1. INTRODUCTION

This chapter briefly introduces the currencies across the world and Indian currency. It also tells the motive behind this work and the research contributions through this work. At the end, it writes about possible applications of this work.

1.1 A BRIEF HISTORY OF CURRENCY

From the moment the barter systems ended, currencies came into existence for daily life. According to the definition on Wikipedia [130], *"the word currency (from Middle English: currant, "in circulation", from Latin: current, -entis), in the most specific use of the word, refers to money in any form when in actual use or circulation as a medium of exchange, especially circulating banknotes and coins"*. A more general definition is that the currency is a system of money (monetary units) in common use, especially in a nation. It is also referred to as banknotes, coins, bills (in the US), etc.

Currencies date back 2000 BC when it was in the form of coins. Later, in between 618 AD to 907 AD, in pre-modern China, during the Tang dynasty, the use of paper-based currencies started. In the medieval Islamic world, during 7th-12th Century, the paper-based currency was introduced that became the base for a stable-high valued currency Dinar. In Europe, Sweden was the first country to introduce paper-based currency in 1661. Each country in this world has its currency, and each currency has a specific denomination that indicates its monetary value. US Dollars, British Pound, Japanese Yen, Euro, and Rupee are a few examples of the currencies of different countries. Following is the list of prominent currencies of the countries across the world according to their market share.

Rank	Currency	ISO 4217 code (symbol)	Rank	Currency	ISO 4217 code (symbol)
1	United States dollar	USD ($)	11	Mexican peso	MXN ($)
2	Euro	EUR (€)	12	Singapore dollar	SGD (S$)
3	Japanese yen	JPY (¥)	13	Hong Kong dollar	HKD (HK$)
4	Pound sterling	GBP (£)	14	Norwegian krone	NOK (kr)
5	Australian dollar	AUD (A$)	15	South Korean won	KRW (₩)
6	Canadian dollar	CAD (C$)	16	Turkish lira	TRY (₺)
7	Swiss franc	CHF (Fr)	17	Russian Ruble	RUB (₽)
8	Renminbi	CNY (元)	18	Indian rupee	INR (₹)
9	Swedish krona	SEK (kr)	19	Brazilian real	BRL (R$)
10	New Zealand dollar	NZD (NZ$)	20	South African	ZAR (R)

Table 1.1 The Currencies of various countries

The next section describes how the Indian Rupee came into existence and its evolution.

1.2 INTRODUCTION TO THE INDIAN CURRENCY

1.2.1 The Indian Rupee (₹)

The Indian Rupee is the official currency of India. Before going into the details about current Indian Rupees, let's go back to the era of 6th century BC when currencies were started in India. It is India who was the first issuer of the coins in the world. The word "*Rupee*" is believed to be derived from the word Rupaa – a Sanskrit name of Silver. The silver coins which were issued were called "Rupaalu," and gradually all those coins were started being called as Rupee. Following image shows the first coins which were issued by Chandragupta Maurya in the 3rd century BC.

Figure 1.1. Silver coins of Maurya Empire

Figure 1.2. Silver coins of Rupee Sher Shah Suri

18 centuries later, in 1540, Sher Shah Suri issued silver coins, called Rupee, in exchange for 40 copper coins of less value called Paisa. These silver coins remained in use during the Mughal and the British rule also. British introduced the Coinage Act in 1835 and the Paper Currency Act in 1861 to have uniform currency throughout India. Since then, a variety of coins were introduced till freedom. In 1950, when India become Republic, the Indian government issued first of its coin replacing the King's portrait with Ashoka's Lion. Following figures show few currencies introduced by the British Empire from Victoria portrait to King George series and other currencies which were in use during the British Rule.

