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Systematic Literature Review of Smart Library Management and a Deep Learning Solution

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Abstract: This work presents a systematic literature review of smart library management system. By studying different papers for past 10 years to address several research questions, the findings are presented. A smart library is based on employing smart information and communication technologies (ICT) to facilitate readers. Five major research questions are answered. What is smart library, the major research challenges in implementing smart library, the advantages of smart library, and the enabling technologies for smart library. Finally, this work presents a smart library management system based on deep learning technique. An android mobile application is developed that digitizes the book records of the library using optical character recognition techniques. The proposed approach comprises various phases such as image acquisition, pre-processing, skew correction, segmentation and classification. The image is first acquired, quantized, de-noised and then segmented into individual characters. A deep neural network is trained and used to digitize the contents of textual image. The proposed approach achieves 95% of accuracy for digitizing the book records.

***Keywords**: Smart Library, Library Automation, Character Recognition, OCR, Digitization*

1. Introduction

In modern days, information and communication technology (ICT) has been playing a dominant role in every walk of life. The emergence of advanced forms of computing gadgets and novel networking paradigms (such as 5G networks, ubiquitous computing and cloud computing) demand smart environments. Several novel applications such as smart government, smart universities, smart offices, and smart cities have therefore been envisioned. This paper presents a systematic literature review on smart libraries and then discusses a case study towards automation of a library management system.

A library can be defined as information resource centers that collects, organize and disseminate the information to quench the end user information needs [21]. Various definitions of library have been discussed in [20]. The libraries in the modern era of 4th industrial revolution demands significantly the employment of disruptive technologies [13]. A novel study on employment of disruptive technologies such as internet of things for smart library management has been discussed in [15]. By employing technologies such as AI, IoT, big data and cloud computing, various aspects of library management such as book borrowing, returns, inventory management can be automated [16].

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Despite the advancements, the current state-of-the-art towards implementation of smart library is at infancy. According to [1], smart library can play a disruptive role in future education. Realizing this, this paper presents a systematic literature review on smart library management. Rest of the sections of this paper is organized as follows. We first discuss the systematic literature review. The proposed technique for smart library management is presented which is followed by further details and implementation of proposed approach. The paper concludes with directions for further research.

2. Related work

Before presenting the SLR, we must mention that similar studies have also been done in various other papers. A review on smart library has been done in [21]. The discussed level of implementation, challenges, and relation between challenges and implementation. [20] has discussed the enabling technologies, challenges and advantages of smart library management. A systematic literature review can be seen in [13].

3. Systematic Literature Review

In this study, a total of 20 papers from leading journals and conferences were considered. These papers were primarily targeted towards smart library. Fig 1 shows the methodology adopted for systematic literature review. The parameters of the study are discussed in Table 1. The table provides information about target years considered, keywords used and the exclusion criteria for systematic literature review.

The research starts with the selection of keywords and identification of data sources. Then, papers were extracted and filtered based on the inclusion and exclusion criteria. A set of research questions were formulated and analysis was performed. The results are reported in this study. Following are the major research questions:

- **RQ1:** How do you define a smart library management system?
- **RQ2:** What is the current state of smart library implementation?
- **RQ3:** What are the enabling technologies for a smart library?
- **RQ4:** What are the major research challenges in implementation of smart library?
- **RQ5:** What are the major advantages of implementing smart library?

Table 1: Details of systematic literature review

Data sources	Googe Scholar, IEEE, ACM
Target years	2020-2025
Keywords	Smart library, smart library management system, library management system
Exclusion criteria	Paper that doesn't target smart library

Figure 1: Methodology for systematic literature review

3.1. What is a smart library?

Smart library is composition of two words i.e. smart and library. The term smart means use of efficient technologies to facilitate automation [20]. A *smart library* can be defined as one that integrates traditional library management with advanced ICT technologies.

