**Thai Banknote Image Recognition**

1. **Introduction**

Nowadays, more than two million currencies are used by several countries around the world. A banknote, which was used in many nations for trading, making purchases, and displaying income, is one item that represents cash. Most people have healthy bodies that allow them to distinguish between different banknotes depending on their value or number. However, there are about 39 million blind people in the world. Many people who go blind lose their eyesight, one of the most important parts of our body. Due to their inability to recognize, locate, identify, and differentiate between environmental objects, people are unable to even identify the value of banknotes, and the only thing they can see is a black image. In addition, 80% of blind people are lived in the continue developing country, and using money is also continuously changing; Thailand is one of them.

Thailand is a country in the South-East Asia Region with an estimated population of 66 million. By a large number of populations in Thailand, there are approximately 369,013 people who are blinded. However, everyday life in Thailand is challenging for blind people because of unaccommodated pavement and walking streets. Therefore, blindness is increasing this challenge as well as banknote recognition that they do not know although touching it by hand. Thailand banknotes are issued in five denominations including 20 Baht, 50 Baht, 100 Baht, 500 Baht, and 1000 Baht with different features, such as sizes, colors, identified numbers, watermarks, and textures as well as general values. Currently, blind people keep different value banknotes in the distributed pocket in order to identify them. However, they must be assisted by a third person to classify it by telling them. Artificial Intelligence (AI) improvements and technology developments are enabled to use in advanced technical performance in order to recognize the actual value of each banknote or currency for making blind people acknowledge.

The banknote recognition has several methodologies to detect and recognize whether neural networks, Markov model, Principal Component Analysis (PCA), Speed-Up Robust Features (SURF), K-Nearest Neighbor (KNN), or Fuzzy Logic.

Therefore, the primary objective of this research is to develop a computer system that will enable blind persons to recognize the actual value of each banknote. People who are blind would recognize the amount of money they possess.  Additionally, it can be used by regular people with the developed technology for recognizing a banknote, such as an automatic teller machine (ATM).

1. **Literature Review**

Several researchers and scientists worldwide used to develop the methodology of banknote recognition in order to distinguish each country's banknote, fake banknote searching, and implementation for blind people. They applied many techniques to proceed with their experiment; the details are as follows:

1. ***Speed Up Robust Features (SURF)***

SURF is one of the most popular features which can be used to generate scale-invariant and rotation-invariant interest points with detectors and descriptors. (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4270050/>) Hasanuzzman, Yang, and Tian used the SURF technique to develop banknote recognition for assisting impaired people. The experiment achieved 100% recognition accuracy for all seven classes, as shown in Table 1. (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4270050/>) In another experiment, Larisa, Mónica, Guillermo, and Ismael used the SURF technique to recognize the EURO banknote for blind people blending with a Haar-like feature. Banknote detection and value recognition accuracy were 84% and 97.5%, respectively. (<https://www.mdpi.com/1424-8220/17/1/184/htm>) Sanchez also used this technique to recognize banknotes for blind people via smartphone. The experiment achieves 98% of recognition with a 100% true recognition rate and 0% false recognition rate. (<https://koreascience.kr/article/JAKO201918440610441.pdf>)

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| --- | --- | --- | --- |
| Ground Truth | No. of images | False Positive | True Positive |
| $1 | 20 | 0 | 100% |
| $2 | 20 | 0 | 100% |
| $5 | 20 | 0 | 100% |
| $10 | 20 | 0 | 100% |
| $20 | 20 | 0 | 100% |
| $50 | 20 | 0 | 100% |
| $100 | 20 | 0 | 100% |

1. ***Haar-like Features***

Haar-like features identify the interest zone instead of pixel scanning (<https://www.mdpi.com/1424-8220/17/1/184/htm>) with the scalar values that represent the different averages between two rectangles. (<https://www.researchgate.net/publication/4193945_Joint_Haar-like_features_for_face_detection>) Larisa, Mónica, Guillermo, and Ismael used this technique for the EURO banknote recognition experiment to increase the modification by approximately 10% of the hit rate detector by using the SURF technique as a recognition algorithm. Increased performance provides high accuracy for banknote recognition including 84% and 97.5% of banknote detector and banknote value recognition respectively. (<https://www.mdpi.com/1424-8220/17/1/184/htm#sec3-sensors-17-00184>)

1. ***Convolutional Neural Network (CNN)***

CNN is a powerful deep learning technique that built several neurons with learnable weights and biases. Imad, Ullah, Hassan, and Naimullah used this technique to develop Pakistani banknote recognition for blind people. The experimental accuracy that recognized seven banknotes of Pakistani is successfully at 96.85%. (<https://al-kindipublisher.com/index.php/jcsts/article/view/529/488>)

