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Development of an Artificial Intelligent Agent for Library Hard Material Distribution Operations

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Abstract

In recent years, automation has emerged as a technological solution that is gaining grounds across various fields. The task of managing updates like sorting, shelving and documenting large collections of books in the shortest possible time is stressful with limited personnel and can be automated. Other important library tasks such as consultation can, therefore, be undertaken effortlessly. This paper which explores the use of automated solutions for the purpose of book sorting in libraries, proposes the You Only Look Once version 5 (YOLOv5) model to detect books, then performs optical character recognition using EasyOCR on the detected book. After the characters have been extracted, the system then classifies the book into its respective library section using OpenAI. The result from testing the system shows that the book detection model gave an accuracy of 74%, the EasyOCR performed with an accuracy of 91% with variations across different image formats. For simplicity, images used were stored in jpg formats for faster execution time and easy processing. The paper emphasizes the revolutionary impact of AI and machine vision in educational institutions, especially in libraries beyond what can be imagined, pushing for the formation of library robots. This project's benefits include object detection and intelligent book categorization which phase to a new direction for study and advances library automation technologies that boost education.

Keywords: Book Sorting, Library Automation, Machine Vision, Object Detection, Optical Character Recognition

1.0 Introduction

Libraries are vital institutions for fostering learning, knowledge acquisition and preservation. It plays a crucial role in providing access to information resources and facilitating learning and research activities(Dokukina & Gumanova, 2020; Durant & Horava, 2015).The traditional library system contains many books holding information for users. Library information is often updated from time to time in the form of new library materials such as books and other hard paper items. The enormous amounts of information and consequent books available in the library have to be arranged in a manner that makes it easily accessible to users. The ease of accessibility is a primary concern for library staff (Yoliadi et al., 2023; Padilla, 2022). In the library system, however, upon the intake or arrival of new set of books into the library, the task of arranging and sorting each book into their respective sections is tedious and time consuming posing significant challenges, resulting in inefficiencies and suboptimal user experiences(Wakeling *et al*.,2018; Wu *et al*.,2015).

In recent times, the concept of library automation has emerged as a transformative solution to overcome library challenges and enhance overall library functionality(Adams & Cook, 2016; Akanbi & Sambo, 2022). Perhaps the traditional library operations of book sorting and shelving are tasks that could be automated to make library activities a lot easier (Aein *et al.*,2013; Ahmadi-Javid & Ardestani-Jaafari, 2021). The objectives of this work are: to develop an unsupervised book identification mechanism using image and text recognition technology, to classify the identified book details using artificial intelligence technology and to test the performance of the developed book identification and classification system using precision, recall and mAP metrics.

For the rest of this paper, section 2 gives a brief literature review on library automation, section 3 presents the detailed methodology, section 4 provides the results and discussion followed by a conclusive remark and recommendation in sections 5 and 6, respectively.

2.0 Literature Review

The automation of library services is an innovative force in the attempt to improve library management and library operations, offering numerous benefits and improvements for library users (Ajani & Buraimo, 2022; Akanbi & Sambo, 2022; Nwachukwu & Adamu, 2016). Extensive research into library automation is set to transform various aspects of library management, with promising progress in areas such as cataloging, circulation, and inventory management (Echedom & Okuonghae, 2021; Engwall & Lopes, 2022; Frank *et al*., 2017). One of the most promising areas of library automation is cataloging, which involves the organization and classification of library materials. Automation solutions for library management could include Radio Frequency Identification (RFID) technology, making it more user-friendly and easy, reducing time and labor to improve library cataloguing as well as security (Vadivel et al., 2020; Amit & Mandal, 2013). RFID tags were attached to library materials allow for seamless identification, tracking, and retrieval, significantly reducing the time and labor required for cataloging tasks (Ganapathy & Fadziso, 2020; Guneysu *et al*., 2020; Guptaet al., 2015).