[17] has defined smart library as those that are managed by means of artificial intelligence and machine learning. The objective of a smart library management system is not to replace but to complement the librarian with efficient management of library operations.

[1] defined smart library as a system that provides seamless digital access to resources such as books, journals and audio/visual content. They identify the role of smart library as more engaging, immersive, more collaborative and efficient.

[2] has defined smart library from a different perspective i.e. one that employs AI and data analytics to facilitate in knowledge provisioning. According to [3], one can define smart library as those that employ technology such as AI, cloud, big data such that intelligent capabilities can be provided to help end-user and the librarian.

[9] has defined smart library as one the employ technology to facilitate users in fulfilling their information needs in an optimized manner. Smart libraries are one that emerged as the employment of latest technologies [11]. Table 1 discusses the various definitions of smart libraries proposed in literature.

Table 1: Various definitions of smart library management systems

Reference	Definition
[1]	Digital access to resources
[2]	Employs AI and data analytics
[3]	That uses AI, cloud, big data
[9]	One that helps user in their information needs
[11]	One that employs latest technology

3.2. Current state of smart library implementation

Despite the emergence of technology, many library systems are still based on conventional technologies [18]. According to [3], many libraries are still employing manual approach to library management. According to research, only moderate level of implementation has been seen in smart libraries [21]. However as [20] have argued, a library is a social space and bound to evolve. Similar motivation has been discussed in [21]. The smart library can help in various ways such as book borrowing, returns, inventory management etc. [1]. The library system has gone from ancient archives of information to a modern digital enabler of information [4]. The modern usage of technology in smart libraries such as automation of metadata generation, semantic processing, predictive analysis enabled enhanced, relevant, optimized and high availability of content [2]. In [3], a path planning robot has been proposed for library management. [5] has discussed employing AI and predictive analytics for smart libraries. However, there is a crisis as far as employing technologies are concerned for smart library management systems[10]. Interested readers are referred to [8] for a comprehensive discussion on state-of-the-art on smart libraries. However, significant effort at strategic level is required.

3.3. Enabling Technologies for Smart Library management

There have been several enabling technologies for smart library management systems. [17] discussed various enabling technologies. [20] have discussed the use of cloud computing, AI, 3D printers, big data, drones and IoT as key technologies for smart library management. [1] has identified the AI, IoT, big data and virtual reality as the next enabler for smart library management system. Coud computing is the provision of dynamic computation resources over the internet on demand.

RFID and IoT: In literature, barcodes and Radio Frequency Identification (RFID) have been proposed to automate library management system. In [23], an RFID based library management system has been proposed. Using the RFID transmitter and receiver, automatic issuance and return of books are managed. [24] have proposed a context-aware smart library management system that employs RFID tags for keeping tracks of books. IoT technologies are used to enhance the efficiency of library operations. In this way, automatic tracking of library assets as well as security can be enhanced. [18] has employed RFID technologies for smart library management.

Information retrieval systems such as those based on NLP and machine learning are being used for managing the huge volume of library records [17]. Cataloguing and classification are also being performed.

Robotics are employing A* algorithms for monitoring, shelf management, book returns etc. [17]. AuRoSS is based on robotic technology to scan the books using RFID technology and reports about misaligned boos [17].

Data analytics: Usage analysis can be performed to understand future demands, attendance, borrowing pattern, etc. For instance, [19] have proposed a smart library management system based on user behavior analysis.

Using **software agents** (LibAgent), a context-aware, augmented reality-based library management system has been prototyped. Similarly, a **3-layered agent-based** library management system has been proposed in [14].

Chatbots: The role of chatbots and virtual assistants can't be denied [2]. They can help with real-time query / complaint resolution, context-aware services and personalized recommendations.

In some studies, 5G technologies have been employed for smart library management [4]. [7] have employed blockchain as a technology that enables security and transparency in library operations.

Fig 2 shows the enabling technology for smart library management.

