A Currency and Denomination Detection System using Raspberry Pi and Machine Learning

Sahil Kumar Gupta[1], Raushan Kumar Gupta[2], Samip Aanand Shah[3], Jaykishor Prasad Chauhan[4], Abhishek Pandey[5] and Gayathri Ramasamy[6*]
{bl.en.u4cse22081@bl.students.amrita.edu[1], bl.en.u4cse22086@bl.students.amrita.edu[2], bl.en.u4cse22087@bl.students.amrita.edu[3], bl.en.u4cse22285@bl.students.amrita.edu[4], bl.en.u4cse22090@bl.students.amrita.edu[5], r_gayathri@bl.amrita.edu[6*]}

Department of Computer Science & Engineering, Amrita School of Computing, Amrita Vishwa Vidyapeetham, Bengaluru, Karnataka, India[1, 2, 3, 4, 5, 6]

Abstract. The development of the note detection system is outlined for an embedment using a Raspberry Pi as the base for the work home with machine learning algorithms. The first domain of this work is currency identification that involves analyzing the amount depicted by a currency note and identifying the country to which the currency belongs to. This system is very applicable on automatic telling machine or better still ATM, vending machines, and currency exchange services since there is need to identify many types of currencies in the shortest time possible. Issues arising out of practice in this area include handling numerous and diverse currencies in relation to aspects such as size, color and security features among others. Another critical challenge is those of identifying between the real and fake coins and notes the task to be accomplished by the system should demonstrate high accuracy. Furthermore, the recognition must be possible regardless of lighting conditions, and the system should be able to recognize partially damaged notes, as well. Some of these difficulties call for efficient image processing and machine learning strategies with a dependable high accuracy level.

Keywords: Computer vision, Currency recognition, Machine learning, Image processing, Raspberry Pi, multi-currency detection.

1 Introduction

To overcome the difficulties related to the recognition of currency notes, this work takes advantage of the calculative power of Raspberry Pi and the machine learning models [12] developed with the help of a large number of currency images. Still, by applying image processing [11] it is possible for the system [14] to perform analysis of patterns. colors as well as other security measures that have been applied to the notes. The training of the models allows the system to adjust and learn and enhance the effectiveness of its detection as more currencies or even variants are added in future.

Still, it is not void of some areas of weakness as explained below: For example, the system may perform poorly when there are two currencies, or where the note is faded or torn. Accessory factors such recordings Depending on the conditions of the lighting it may lead to improper classification of the note detection. Some of the disadvantages of the design of the Raspberry Pi is also likely to face limitations when processing quantitative data or large data sets and may take longer time than expected to process an algorithm.

ICITSM-Part II 2025, April 28-29, Tiruchengode, India

DOI 10.4108/eai.28-4-2025.2357994

To overcome these disadvantages, additional work will be devoted to fine-tuning the machine learning models [12] for their performance on the hardware constraints of the Raspberry Pi. Further, finer preprocessing such as use of adaptive thresholding, contrast enhancement will also reduce the problem due to poor lighting and worn notes. It will also have the mechanism to upgrade its database so as to accommodate more currencies and to enhance the strength and efficiency of the system. The device should be smaller and easier to carry for better mobility.

2 Related Works

Rashid et al. [1] presented the work on banknote recognition system using content-based image retrieval approach to publish the work. Thus, namely the proposed dense sift based on SIFT feature with bag-of-words model and SVM classifier is used. The system was proved to be fairly tolerant for various defects and could incorporate other applications such as fake bill detection. Comparing SVM, ANN, and HMM the results reveal that the first algorithm SVM is the most efficient in terms of speed and accuracy under the embedded environment. The results reflect the high efficiency of the SVM classifier for banknote recognition tasks.

Aseffa et al. [2] introduced a deep learning- [16] based system for banknote recognition and counterfeit identification. It is implemented and trained for Ethiopian banknotes for classification with the models InceptionV3, MobileNetV2, XceptionNet, and ResNet50. Here, it appears that MobileNetV2 using RMSProp for optimization reached the accuracy of 96.4%. To implement this model, an embedded platform was created with a Raspberry Pi 3 B+. The implementation of a Web-based User Interface for real-time fake note detection was also done.

