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Features of Smart University Libraries in Light of Artificial Intelligence Applications: Technological Integration and Transformation Requirements

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Abstract

University libraries are undergoing successive transformations as a result of developments in information and communication technologies. Their role is no longer limited to collecting, organizing, and providing access to knowledge resources; rather, it has expanded to include developing methods of accessing information, improving users' experiences, and supporting scientific research. In this context, the concept of the smart university library has emerged as an approach that combines artificial intelligence applications with supporting digital technologies, such as expert systems, the Internet of Things, robotics, and virtual and augmented reality.

This study aims to clarify the features of this transformation, analyze the functions and limitations of the aforementioned applications, and demonstrate the importance of integration among them. It also seeks to review the technical, human, organizational, and ethical requirements and challenges associated with their implementation. The study adopts the descriptive-analytical approach by presenting the relevant concepts and applications and discussing their roles and the conditions necessary to benefit from them.

The findings conclude that a smart library is not defined merely by acquiring various technological tools, but rather by its ability to employ them in an integrated manner in accordance with users' needs and the objectives of the university institution, while simultaneously preserving the role of library staff and protecting users' data.

Keywords: Smart Libraries; University Libraries; Artificial Intelligence; Expert Systems; Internet of Things; Intelligent Robots; Virtual Reality; Augmented Reality.

First: Introduction and Methodological Framework of the Study

With the increasing reliance of universities on modern technologies, the role of libraries is no longer confined to preserving and organizing books and documents. Rather, it has expanded to include facilitating

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access to knowledge, supporting scientific research, and providing services that meet the needs of students, professors, and researchers. The spread of digital systems has created broader opportunities for managing collections and providing information resources, while artificial intelligence applications and advanced communication technologies have opened up extensive possibilities for envisioning a more interconnected approach to library services.

Smart libraries rely on a range of technologies with different functions. Expert systems can support certain technical operations and reference services, while the Internet of Things enables resources and devices to be interconnected and data about them to be collected. Some intelligent robots assist with guidance and interaction, whereas virtual and augmented reality introduce interactive methods for exploring content or accessing resources. However, these technologies are not synonymous, and their presence within a library does not necessarily mean that they are all intelligent applications. Rather, some may constitute supporting technologies whose effectiveness increases when they are connected to artificial intelligence systems.

Research Problem

The research problem revolves around the following central question:

How do artificial intelligence applications and supporting digital technologies contribute to shaping the features of smart university libraries?

This central question gives rise to the following sub-questions:

1. What is meant by a university library, and how has its concept evolved from the traditional library to the digital and smart library?
2. What roles do expert systems, the Internet of Things, robotics, and virtual and augmented reality play in developing library services?
3. How can these applications be integrated to serve users and improve resource management?
4. What requirements and challenges should be taken into consideration when considering the transformation towards a smart university library?

Significance and Objectives of the Study

The significance of this study stems from the connection between the topic of smart libraries and the digital transformations taking place in higher education institutions, as well as the opportunities that smart applications can provide for facilitating access to information resources, supporting collection organization, and developing reference and guidance services.

The objectives of the study are to present the functions of university libraries and some of the applications used or proposed to develop their services, and subsequently discuss their potential, the conditions necessary to benefit from them, and the challenges associated with their implementation.

Research Methodology

This study falls within the category of descriptive studies and adopts the descriptive-analytical approach. It seeks to highlight the main functions of traditional university libraries and the changes they have undergone through the employment of expert systems and the Internet of Things in various library services, as well as the roles of intelligent robots and virtual and augmented reality within libraries. It also examines the

key requirements for the optimal deployment of these applications and the challenges associated with their implementation.

Second: The Conceptual and Functional Framework of the Smart University Library

1. University Libraries and Their Functions

University libraries serve higher education and scientific research. To fulfil this role, they require diverse collections of information resources in printed, audio, and visual formats, as well as qualified specialists responsible for organizing these resources, making them accessible, and providing related services. They also contribute to supporting self-directed learning, reinforcing academic courses, and developing students' and researchers' ability to access and utilize information (Ali, 2022, p. 177).