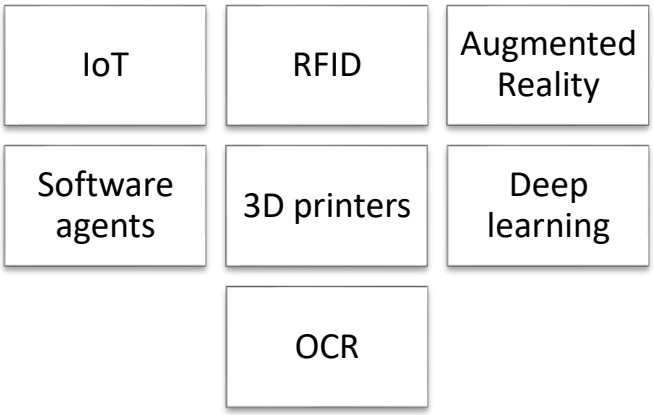


Fig 2: Enabling technology for smart libraries

3.4. Challenges of smart library management

[20] have discussed various challenges of smart library such as technological challenges, more training, technophobia, data privacy and poor power supply. The librarians might perceive that they will be replaced [21]. [8] discussed various challenges for smart library management implementation such as AI algorithms that need to be developed tailored for LIS. The scalability and interoperability of smart systems also require extensive RnD. One also needs to consider ethical issues, biasedness and opacity etc.

The accountability and explainability issues of modern machine learning also apply to smart libraries. Financial considerations are also an implementation challenge [2]. There also exist digital divided based on gender, location and social and economic dimensions. The challenges

imposed due to cybersecurity can't be underestimated. These risks are highly probabilistic; however, it is expected that machine learning and AI can help in combating these risks.

3.5. Advantages of smart library management

According to [20, 21] smart library provides several advantages such as: working hours expansion, better access to information resource, eliminates spatiotemporal barriers, space saving, cost effective, increased visibility, distance learning and saves the time of the reader. With the help of AI, better and relevant reference services can be provided [2]. Based on semantics, better searching capabilities can be provided. Operations such as inventory management, checkout, real-time tracking and enhanced security services can be provided. According to [17], several benefits can be observed such as automated checkouts, smart inventory management, tracking of books, surveillance. [8] discussed improved user satisfaction and resource optimization by employing smart approaches to library management.

After the systematic literature review, table 2 presents answers to various research questions.

Table 2: Research questions for smart library management

RQ1: What is a smart library management system?	A smart library is one that employs state-of-the-art technologies available to provide efficiency in terms of resource management and information provisioning.
RQ2: What is the current state of smart library implementation	Most of current library systems are manual [3,10]
RQ3: What are the enabling technologies for smart library management system	AI[19], RFID [2], IoT [24], chatbots[2], 5G[4], NLP [17]
RQ4: What are the challenges in smart library management system	Scalability and availability[8], data privacy[20], digital divide[2]
RQ5: Advantages of smart library	Efficiency[20], User satisfaction[8]

4. Proposed deep-learning based OCR solution

In this section, deep learning-based OCR solution for smart library management is discussed.