RFID-based automation enhances security measures by enabling more effective monitoring and control of library resources.Barcode-based systems are similar yet more cost effective solution to provide some level of automation that is widely employed in inventory control, circulation, user statistics and stock taking and verification (Dutta, 2022; Iqbal *et al*., 2020). This allows for quick and accurate scanning of library materials to facilitate the efficiency of various library activities and streamlining operations. These solutions although improving the speed, accuracy and reliability of library activities automating cataloging and circulation processes and streamlining operations are however still heavily reliant on human interventions are still limited in scalability. These solutions require manual scanning or handling of materials and in some cases human expertise for tasks such as decision-making for classification or resolving exceptions.

Digital Libraries are modern solutions to the automation of libraries, the concepts integrate the catalogues and materials contained in a library but with entry points accessible by computer. The collection of digital materials eradicates entirely physical libraries as well as human intervention. The novel approach is quite revolutionary but the realization of digital libraries across all spheres is a possibility that still remains out of reach. Physical libraries are still prevalent in many institutions and organization. Hence, a more balanced solution is needed for the automation of physical libraries (Singh, 2016; Catlin & Blamires, 2019).

Despite advancements in many library operations, automating book sorting and shelving operations is an area that is still in need of innovation and improvement(Zhang & Cheng, 2019; Pitsch *et al*., 2009; Zia *et al*.,2022).

Real time robots with advanced technologies for obstacle avoidance, automatic floor crossing, book recognition, stock taking with advanced image processing and shortest path finding could be the future of library automation (Vadivel et al., 2020). Robotic technology offers a promising solution to revolutionize book sorting and shelving operations in libraries (Angal & Gade, 2017; Arlitsch & Newell,2017). Robots, defined as autonomous or semi-autonomous machines capable of programmatically performing tasks, have already demonstrated their effectiveness in various industries, such as manufacturing, logistics, and healthcare. The application of robots in libraries can bring significant benefits, including increased efficiency, improved accuracy, and cost-effectiveness (Tella & Ajani, 2022; Maldonado-Ramirez *et al*., 2021; Mckie & Narayan,2019; Mehta & Sahu, 2020; Jing *et al*., 2017; Lyu *et al*., 2021).

Object detection and recognition can be achieved by robots to help in identification and classification. The accuracy of proposed object recognition techniques often achieved with machine vision is improved by training robot models to recognize objects based on scene texts. The ability of a robot to detect scene-based texts and classify objects based on the text detected improves traditional object recognition models by nearly 1.3% (Liu et al., 2021; Basha *et al*., 2019). Text-detection using Optical Character Recognition can be used with the Naïve Bayes Classifier for image classification and validation (Hubert et al., 2021; Kang *et al*.,2019; Kayani, 2019; Lee,2015; Sri & Agustine, 2021; Papanastasiou *et al*., 2018).

3.0 RESEARCH METHODOLOGY

The development of the library artificial agent involves several crucial design phases, each contributing to the overall functionality of the system. The materials used in this research include camera, Raspberry Pi and an AI web API. The methods are as follows:

3.1 Book Detection System

In order to detect or identify library books, the system was trained on a single neural network. The network predicts the books using identified features from the captured frames of the input video stream. Although the network is capable of predicting multiple detections on single frame, the detections are limited to only one per frame for proper focus on book identification and other processing tasks. The YOLO model enables end-to-end training and real-time speeds while maintaining high average precision.

The system partitions the input image into a grid of size S×S. If the central point of an object resides within a specific grid cell, that cell is tasked with detecting the object. Each grid cell provides predictions for B bounding boxes and their corresponding confidence scores. These confidence scores gauge the model's certainty that a given box contains an object, as well as the accuracy of the predicted box.

Formally, confidence (Conf) is defined as:

$$\mathrm{Conf} = \Pr(\mathrm{Object}) \times \mathrm{IoU}, \qquad (1)$$

where, IoU is the Intersection over Union between the predicted box and the ground truth.