1. ***Hidden Markov Models (HMM)***

HMM has employed banknote surfaces as a random process that can read all values with different denominations to distinguish the value of a banknote. (<https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.330.7474&rep=rep1&type=pdf>) (<https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.303.6988&rep=rep1&type=pdf>) Hassanpour and Hallajian used this method to distinguish 101 different denominations from 23 countries. In the experiment, the performance results of applying this methodology to 23 countries’ banknotes can be indicated as 95% accuracy. (<https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.330.7474&rep=rep1&type=pdf>) Abbas and Anisheh also used this method with the Fourier-Mellin and Support Vector Machine to recognize the different denominations from 23 countries. They applied several experiments with 40% torn, worn, and rotated banknotes from the database. In the experiment, the proposed techniques achieved the result of 98.7% accuracy. (<https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.303.6988&rep=rep1&type=pdf>)

1. ***Support Vector Machine (SVM)***

SVM is a classifier derived from statistical learning which finds the maximum margin hyperplane to separate training data into two groups. The SVM has advantages in solving main problems including high dimensional data and high generalization performance as well as finding the correctly optimal hyperplane. (<https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.303.6988&rep=rep1&type=pdf>) (<https://www.semanticscholar.org/paper/Employing-multiple-kernel-support-vector-machines-Yeh-Su/4bbe79673311fd8dc5409fe03c3638bf5e4b8b12>) Chi-Yuan, Wen-Pin, and Shie-Jue used this technique with multiple-kernel to recognize the counterfeit banknote. The experiment has four rounds applied to a banknotes data set that achieved 93.548% accuracy (<https://www.semanticscholar.org/paper/Employing-multiple-kernel-support-vector-machines-Yeh-Su/4bbe79673311fd8dc5409fe03c3638bf5e4b8b12>) Bo-Yuan, Mingwu, Xu-Yao, and Ching also used this technique to recognize part-based of the serial number in banknotes. In the experiment, they separated results into two parts including baseline recognition results containing 98.90% with Linear kernel and 99.31% with RBF kernel, and part-based recognition results containing 99.27% with Linear kernel and 99.43% with RBF kernel. (<https://link.springer.com/chapter/10.1007/978-3-319-11656-3_19>)

1. ***K-Nearest Neighbor (KNN)***

KNN is a methodology that classified objects based on the nearest training point by declaring distances based on Euclidean Distance. (<https://www.ijstr.org/final-print/aug2019/Implementation-Of-Template-Matching-Fuzzy-Logic-And-K-Nearest-Neighbor-Classifier-On-Philippine-Banknote-Recognition-System-.pdf>) Hardani, Luthfianto, and Tamam used this classification method to identify the authenticity of Rupiah banknote. The result of this experiment showed an accuracy rate of 100% for k=1, 77.78% for k=3, and 55.56% for k=5. (<http://journal.uad.ac.id/index.php/JITEKI/article/view/13324>) Raho, Al-Khiat, and Al-Hamami also used this methodology to recognize cash currencies. The experiment applied this model to 100 banknotes with a success accuracy of 91% and 9% failure. (<https://aircconline.com/ijwest/V6N4/6415ijwest02.pdf>)

1. ***PCA***

(<https://www.mdpi.com/1424-8220/16/3/328/htm>) (<https://www.researchgate.net/publication/3090942_PCA-Based_Feature_Selection_Scheme_for_Machine_Defect_Classification>)

1. ***K-Mean***

**References**

1. <https://www.mdpi.com/1424-8220/17/1/184/htm>
2. <https://koreascience.kr/article/JAKO201918440610441.pdf> - <https://koreascience.kr/article/JAKO201918440610441.view?orgId=anpor&hide=breadcrumb,journalinfo>
3. <https://link.springer.com/chapter/10.1007/11744023_32>
4. <https://www.ijstr.org/final-print/aug2019/Implementation-Of-Template-Matching-Fuzzy-Logic-And-K-Nearest-Neighbor-Classifier-On-Philippine-Banknote-Recognition-System-.pdf>
5. <https://www.mdpi.com/1424-8220/17/2/313/htm>
6. <https://jcst.rsu.ac.th/files/issues/V2N2/2012_2_2_full_120202_20150908_1858.pdf>
7. <https://www.mdpi.com/1424-8220/16/3/328/htm>
8. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4270050/>
9. <https://al-kindipublisher.com/index.php/jcsts/article/view/529>
10. <https://www.researchgate.net/publication/4193945_Joint_Haar-like_features_for_face_detection>
11. <https://www.semanticscholar.org/paper/Banknote-recognition-on-Android-platform-Toytman-Thambidurai/010ac6a60a6f5f154c5eb9f6e7ce841b1df3e4bd>
12. <https://www.researchgate.net/publication/3090942_PCA-Based_Feature_Selection_Scheme_for_Machine_Defect_Classification>
13. <https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.330.7474&rep=rep1&type=pdf>
14. <https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.303.6988&rep=rep1&type=pdf>
15. <http://journal.uad.ac.id/index.php/JITEKI/article/view/13324>
16. <https://www.sciencedirect.com/science/article/pii/S1877050915029580?ref=pdf_download&fr=RR-2&rr=74585cea6bd55ac2>
17. <https://aircconline.com/ijwest/V6N4/6415ijwest02.pdf>
18. <https://www.semanticscholar.org/paper/Employing-multiple-kernel-support-vector-machines-Yeh-Su/4bbe79673311fd8dc5409fe03c3638bf5e4b8b12>