4.1. Optical character Recognition

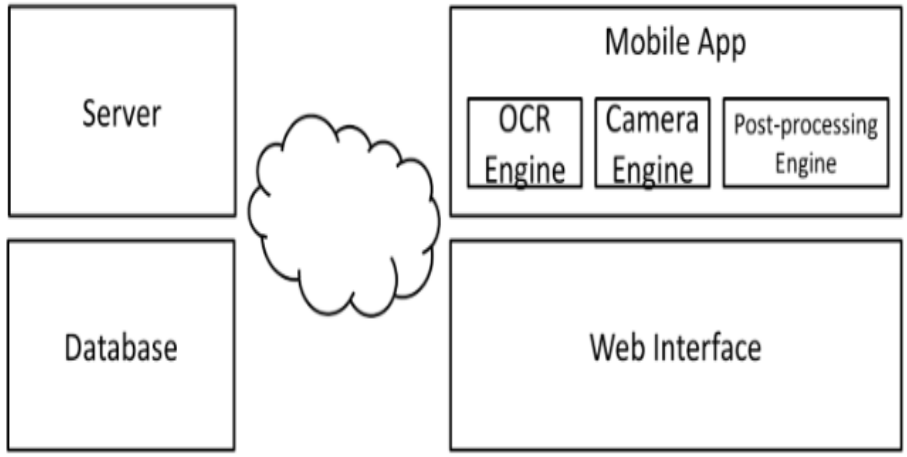
Character recognition is not a simple activity but comprises a set of activities. In the first step, an image is *acquired* such as using camera or scanner. The image is then *processed* to remove noise and enhance the quality of image. In the next step, the image is *segmented* into individual characters. The *features* of individual characters are then extracted and then classified using any pattern classification algorithm. In some of the cases, the accuracy of the classification is further improved by applying different *post processing* techniques.

When the image background is simple, character recognition is relatively easier process. However, to recognize the text in scenes, the text must be located first, or some process is applied to isolate the background from the actual text.

4.2. Block diagram

Fig. 3 shows the block diagram describing the proposed library management system. A client-side mobile application provides a graphical user interface (GUI) to the librarian while the server side is used to manage different back-end tasks. Mobile applications can be used for performing different library management tasks such as:

- **Adding a newly arrived book:** The librarian will use the camera to acquire the image of the front cover of the book. This image is processed to obtain the details of the book and then sent to the server.
- **Issuing a book:** The barcode of the book is scanned using the scanner. Using the details of the book saved in the server, the corresponding books are issued.
- **Searching a book:** The various books available in the library can be searched using this interface.
- **Returning the book:** A book can be returned by the user. Late charges can also be applied based on the return date.



3: Block diagram for proposed library management system

In order to add a new book, the librarian can acquire the image of front cover containing the title, author, publisher and year of publication. The image is then processed by the OCR module. A set of algorithms are applied to locate and recognize the details of the book. The details of the book are presented to the user through the add book interface. Users can make corrections and modify the details.

The mobile application is connected to the library server. Once the book details are obtained and confirmed by the librarian, it is transmitted to the library server which saves the details in the database server. Extensible Markup Language (XML) is used for transmission of information to the database server.

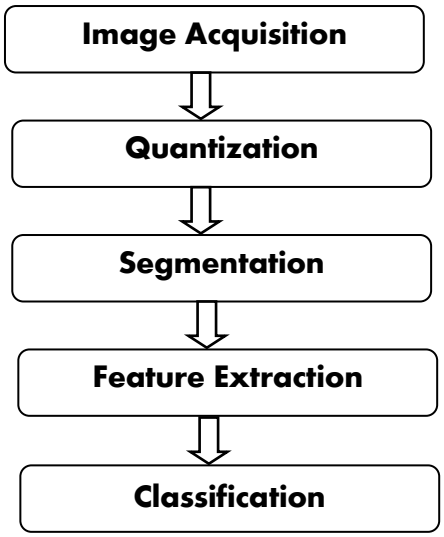


Fig 4: Steps of Optical Character Recognition

4.3. Implementation details

For validating the proposed approach, an optical character recognition (OCR) has been prototyped. The target language is English. The software can recognize characters written in any of the three styles i.e. bold, italic, and regular. Fig. 4 shows the various steps performed during the optical character recognition phase.

Preprocessing: In the first step, the OCR module acquires an image using the camera module of mobile device. The image is then quantized into binary form. If the value of a pixel is above a particular threshold, it is considered as black; otherwise, the pixel is marked as white. Salt and pepper noise is then removed from the image.

In the next phase, text lines are extracted from the acquired image. For this purpose, horizontal projection has been implemented. Once the text lines are output as the result of previous step, the top-left and bottom-rights positions of every text line is stored in a Rectangle data structure.