Each bounding box is characterized by five predictions: (x, y, w, h), and (Conf). The coordinates (x) and (y) denote the center of the box relative to the boundaries of the grid cell, while (w) and (h) represent the width and height, predicted relative to the entire image. The (Conf) prediction reflects the IoU between the predicted box and any ground truth box.

During testing, the system computes class-specific confidence scores for each box by multiplying the conditional class probabilities Pr(Classi |Object) and individual box confidence predictions (Conf). These scores encapsulate both the likelihood of the class appearing in the box and the degree to which the predicted box aligns with the actual object.

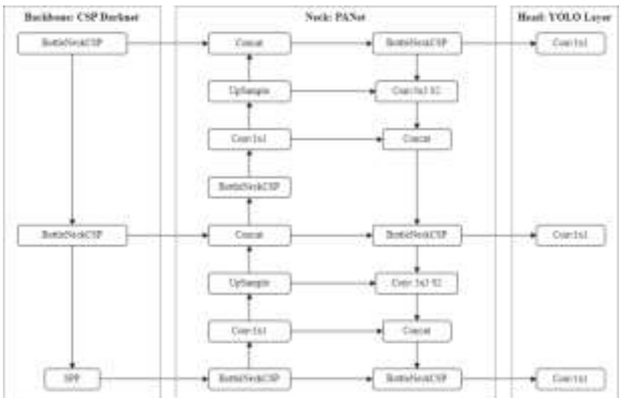

Figure 1: YLOv5 Neural Network Architecture

The model was trained on the pre-trained convolutional network layer, YOLOv5 on an open-source custom dataset (bookdetection-yoeop) from roboflow which had a total of 1141 images across its test, train and valid datasets. The pre-trained neural network architecture works on images of 640×640pixels and makes use of 157 convolutional layers (For pretraining we use the first 20 convolutional layers from Figure 1 followed by a average-pooling layer and a fully connected layer).

The model training time was approximately four hours using a high computation power computer system. The neural network framework used for the training and inference was the Darknet research framework which was then converted to the Pytorch framework for deployment. Detection often requires fine-grained visual information, however, with the limitation of computational power, resolutions higher than 640×640 pixels become a computational burden on the Raspberry Pi. The trained model predicts the object detected probabilities and bounding box coordinates.

$$\varphi(x) = \begin{cases} 1, & \\ 0. & \end{cases} \quad if\ x > 0\ otherwise \qquad (2)$$

During the training process, hyperparameters evolved to improve the model performance. To ensure that optimal values for various aspects and features of the training are found, optimization algorithms such as the Genetic algorithm (GA) are employed. This is also employed in maximizing the fitness values which is dependent on the Precision, Recall, mAP@0.5 and mAP@0.5:0.95. In the YOLO framework, multiple bounding boxes are predicted for each grid cell, which helped in designating singular bounding box predictor to take responsibility for each object. This assignment is determined by selecting the predictor with the highest current Intersection over Union (IOU) with the ground truth. This strategy fosters specialization among the bounding box predictors, as each becomes adept at predicting specific sizes, aspect ratios, or classes of objects. The model was trained on the neural network for 100 epochs on the training and validation data sets from Book Detection-Yoeop.

3.2 Optical Character Recognition (OCR) Model

The process of detecting the book information from the images involved a multi-stage procedure that relies on recognizing the words on the book cover page. Each step contributes to the accurate extraction of information on the book cover page:

i. Preprocessing the Image

The initial stage involves enhancing the image to prepare it for text extraction. During this step, various operations were performed to improve the image's quality and make it more suitable for text recognition. Noise reduction was achieved by applying filters such as Gaussian blur and median blur, effectively removing any unwanted visual interference. Subsequently, the image was converted into a binary format using techniques Otsu's method and adaptive thresholding. These preprocessing operations ensure that the text stands out distinctly against the background.

ii. Character Region Awareness for Text Detection (CRAFT)