Saldanha et al. [3] are specifically aimed at the establishment of a low-cost FPGA based system to recognize handwritten digit using a deep neural network. This seems to have been done to address the issue of getting good performance on low-powered embedded processors; following this, a regularization method deployed aimed cut out Floating Point operations. The optimized implementation made it almost 3 times as fast as the unoptimized version with decent accuracy. This proves that FPGAs can be used to deploy heavy AI models as seen in the deployment of the MobileNet model with OpenCL. Not only is it a perfect solution to the problem, it is also cheap and perfect for the use in embedded systems.

Hassanpour et al. [4] collectively presented a novel way of detecting the paper currency based on size, color and texture of the corresponding paper currency. Color starting with the color images and working within image histograms is considered as the feature extractors while modeling texture involves using the concept of the Markov chain. The method needs just one good specimen of each specimen of currency for training. It can take images of currencies from at least two countries. These were tested on over 100 denominations and the system gave a recognition accuracy of 95%.

Zhang, Er-Hu, et al. [5] The use of edge detection and neural networks was introduced in a method for RENMINGBI (RMB) currency recognition. It eliminates the background noise by performing linear transform on the image and sharpening the edges part of the image. The image is then partitioned into segments, the measure of edge pixels in the segment is fed into a three-layered neural net. The method is fast, easy and efficient for different RMB styles. It is evident from the experimental outcome that the recognition rates collected are exceptionally high; the algorithm identifies with an accuracy range of 95% to 99% for various denominations.

Omatu et al. [6] proposed a neuro-classifiers technique for enhancing the accuracy of banknote recognition. For this purpose, it uses a local principal component analysis (PCA) to per- form a feature selection by eliminating non-linear relationships. Using SOM model, the data is then partitioned into regions to which PCA is then applied. As the main classifier, a learning vector quantization (LVQ) network is employed. Using optimum number of regions and the concluding codebook vectors, the proposed approach was 100% accurate on 1,200 samples of the USD bank notes.

Omatu et al. [7] jointly proposed a banknote recognition approach to improve reliability which is based on principal component analysis (PCA). It mainly concerns with the technique of classification of US dollar bills trying to reverse engineer the best features and use eigenvector working to reduce data size with PCA. A linear vector quantization (LVQ) network is applied as the principle classifier, these obtains 95% reliability with optimal PCA parts and LVQ vectors. We also evaluate Hidden Markov models (HMMs) as a different classifier for comparison purposes as well. The approach is used to support reliable classification of banknotes.

Mefenz et al. [8] presented a technique for rapid prototyping of the embedded video application using OpenCV. It implements a high-level specification of a system and transforms this into a system-on-chip (SoC) prototype in FPGA format using semiautomated techniques. OpenCV has been integrated for software part, SystemC/TLM for defining the hardware platform, and QEMU- OS/UVM for virtual modeling and testing. It minimizes user involvement because it places the high-level designs into another level of implementation optimally. The given framework is applied to the design of driving assistance and recognizing objects, proving the efficiency of the offered method in providing accurate and high-performance designs.

Jin et al [9] proposed a mode for a new banknote image processing system, which is based on the techniques of recognition, attrition evaluation [15] and feature identification, which is the first to analyze banknote deterioration in detail. It presents a banknote image registration by developing a free-form deformations model which essentially uses a homogeneity-based banknote deterioration energy as the cost function. It enhances the performance of the system for handling low quality banknotes as well. Most of this reduces the false reject rate to a great extent. In general, the system improves the accuracy of identifying banknotes.

Rosero-Montalvo et al [10], reviewed the ever-increasing incorporation of embedded systems in different areas of life and how they make life easier. These systems gather information from the user and are flexible enough for use in a different environment and Can only get their information from a data network. It underlines means for enhancing computational efficiency so as not to overwhelm the overall resources including memory and battery. This work also presents a literature review of data storage methods and techniques of machine learning for the embedded systems. Indeed, it mainly deals with methods and approaches, as well as specific technologies such as IoT, concerning data analytic for decision making.