Segmentation: After preprocessing is performed, the individual characters are extracted from the lines called the segmentation phase. For this purpose, horizontal projection technique is employed. The horizontal projection if visualized provides valleys between characters. Besides, the paper overall provides two character's segmentation techniques. The first approach is based on vertical projection of lines of white pixels.

This information can be used for segmenting characters. at desired locations. The second approach is based on connected component analysis. After these two steps, the individual characters are stored into a data structure. The characters are then furnished to feature extraction phase.

Feature extraction: Features play a very important role. The individual characters are passed to a feature extraction where appropriate features are extracted.

In this work, different experiments are conducted for two different types of features. The first one is extracted by the analysis of projection histograms. The second feature employed is the moment invariants. In this work, seven moment invariants are extracted.

Classification: Then character classification is performed. For performing character classification, a deep neural network is used. The dataset for training is available at [22]. Table 3 shows the parameters for the training of neural network.

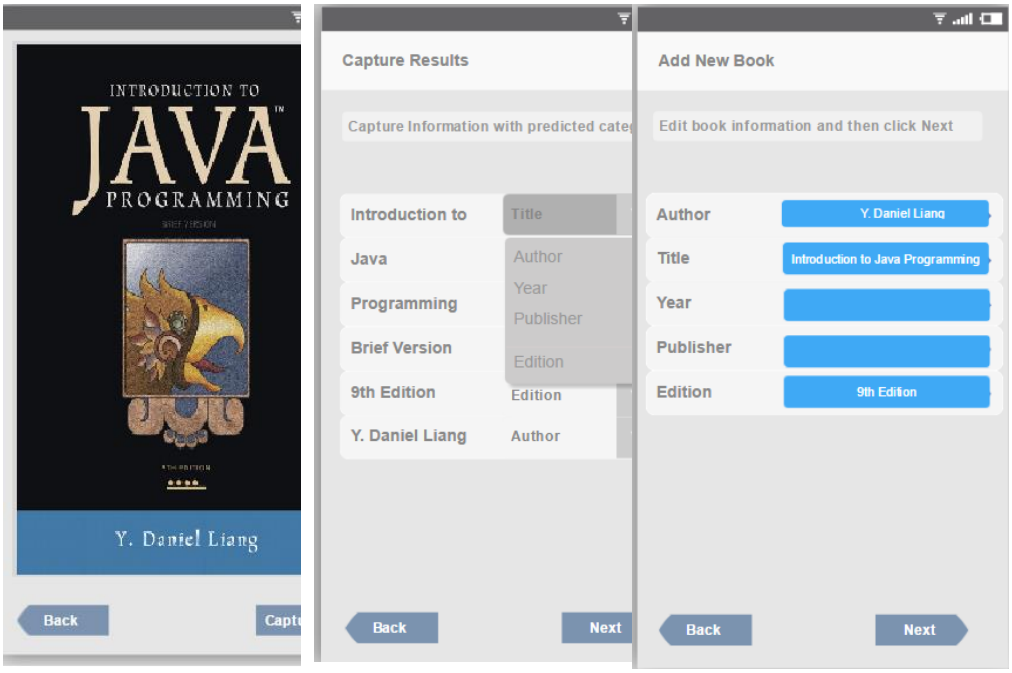
Postprocessing: The final step is post-processing in which the classified character is matched with the database. The objective is to determine whether the recognized word is an author, title, year or publisher of the book.

Once the characters are classified, they are mapped into appropriate categories. For this purpose, n-grams are generated and Hidden Markov Models are used to determine if a recognized sentence is an author, year, book title, publisher or edition of the book.