The library's functions include collecting information resources from various formats, organizing, cataloguing, classifying, and arranging them in a manner that facilitates their retrieval when needed, in addition to providing lending, photocopying, guidance, and other services. University libraries may adopt various organizational forms, including central libraries, faculty libraries, and departmental libraries (Kouar, 2022, pp. 219–220).

Accordingly, these functions remain the foundation of any technological transformation, since the value of modern tools is measured by the extent to which they support the library's knowledge-related and educational functions.

2. From the Traditional Library to the Digital and Then the Smart Library

The development of the university library can be viewed across three interconnected levels, without treating them as entirely separate stages. The traditional library relies heavily on physical resources and procedures, whereas the digital library employs electronic systems to manage information resources and make them accessible through networks. The smart library, in turn, seeks to introduce an additional level of interconnectivity, analysis, and responsiveness through the use of data, connected systems, and applications capable of supporting certain decisions and services.

Accordingly, converting a paper catalogue into an electronic one or adding connected devices is not sufficient to establish the existence of a smart library. This concept requires a clear vision of how technology can be employed to improve a specific service, connect relevant systems, and evaluate its impact on users and resource management. The move towards smart libraries reflects an approach that combines multiple applications while taking into consideration library users' needs and sustainable development requirements (Hamza & Abdelmalek, 2019, p. 170).

Third: Applications for Improving Library Services and the Capabilities They Provide

1. Expert Systems and Support for Library Operations

Expert systems constitute one of the most important artificial intelligence applications that can be employed in specific library tasks. They rely on knowledge and rules represented within the system to provide assistance or suggest solutions in a particular field. Several models are available for document analysis and retrieval, such as CODER, cataloguing systems such as REBEIC, and information retrieval systems such

as GEMI, in addition to applications that can support acquisitions, reference services, reading guidance, cataloguing, classification, and other library operations (Ibrahim, 2010, p. 123).

The value of these systems lies in their ability to assist staff in carrying out specialized tasks in an organized manner and to provide preliminary guidance to users. However, the quality of their outputs depends on the suitability of the knowledge and rules on which they rely for the actual task, as well as on continuous updating and verification. Therefore, they should be regarded as supporting tools rather than substitutes for the professional expertise and specialized judgement of library staff (Al-Hassi & Farkash, 2020, p. 129).

2. The Internet of Things and Library Resource Management

The Internet of Things refers to the use of connected devices and sensors to collect and exchange data, thereby enabling resources and devices to be monitored and interacted with within the physical environment. In university libraries, this approach can support collection management, monitor the circulation of materials, facilitate certain repetitive procedures, and create opportunities to connect catalogues with physical devices and services (Al-Mansi & Hammam, 2022, p. 623).

Technologies associated with this field include Radio Frequency Identification (RFID), alongside other connected tools and devices such as iBeacon, as well as certain sensing systems and material-location tracking technologies. Numerous applications exist in this context, including book identification tools, book-location systems, and smart chairs, among others. This reflects the diversity of possible applications of the Internet of Things in the library environment (Neil & Sadouk, 2022, pp. 101–104).

Potential areas of application include providing mobile access to catalogues, monitoring book circulation, issuing notifications concerning overdue materials, helping identify misplaced books, and managing certain facilities such as lighting and air conditioning. Reading stations, identification devices, and wireless communication technologies may also contribute to facilitating access to resources (Ben Tayeb, 2021, pp. 20–22).

Consequently, these benefits cannot be achieved merely by connecting devices to a network. They require proper data organization, ensuring data reliability, maintaining equipment, and updating it regularly.