3 Methodology

The technique of this work involves the following steps: data collection, then building and implementing an ML model for currency and denomination detection on the Raspberry Pi. By parsing it with sophisticated algorithms based on Image processing and machine learning, the system identifies these features to assign a value to a currency note as well as to identify its country of origin. The main potential uses of this technology include banking machines, automatic vending machines, and foreign exchange operations whereby prompt, accurate identification of various currencies is essential. To assure its high accuracy and high performance on shut embedded platform the approach is divided into the following stages:

3.1 Flowchart

Fig 1. illustrates the end to end workflow of the data collection process, the training of the machine learning model and the transferring of the built model into the raspberry pi through pickle file format. Speaker is employed in order to provide voice output as result to make the device more sensitive to users commands.

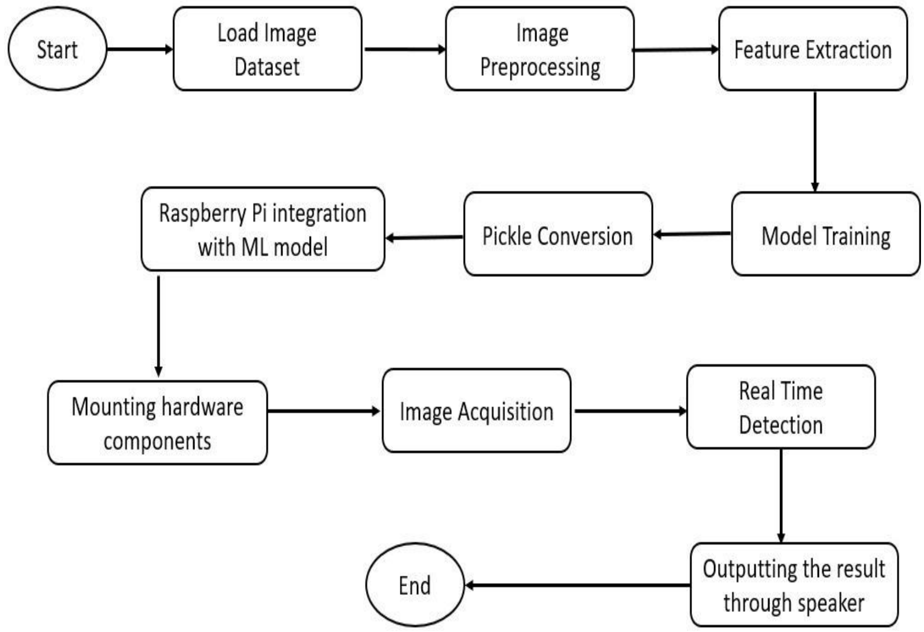

Fig. 1. Workflow Diagram of the work.

3.2 Architecture Diagram

In structural terms, the general architecture for the system is depicted in Fig 2 below. This one is used for real time image capturing, which helps to get the images needed for further processing. The image after being captured is conveyed to the microprocessor which serves the function of the processor in the system. Connected to the same microcontroller, an organizing Raspberry Pi contains a pre-trained machine learning model in pickle format.

On receipt of the image, the microprocessor starts with a preprocessing function. In this context, the image requires different manipulations, including resizing, normalization, and feature extraction [18], among others, to the image to meet the appropriate specifications for any machine learning model an organization wishes to incorporate. The preprocessed image is then passed from the mentioned layer and the model proceeds to calculate what is required and produce the output.

The output generated is then passed on to the speaker module, which as its function, will be to transform the system's outputs into audio form. These audio signals act as a bridge for the user or an interface which provides directional information to control the rotational drive of the robotic structures. This kind of integration of modules in a single system makes the overall communication between the robotic system and the environment smooth and accurate.