To pinpoint text regions within the image, Character Region Awareness for Text Detection (CRAFT) model was employed. CRAFT is highly efficient at detecting text of various sizes, orientations, and fonts. It employs a Convolutional Neural Network (CNN) to create two critical output maps: the character region score map and the affinity score map. The character region score map identifies areas with potential characters, while the affinity score map links adjacent characters to form complete text instances or words.

iii.Convolutional and Recurrent Neural Network (CRNN)

This approach combines Convolutional and Recurrent Neural Network (CRNN) components for text recognition. The Convolutional layers were responsible for extracting sequential feature representations from the image. These features were then fed into Recurrent layers, particularly Long Short-Term Memory (LSTM) cells. The LSTM layers were used to capture long-term dependencies in sequential data, ensuring the accurate recognition of text.

iv**. *Connectionist Temporal Classification (CTC)***

The Connectionist Temporal Classification (CTC) algorithm plays a pivotal role in the decoding process. It was responsible for translating the per-frame predictions made by the Recurrent Neural Network into coherent text sequences. This algorithm was instrumental in identifying the most probable sequence of characters based on the output probabilities.

v. Post-processing the Recognized Text

After text recognition, a post-processing step was implemented. This stage includes techniques such as spell checking, language modeling, and text normalization. Its purpose was to rectify errors, enhance language coherence, and ensure the recognized text adheres to a standardized format.

3.3 Book Classification Model

After successfully detecting book information from the provided images, the next step was book classification. The information extracted from the images may not be readily usable in its raw form for classification. To improve this, the information was then processed through the OpenAI GPT-3.5 with an API to transform this data into a structured and coherent format.

The role of the OpenAI GPT-3.5 model is multi-faceted. It takes the initially detected data and reconstructs it into user-friendly and comprehensible information, such as book authors, titles, publication years, and other relevant details that were detected from the book cover page. This step is crucial in ensuring that the book information is accurate and formatted in a way that facilitates efficient library operations.

Furthermore, the model plays a pivotal role in the classification of books into appropriate library sections based on the Library of Congress Classification (LCC) system. The LCC system is the established method for categorizing books into various sections in our local library hence our choice of classification.

4.0 RESULTS AND DISCUSSIONS

In this section, the results of the book character and title identification are presented. In addition, the outcomes and implications are discussed as follows.

4.1 Book Identification

The system underwent testing using a diverse set of images featuring books, encompassing various lighting conditions and varying levels of book density. The system demonstrated precise detection capabilities for identifying the presence of books in these images. Evaluation metrics for the book detection model can be found in Table 1. It shows a high level of precision and recall, which means the model performs well on the test data.

Table 1: Results of the proposed system

Precision	**Recall**	**mAP_0.5**	**mAP_0.5:0.95**
91%	81%	88%	74%

4.2 Optical Character Recognition (OCR)

This section presents the results for the tests of the OCR model. For sample test 1 as shown in Figure 2, which contained a sample of 6 image inputs, the EasyOCR model was tested to determine the efficiency for the task of identifying cover book information. After testing, the following were results obtained from the EasyOCR model.

Figure 2: Book Samples for OCR test

a) ['N E W', 'Yo Rk', 'TiME $', 'SON', 'D', 'HAM AS', 'BETRAYAL, Political intrigue,', 'And U nthinkABLe choices', 'MOSAB HASSAN Y OUSEF']
b) ['Engineering', 'Physics', 'RK GAUR', 'S L GUPTA', 'DHANPAT RAI PUBLICATIONS', '2']
c) ['NEW SCHOOL', 'HEMISTRY', 'Senior Secondary Schools', 'Revised by:', 'S: Akpanisi']
d) ['KA,STROUD', 'WITH ADDITIONS BV DEXTER J. BOOTH', '6th', 'EDITION', 'ompanion Website']
e) ['Revlsed Edition', 'A TEXTBOOK OF', 'FLUID', 'MECHANICS', 'Fluid Mechanies', 'Hydraullc Machines', '-Pant-|', 'IN SI UNITS', 'Er RK RAJPUT', 'S. CHAND', 'and']
f) ['A', 'Textbook of', 'ELECTRICAL', 'TECHNOLOGY', 'S, CHAND']