3. Intelligent Robots and Their Guidance and Interaction Capabilities

The growing use of smart technologies has diversified the capabilities of robots in performing specific tasks and interacting with their surrounding environments. Some libraries have begun experimenting with robots and voice assistants for guidance, communication, and providing preliminary information to users. Examples include the virtual assistant Alexa, which is associated with services at the University of Oklahoma, alongside models such as Tu Bao and Xiao Tu, as well as the BOB robot in Birmingham (Wang, 2017, p. 7).

Robots differ in terms of their design and capabilities. Some interact directly with users, while others perform specific tasks or provide guidance. They may be stationary, mobile, or integrated into devices. Other types include remote-controlled robots and humanoid robots, together with their applications and challenges in libraries (Tella & Ogbonna, 2023).

It should not be assumed that all robots are equally intelligent, as their level of autonomy depends on the system and the technologies integrated into them. Furthermore, determining a robot's effectiveness in

a library requires clarity regarding the task it performs, its ability to respond to users' needs, its ease of maintenance, and the extent to which it integrates with existing human services. Therefore, robots can help reduce certain repetitive tasks, but they cannot replace specialized human guidance or eliminate the need for staff intervention when dealing with complex questions or exceptional situations (Nguyen, 2020, p. 132).

4. Virtual and Augmented Reality and Their Role in Knowledge Exploration

Virtual reality makes it possible to create digital environments that users can explore and interact with, opening up opportunities to present information and educational experiences in different ways. In university libraries, it can be employed to provide interactive experiences or explore educational environments and resources, thereby introducing new methods of interacting with content (Frost et al., 2020).

However, the usefulness of these applications depends on the nature of the content, educational objectives, available equipment, and the extent to which they meet users' needs.

Augmented reality, on the other hand, adds digital information or elements to the physical environment in which the user is situated, rather than replacing it with a fully virtual environment. It can help provide guidance within the library, display additional information about a particular resource, or support the identification and location of materials. Specialized literature presents the arShelv application as an example of tools designed to help identify books that have been misplaced (Jamnik, 2024, p. 74).

Thus, virtual and augmented reality add an interactive dimension to library services. However, each should be selected on the basis of a clearly identified need, such as guidance, displaying additional information, or supporting learning, rather than merely because the technology is new. Furthermore, their integration with artificial intelligence should be described accurately, according to the actual functions performed by the system (Hussain, 2022).

Fourth: Integration among Applications as the Foundation of the Smart Library

A smart library is not simply a list of separate devices and applications; rather, it is defined by the institution's ability to make them operate within an interconnected service process. An expert system may help interpret a user's request or direct them towards appropriate resources, while a cataloguing system provides information about the resource. Internet of Things technologies or RFID may then help identify the item's location or circulation status, after which an interactive interface or guidance robot can provide additional assistance in accessing it.

This example remains an illustrative scenario of how integration can take place, rather than a description of a specific implemented system. Such integration requires clearly defined roles, system compatibility, and secure data exchange, in addition to identifying the responsibilities of each system and the staff members supervising it.

If systems do not exchange data or if their information is not updated, the multiplicity of applications may increase complexity rather than improve services. Therefore, the design of smart services should begin with the user's service journey and actual needs, after which appropriate tools should be selected and connected to the necessary systems and procedures (Balakrishnan, 2019, p. 191).

Accordingly, the evaluation of a smart library should not be limited to the number of technologies it possesses. Rather, it should also consider their impact on the time required to access resources, retrieval

accuracy, user satisfaction, service reliability, operating and maintenance costs, and data protection. These indicators represent analytical proposals that may be adopted in future evaluations; they are not the results of empirical measurements conducted in this study.

Fifth: Requirements for the Transformation towards Smart Libraries and Associated Challenges

1. Technical, Organizational, and Human Requirements

The transformation towards a smart university library requires an appropriate technological infrastructure, including stable connectivity, equipment and software that can be maintained and updated, and systems capable of exchanging data, in addition to clear procedures for data management and quality assurance.