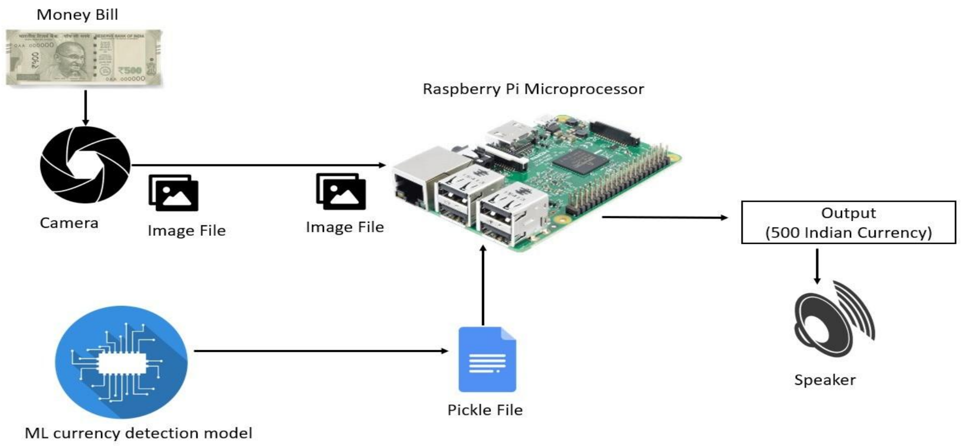

Fig. 2. Architecture Diagram of the work.

3.3 Hardware Setup

The hardware part of the embedded system is as follows which co-ordinate and help in the detection of cash denominations and for that their nation of origin. The Raspberry Pi 3 B+ is the cheap and compact computer platform well fitted for embedded applications as the main processing unit. Camera control, as well as real-time money recognition decision-making and Image processing, are centralized at the Raspberry Pi.

Camera Module Preliminary images of cash notes are captured using a high-end camera module with supportive integration with the Raspberry Pi system. The HTC hub remains with a camera that watches and monitors for any coins placed before it. If a genuine note is seen by the camera, then a close-up image is taken and analyzed, to ascertain the type of note and the country of issue. The processed data is then sent to Bluetooth module for further process.

Bluetooth Speaker The technology, designed to play real-time feedback, employs a Bluetooth speaker. This speaker makes the system very friendly for the blind since it will read the identified currency denomination as well as the country of origin. The Raspberry Pi is connected to a Bluetooth speaker this means that she can provide voice feedback as soon as the cash note is identified.

3.4 Software Framework

The software component of the system employs Python language for training machine learning models [12] using TensorFlow and other requisites such as OpenCV for image processing [11]. The training data set is obtained from Kaggle and contains various cash photos of different international locations. This dataset is necessary for training the Vision Transformer (ViT-16) model that is more appropriate for this task than the regular Convolutional Neural Networks (CNNs). The ViT-16 model was used because it can accept large amounts of data with intricate patterns as common for identification of various banknotes.

Image Preprocessing The images of the currency notes which come under the camera usually go through several steps of preprocessing using open-source tools such as OpenCV available in Python. First, the images are preprocessed where the images are converted to grayscale so that the input fed to the subsequent feature extraction [18] is simple. After that, noise reduction filters are used to reduce the interference or noise in the extracted image, thus other aspects of the currency notes can be more apparent for examination. Features like security marks or colors and textual components are well displayed with the help of adaptive thresholding and edge detection algorithms.

Model Training Thus, the Vision Transformer (ViT-16) that employs state-of-the-art deep learning techniques [13] is trained on the preprocessed data set. Over the training process, the ViT-16 model acquires capacities for recognition of meaningful imagery components of currency notes, such as color gradients, texture, forms and other nuances. To ensure the model can learn from a range of examples, the dataset is split into two sets during the training phase: training and validation. Many specific settings of the ViT-16 model, including the learning rate and the size of the batch, are carefully tuned for faster and accurate training to ensure that the model can be run on the Raspberry Pi simultaneously with the lack of essential features.

Deployment After training the model, for it to be run on the raspberry Pi in real-time, it is quantized into low size through the use of applications such as TensorFlow lite or similar applications. Specifically, this model version can efficiently process new photos of money notes at the edge using the available device, which has low computational power. The ViT-16 model categorizes the notes according to the attributes that are extracted, with predictions made in real-time whenever new image is taken by the camera and preprocessed. Subsequently, the generated results which consist of the denomination, and the nation of origin are displayed on the user interface annexed below. These are then communicated immediately through the Bluetooth speaker used as shown below.