Table 3: Parameters for training of OCR classifier

Train-test split	80-20
Number of epochs	15
Activation functions	ReLu
Layers	input * 256 * 128 * output

The proposed OCR has been implemented in Java Android. Fig 4 shows the snapshot of the mobile application. A picture is acquired using mobile camera (Fig 5a) whose results are displayed to end user for correction (Fig 5c), if needed. The information is then submitted to server in the form of XML (as shown in Fig 6) which is saved in database.



a. Acquiring picture b. Acquisition results c. Adding a new book

Fig 5: Snapshot of proposed mobile app

```
<?xml version="1.0">
<book>
    <author>
        Y. Daniel Liang
    </author>
    <title>
        Introduction to Java Programming
    </title>
    <year>
        2016
    </year>
    <publisher>
        Orielly
    </publisher>
    <edition>
        9th Edition
    </edition>
</book>
```

Listing 1.: XML information transmitted from mobile app to the server

4.4. Results

The proposed mobile application has been developed on Android platform. To generate barcode, Free3of9 is used. The web application has been developed using Java Server Pages (JSP). Fig 4 and 5 shows the accuracy of proposed OCR under various scenarios. The software provides an average accuracy of 95%. However, it is found that the software can't recognize with the same accuracy when the test data is in fonts different than the training data.

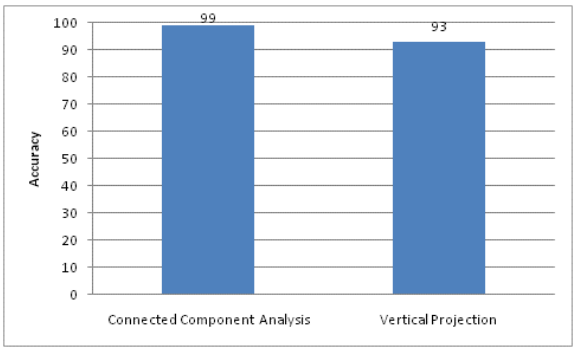


Fig 7: Accuracy of proposed scheme with various segmentation techniques

Figure 7 shows a comparison when connected component analysis is used and then vertical projection is used for segmentation of characters.

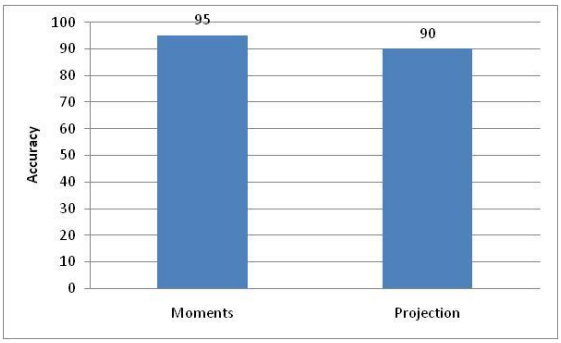


Fig 8: Accuracy of proposed scheme with various types of features

Figure 8 shows the accuracy of OCR with various types of features. Various experiments that are conducted with projection histogram reveal the fact that they are not invariant to rotation. In contrast, moments demonstrated invariance against to various types of image transformations. The incorporation of contextual information during post-processing can further enhance accuracy.

5. Conclusion

In this research, a systematic literature review on smart library management system is performed. The research answers five questions related to definition, implementation, challenges and enabling technologies. It is found that status of smart library is at infancy. Future work can be done on enhancing SLR with more relevant work. In addition, employing various ICT technologies along with their integration can help in enabling smart libraries in a better way. Realizing the need for smart libraries, an OCR based smart library management system is presented. Accuracy of 95% is observed. Similar result has been reported in [26]. As the dataset is balanced, hence, other metrics are not recorded. Future work is required in multilingual systems that can work with other languages such as Urdu, Arabic and Chinese etc. If such a system is to be deployed on large scale, further work is required on scalability of the system. In this direction [25] have discussed the scalability aspect in detail. Finally, the importance of security and privacy can't be denied for smart libraries. As the IoT sensors are deployed and capturing real-time data of the user, there needs to be appropriate mechanisms to ensure that the security and privacy of the users are not compromised. Future work must consider these integration challenges with RFID and IoT.

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