It also requires funding that is not limited to initial purchasing costs but extends to maintenance, updating, technical support, and continuous training. Human resources remain a central element in this transformation, as staff members need to develop their skills in dealing with digital systems and understanding their limitations. They should also be involved in selecting applications, designing work procedures, and evaluating outcomes.

Technology does not eliminate the professional role of library staff; rather, it can reshape that role towards supervising systems, assisting users, verifying information, and handling situations that systems cannot adequately address (Ibrahim, 2012, pp. 44–45).

2. Technical and Financial Challenges

2. Technical and Financial Challenges

Institutions may face challenges related to the suitability of their infrastructure, system compatibility, and the availability of equipment and organized data, in addition to the costs of acquiring, maintaining, and updating technological solutions. The literature indicates that limitations in technological infrastructure and available resources may hinder the implementation of certain artificial intelligence technologies. This makes assessing actual needs and available capabilities a prerequisite for selecting appropriate solutions (Du Boulay, 2022, p. 9).

Accordingly, this description should not be generalized to all institutions, since determining the level of readiness requires data specific to each university and library.

3. Human, Ethical, and Legal Challenges

A lack of training or limited expertise in using applications may restrict the benefits derived from them. Furthermore, the transformation may raise concerns regarding changes in professional roles. Addressing these issues requires adopting continuous training programmes and involving staff members in the planning and implementation stages, rather than presenting these systems as substitutes for them.

From an ethical and legal perspective, the use of intelligent systems raises questions concerning users' privacy and data security, the transparency of decisions or recommendations, the possibility of bias in results, and the accuracy of information generated by these systems. These are ethical risks associated with integrating artificial intelligence into educational fields, which must be addressed through appropriate measures and solutions.

In the library environment, responsible use requires identifying the data collected by systems and the purposes for which it is collected, regulating access permissions, verifying system outputs, and clarifying responsibility for human intervention when errors occur (Bu, 2022, p. 562).

4. Requirements for Studying the Transformation in Algerian Universities

Examining the potential of smart libraries in Algerian universities requires distinguishing between the general theoretical orientation and the actual circumstances of each individual university institution. It is not possible to make definitive claims regarding the level of equipment, the adequacy of budgets, or the skills of staff members across all universities without documented data. Therefore, any practical initiative should begin with an assessment of the infrastructure, existing systems, nature of collections and services, needs of students and researchers, staff competencies within these universities, and the resources available for maintenance and training.

Furthermore, the transformation should preferably be gradual and carefully planned, beginning with the identification of a clearly defined service-related problem, followed by the selection of an appropriate application, testing it on a limited scale, and evaluating its results according to clear indicators before expanding its implementation. This approach makes it possible to reduce financial and technical risks and adjust solutions in accordance with feedback from users and staff members. Cooperation between library and information specialists, system developers, and university administrators remains an essential condition for developing sustainable services.

Sixth: Conclusion

Based on the foregoing discussion, it can be concluded that university libraries are increasingly seeking to benefit from digital and smart applications to improve the organization and accessibility of information resources and enhance the services provided to students and researchers. Expert systems offer opportunities to support certain technical operations and reference services, while the Internet of Things helps connect and monitor resources and devices. Robots, in turn, can support guidance and interaction, whereas virtual and augmented reality provide new ways of exploring content and accessing resources.

However, these applications differ in nature and cannot all be considered artificial intelligence applications in the same sense. Furthermore, a smart library cannot be established merely by bringing together separate technologies; rather, it requires integrating them within a clearly defined service-oriented framework that connects users' needs with systems and human resources. The effectiveness of this transformation remains dependent on the availability of technological infrastructure, data quality, training, maintenance, privacy protection, and the ability to continuously evaluate the impact of these applications.

Accordingly, the study recommends that university libraries begin by assessing their needs before acquiring technologies, select applications according to their priorities and available resources, and adopt gradual experimentation and evaluation at every stage. They should also establish safeguards for data protection and the verification of system outputs while preserving the professional role of library staff.

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