3.5 Optimization and Testing

The system employs several optimization techniques to overcome Raspberry Pi’s processing capabilities. To enhance the ViT-16 model, different methods such as quantization and trimming are employed. These methods help to make predictions more quickly and accurately due to lesser use of memory and time. This may make the model run in real-time on the Raspberry Pi. It is good news that this improved model does not compromise the system’s performance. To achieve optimal utilization of CPU and in general shorten the overall computation time, multi-threaded approach is used. By facilitating parallel processing on the device and quicker inference times even when the system is performing multiple tasks simultaneously. To increase reliability and ensure that it can perform in real time, it is subjected to testing in various conditions of a functional environment. In this it involves checking with partial note, the partial note with different shades of light, discriminating between different variations of the currency. According to these tests the performance and accuracy of the system is determined and optimized thereby ensuring its reliability in a variety of circumstances.

4 Result and Analysis

From the India banknotes, the currency and denomination recognition system were successfully tested proving its responsiveness in identifying the currencies as well as categorizing them appropriately. The use of a Bluetooth speaker was beneficial for announcing the results as TOD gave the participants instantaneous auditable feedback.

Fig. 3. Working Prototype.

The working device obtained as a result is shown in Fig 3. The device has a Bluetooth speaker connected to it for output and a Raspberry Pi camera module as input. The banknote of Indian currency with the denomination 500 is shown to the camera in Fig 3 and the speaker outputted the denomination as “500” and the currency as “Indian Rupees”.

4.1 Performance Evaluation

The authors found that the identification and classification accuracy rate of the Indian currency notes was approximately 85 %. Despite being applied in different scenarios the Vision Transformer (ViT-16) model was still able to identify features such as patterns, color, and textures on the notes.

4.2 Usability and Response Time

The camera module engaged in the task of taking and processing photos with simplicity in addition to the constant scanning of cash notes. Users got feedback in time because the overall response time for the system, from recognizing a note and announcing the outcome through the Bluetooth speaker, was about 4 seconds. Due to this, the system is effective and fairly easy to apply in general practice.

4.3 Testing Scenarios

Both new and old designs of Indian currency notes were used to test the system under various circumstances, including:

- **Properly Placed Notes:** Delivered consistent and accurate results.

- **Different lighting conditions:** Showed robust performance, though dim lighting slightly impacted detection accuracy.

- **Partially Visible Notes:** The system experienced accuracy problems while dealing with partially visible notes because it could not properly recognize these notes.

- **Overlapping or Folded Notes:** Note stacks and folds created challenges for the system to distinguish separate notes which diminished its accuracy levels.

5 Conclusion and Future Work

Cash and denomination identification technology acts as an essential assistive system that enables visually impaired people to make financial transactions on their own. A recognition accuracy [17] of 85% belongs to the system's ability to categorize Indian rupee notes while it uses deep learning through Vision Transformer (ViT-16). Users receive immediate audio notifications through the system that implements this model combined with Raspberry Pi electronics mounted with a camera module and Bluetooth speaker. The system provides users with effortless operation which lets visually impaired persons identify their money without any additional support. Under different lighting scenarios and with notes of modest wear the system proves suitable for practical uses. The research demonstrates how embedded systems with artificial intelligence capabilities can handle daily difficulties experienced by people who are blind.

The system's performance will benefit from extended training on an expanded dataset which will enhance its accuracy level [19] and decrease recognition errors. Faster system response times through optimization will generate a user-friendly and efficient experience for end-users. The detection of counterfeit currency represents a future possibility which proposes better financial security. The system can serve users better by acquiring the capability to recognize different currencies at once since they encounter multiple payment methods. The system's performance would increase because of the integration of a more compact and portable design together with rechargeability features that enable better use in diverse settings. These improvements to the device would make the system more functional while driving its adoption by visually impaired users at large.

Users need an offline processing addition to access the system since they should not depend on internet connectivity. High reliability of the system becomes achievable through this addition because users can maintain access to the system while lacking connectivity in remote areas.

These system updates would make the technology more adaptable across different environments thus enhancing opportunities for blind individuals to access it. The expansion of these system capabilities will enable visually impaired users to become more independent in financial dealings and improve their inclusion in standard transactions.

References

[1] Rashid, Adnan, Andrea Prati, and Rita Cucchiara. "On the design of embedded solutions to banknote recognition." Optical Engineering 52.9 (2013): 093106-093106

[2] Aseffa, Dereje Tekilu, Harish Kalla, and Satyasis Mishra. "Ethiopian banknote recognition using convolutional neural network and its prototype development using embedded platform." Journal of Sensors 2022.1 (2022): 45050

[3] Saldanha, Luca B., and Christophe Bobda. "An embedded system for handwritten digit recognition." Journal of Systems Architecture 61.10 (2015): 693-699.