The EasyOCR model was able to extract texts from the images acquired as shown above. The model performed excellently detecting the necessary author names and book titles needed for the book classification. In terms of execution times, the model performed relatively average with an average execution time of 50 secs for images with jpg formats, 35secs for jpeg formats and 1min40secs for png formats. The model accuracy for the task was about 96%.

4.3 Book Classification Model Results

This section presents the results for the tests of the OpenAI model. For sample test as shown in Figure 3 which contained a sample of 6 image inputs, the OpenAI model was tested to determine the efficiency for the task of identifying library section, author names and book titles.

a) BOOK TITLE: Son of Hamas
BOOK AUTHOR: Mosab Hassan Yousef
LIBRARY SECTION: DS - Asia - Middle East
b) BOOK TITLE: Engineering Physics
BOOK AUTHOR: RK Gaur, S L Gupta
LIBRARY SECTION: QC - Physics - General physics
c) BOOK TITLE: NEW SCHOOL HEMISTRY
BOOK AUTHOR: S. Akpanisi
LIBRARY SECTION: QD - Chemistry - General chemistry
d) BOOK TITLE: KA Stroud With Additions Bv Dexter J. Booth 6th EDITION
BOOK AUTHOR: KA Stroud With Additions Bv Dexter J. Booth 6th EDITION
LIBRARY SECTION: QA. - Mathematics - Algebra
e) BOOK TITLE: A Textbook of Fluid Mechanics
BOOK AUTHOR: RK Rajput
LIBRARY SECTION: TA - Engineering -

Fluid Mechanics

f) BOOK TITLE: A Textbook of ELECTRICAL TECHNOLOGY
BOOK AUTHOR: S. CHAND
LIBRARY Section: TK - Electrical engineering - General electrical engineering

The revolutionary OpenAI model was excellent in classifying books according to their library sections (LCC). The model accuracy on book classification was 100%. The model however performed relatively more modestly with book title and author names which were affected by the EasyOCR model

4.4 Discussion of Results

The combined assessment of the Object Detection System, OCR Information Extraction, and AI Book Classification Algorithm demonstrates a well-integrated vision system with high accuracy in identification, information extraction, and categorization of books. The speed metrics affirm the system's efficiency, ensuring timely decision-making and contributing to the overall effectiveness of the robot in automated library sorting tasks.

5.0 CONCLUSION

In conclusion, this research demonstrates the transformative impact of artificial intelligence (AI) and machine vision in educational and library settings. The design of this library assistant system showcased exceptional advantages in educational environments. These intelligent systems transcend traditional roles, offering a spectrum of services, including object detection, information extraction, and intelligent book categorization. The key to success lies in the system's remarkable precision and efficiency, with a practical run time of approximately 90 seconds per book sorted. The study's implications for future library automation underscore the potential of integrating advanced technologies to augment human capabilities. This paradigm shift encourages further research in creating intelligent systems that redefine the library experience. In conclusion, the project represents a significant leap toward realizing the full potential of AI and machine vision, envisioning a future where autonomous library assistants become indispensable components, marking a new era in library automation for an elevated educational experience.

6.0 RECOMMENDATIONS

The implementation of Simultaneous Localization and Mapping (SLAM) algorithms is recommended to include navigation in the robot's capabilities, providing dynamic spatial awareness and precise adaptability. Also, the integration of robot arms for shelving operations would also transform the system into a more comprehensive assistant capable of physically placing books on shelves. These recommendations will enhance the library sorting robot's performance and functionality.

CONFLICT OF INTEREST

This author declares no conflict of interest.

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