optimizing the prOcess of FeeDing*). The web services developed, and the structure of the consumed/generated data are presented.

Chapter 3 addresses the architecture based on microservices, which represents a strategic shift from traditional monolithic application architectures, offering a modular approach by dividing applications into smaller, independently runnable units. This architecture improves flexibility and ease of maintenance, which is particularly advantageous in cloud environments, facilitating better scalability and management. The segmented structure of

microservices allows for more efficient updates and modifications, as changes to one service do not require alterations to others.

Microservices architecture not only supports high availability and efficient management but also allows each team within an organization to work independently on different services, boosting overall productivity. Each microservice can independently scale based on demand, and in the event of a fault, only the affected service is disrupted, leaving the rest of the system operational. This architectural style allows the use of diverse technologies, improving the adaptability and robustness of the system over time. Thus, microservices are highly effective for applications requiring frequent updates and scalability, providing a reliable framework that supports continuous integration and deployment.

Implementing microservices in systems like SAVE (*SAfety of elderly people and Vicinity Ensuring*) illustrates the practical benefits of this approach, including improved management capabilities and increased flexibility to adapt to changing requirements. Microservices in such contexts communicate through standardized interfaces, often using HTTP or HTTPS protocols, with JSON for data exchange, ensuring seamless interactions between services. This architecture not only simplifies development and accelerates the deployment of new functionalities but also leverages cloud infrastructure advantages, making it ideal for dynamic, scalable applications that require robust, fault-tolerant solutions.

In **Chapter 4**, the use and advantages of *Internet of Things* devices in AAL systems are presented. The Internet of Things transforms AAL systems by integrating everyday objects with the internet, allowing them to send and receive data. This technology supports the elderly and people with disabilities, enhancing their quality of life through intelligent support systems. IoT in AAL employs sensors and actuators to collect and act upon data, these components being connected through a robust communication network. This setup not only ensures a timely response but also facilitates personalized interactions, essential for adapting services to individual needs.

The chapter includes two case studies. The first is taken from the HELICOPTER project (*Healthy Life support through Comprehensive Tracking of individual and Environmental Behaviors*) and showcases the software ecosystem required to connect to a server application, via the internet, a local sensor network (based on the *Zigbee* protocol) using a mini-computer Gateway system.

The second case study, taken from the SAVE project, details the hardware and software implementation of a device for collecting data from a monitoring system and transmitting them, via the internet, to the SAVE system services.

Chapter 5 offers a brief introduction to the topic of databases and database management systems.

Databases are integral components of modern information systems, serving as critical repositories of data for various sectors, including business, health, and education. They have evolved from hierarchical and network models in the 1960s to more flexible relational databases and, more recently, to NoSQL and NewSQL models to meet the needs of the internet and big data era.

Relational database management systems are based on a structured model that organizes data in tables. This format supports efficient data manipulation and retrieval, essential for many business applications. Since its creation by Edgar F. Codd in 1970, these systems have grown to support distributed systems and online analytical processing, among other advanced functions. Despite the challenges with managing large volumes of data and unstructured data, the relational system remains vital in data management, with ongoing evolution expected for better adaptability and functionality.

In specific applications, such as the FOOD system, databases play an essential role in managing data from sensor networks. This involves a hierarchical structure where low-level data from sensors are stored and managed in a *MySQL* database, allowing for real-time operational control and historical data analysis. High-level management of this data uses a relational database synchronized with web services to facilitate user interaction and system monitoring. Such architectures highlight the dynamic and scalable nature of modern databases in supporting complex systems and applications, underscoring the continuous integration of database technology with other innovations to meet changing technological demands.

Chapter 6 addresses the topic of human-computer interaction (user interfaces). Human-computer interaction in user interface design focuses on optimizing the interaction between users and devices, aiming for simplicity, efficiency, and ease of use. Good user interface (UI) design ensures that users can complete tasks efficiently without unnecessary complications, supported by graphic design to enhance usability. UI design processes balance technical functionality with aesthetic elements to effectively meet changing user needs.

For elderly users, design considerations adjust to accommodate typical age-related declines in vision, memory, attention, and motor skills. For example, interfaces may use larger, sans-serif fonts and high-contrast colour schemes to aid readability, simplify tasks to minimize cognitive load, and design audible alerts in lower frequency ranges to accommodate auditory sensitivities. These adaptations help maintain the usability of devices and applications among older adults, enhancing their interaction experience without overwhelming them with complex functionalities.

Moreover, user interface planning involves conceptualizing how services are presented and accessed through interfaces, using methods such as conceptual maps, wireframes, and mock-ups to align technical functionalities with user needs. For example, in specialized applications such as the FOOD system, the user interface is tailored to assist the elderly in seamlessly interacting with various functionalities, such as cooking cycles on smart appliances, implemented in multiple languages to serve a diverse user base.

In **Chapter 7**, the topic of cloud computing is addressed, which is essential in enhancing AAL systems by providing scalable, flexible, and efficient computing resources. This technology supports various AAL applications, including health monitoring, emergency response, and smart home implementation. In health monitoring, cloud platforms collect and analyse data from devices such as smartwatches, allowing healthcare providers to intervene in a timely manner. In emergencies, cloud systems promptly notify caregivers and emergency services, providing important information about the user's condition. For smart homes, cloud computing facilitates the control of home systems, such as lighting and heating, enhancing comfort and safety for the elderly.

The benefits of using cloud computing in AAL include sophisticated data management and analysis capabilities, scalability of resources to meet varying demands, and cost efficiency by minimizing expenses for hardware and software maintenance. These advantages make AAL technologies more accessible and effective, supporting proactive health management and improving the quality of life for users.

However, there are challenges, such as ensuring the confidentiality and security of sensitive data, maintaining reliable connectivity, and achieving easy integration between diverse devices and platforms. These challenges underscore the need for robust security measures, reliable internet services, and standardized protocols to ensure the effective implementation of cloud-based AAL systems. Additionally, tools such as *Node-RED* offer flow-based programming to facilitate the development of AAL applications, exemplifying the integration of advanced cloud computing techniques in supporting and scaling AAL services.

In the final part of the paper, the author's academic and research achievements and future research and professional fulfilment coordinates are presented.