[4] Hassanpour, Hamid, A. Yaseri, and G. Ardeshiri. "Feature extraction for paper currency recognition." 2007 9th International Symposium on signal processing and its applications. IEEE, 2007

[5] Zhang, Er-Hu, et al. "Research on paper currency recognition by neural networks." Proceedings of the 2003 international conference on machine learning and cybernetics (IEEE Cat. No. 03EX693). Vol. 4. IEEE, 2003

[6] Omatu, Sigeru, Michifumi Yoshioka, and Yoshihisa Kosaka. "Bank note classification using neural networks." 2007 IEEE Conference on Emerging Technologies and Factory Automation (EFTA 2007). IEEE, 2007

[7] Omatu, Sigeru, Michifumi Yoshioka, and Yoshihisa Kosaka. "Reliable banknote classification using neural net- works." 2009 Third International Conference on Advanced Engineering Computing and Applications in Sciences. IEEE, 2009.

[8] Mefenza, Michael, et al. "A framework for rapid prototyping of embedded vision applications." Proceedings of the 2014 Conference on Design and Architectures for Signal and Image Processing. IEEE, 2014

[9] Jin, Ye, et al. "A hierarchical approach for banknote image processing using homogeneity and FFD model." IEEE Signal Processing Letters 15 (2008): 425-428

[10] Rosero-Montalvo, Paul D., et al. "Intelligence in embedded systems: overview and applications." Proceedings of the Future Technologies Conference (FTC) 2018: Volume 1. Springer International Publishing, 2019.

[11] Kumar, Matha Vijaya Phanindra, and R. Karthika. "Traffic Sign Detection and Recognition with Deep CNN Using Raspberry Pi 4 in Real-time." 2023 IEEE 11th Region 10 Humanitarian Technology Conference (R10- HTC). IEEE, 2023.

[12] Akshay, S., et al. "Energy and performance analysis of raspberry pi with modern computing devices." International Journal of Engineering Technology 7 (2018): 777-779.

[13] Rakesh, N., and U. Kumaran. "Performance analysis of water quality monitoring system in IoT using machine learning techniques." 2021 International Conference On Forensics, Analytics, Big Data, Security (FABS). Vol. 1. IEEE, 2021.

[14] Danymol, R., T. Ajitha, and R. Gandhiraj. "Real-time communication system design using RTL-SDR and Raspberry Pi." 2013 International Conference on Advanced Computing and Communication Systems. IEEE, 2013.

[15] Kumar, V. Sanjay, et al. "Smart driver assistance system using raspberry pi and sensor networks." Microprocessors and Microsystems 79 (2020): 103275.

[16] Niranjan, D. K., and N. Rakesh. "Design of a Water and Oxygen Generator from Atmospheric Pollutant Air Using Internet of Things." Intelligent Data Communication Technologies and Internet of Things: Proceedings of ICICI 2020. Springer Singapore, 2021.

[17] G. Prasath, A. Pranav, V. Sunil, Chandan and I. Karuppasamy, "Classification of Power Quality Issues on the Distribution Grid Due to the Impact of Electric Vehicle Charging Using Machine

Learning Tool," 2023 IEEE Guwahati Subsection Conference (GCON), Guwahati,
[18] S. S. Kamble, M. Y. Priya, S. Sridhar, S. P. Shendre and D. K. Niranjan, "Advanced Smart Filtration Techniques for Real-time Air Quality Monitoring and Improvement, along with a machine learning-based alert system," 2024 15th International Conference on Computing Communication and Networking Technologies (ICCCNT), Kamand, India, 2024,
[19] Sainadh, Kedarisetty Vishnu, Kukkadapu Satwik, Vadde Ashrith, and D. K. Niranjan. "A Real-Time Human Computer Interaction Using Hand Gestures in OpenCV." In International Conference on Information and Com- munication Technology for Intelligent Systems, pp. 271-282. Singapore: Springer Nature Singapore, 2023.