Figure 1.3. 1 Paisa issued by Sayla State

Figure 1.4. Indian Rupee coins in 1862

Figure 1.5. Half Aana of King George VI series, 1945

Figure 1.6. British India Rupee in 1947

Figure 1.7. ₹ 100 of Hyderabad State

Figure 1.8. Five Rupees, 1922

Figure 1.9. Portuguese Indian 1 Rupee, 1924

Figure 1.10. French Indian 1 Rupee, 1938

Figure 1.11. George VI Indian 1 Rupee, RBI 1937

Figure 1.12. 1 Rupee, British India

1.2.2 The Reserve Bank of India and New Currencies

The Reserve Bank of India formally started in 1935, is the chief controlling authority for the issuance of the currency. In earlier days, Indian currency was from 1 Aana to 100 Rupees. The currency had denominations like 1, 5, 10, 20, 25 and 50 in terms of paisa. However, except ₹1 and ₹2 coins, the other coins have been discontinued, and new coins of ₹1, ₹2, ₹5 and ₹10 have been introduced. The currency is available in a denomination value of ₹1, ₹2, ₹5, ₹10, ₹20, ₹50, ₹100, ₹200, ₹500 and ₹2,000. The symbol for the Indian rupee, ₹, has been designed by D. Udaya Kumar in a competition. On 15 July 2010, Government of India declared it as the official sign for the Indian Rupee.

The currently running series of the Indian Rupees was introduced in 1996 and is called the Mahatma Gandhi series. Since then every Indian currency note has a Mahatma Gandhi photo on it. These currency notes are printed at the Government of India's Currency Note Press located at Nashik, Dewas, Salboni, Mysore, and Hoshangabad. Each banknote has its denomination written in 18 Indian languages of which English, Hindi, and Devanagari languages are used on the front and back side both and the other 15 regional languages of India on the back side.

In a historical event, on November 8, 2016, the Hon'ble Prime Minister of India declared a cancellation of the then currencies of ₹500 and ₹1,000 and introduced new currencies of ₹2,000 and ₹500. The reasons that the Prime Minister cited in his Address were to curb the black money and corruption menace, to stop terror funding and Hawala business. The new notes of ₹2,000 and ₹500 have different size and security features. Now, in India, the ATMs usually dispense ₹100, ₹500, and ₹2000 currency notes. The following table shows the various Indian currencies of different denomination and sizes which are currently in circulation.

Image		Value	Size	Main color	Description			Date of Issue	Circulation
Front	Back				Front	Back	Water-mark		
		₹1	97X63 mm	Green & Pink	One-rupee coin	Sagar Samrat oil rig	Pillars of Ashoka	2015	Valid
		₹5	117X63 mm	Green		Tractor		2002/2009	Limited
		₹10	123X63 mm	Chocolate brown	Mahatma Gandhi	Konark Sun Temple	Mahatma Gandhi	2005/2018	Wide
		₹20	147X63 mm	Red-orange		Mount Harriet, Port Blair		2001/2006	Wide
		₹50	135X66 mm	Aqua		Hampi with Chariot		1997/2005/2017	Wide

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Denomination	Dimension	Colour	Motif	Year	Security Thread		
₹100	157 X73 mm	Purple, green and blue	Himalaya Mountains	1996/2005	Wide		
₹200	146 X66 mm	Bright yellow	Sanchi Stupa	2017	Wide		
₹500	150 X66 mm	Stone grey	Red Fort	2016	Wide		
₹2000	166 X66 mm	Magenta	Mangalyaan	2016	Wide		

Table 1.2 The Indian Currencies of various denominations in circulation

In recent years, the currency notes are slightly modified to include a see-through register on the left side of the obverse. Along with this, the year is now printed on the back side. Fake currencies are also being dumped in circulation by enemies to break the country's economy and sponsor the terror funding. The RBI has introduced so many security features in the currency notes to prevent such fraudulent or printing of counterfeit notes. The following section discusses the security features of the Indian currencies.

1.2.3 Unique features of the Indian Currency notes

Watermark: The Mahatma Gandhi Series of banknotes contain the Mahatma Gandhi watermark with a light and shade effect and multi-directional lines in the watermark window.

Security Thread: ₹1000 notes introduced in October 2000 contain a readable, windowed security thread alternately visible on the obverse with the inscriptions 'Bharat' (in Hindi), '1000' and 'RBI' but embedded on the reverse. The ₹500 and ₹100 notes have a security thread with similar visible features and inscription 'Bharat' (in Hindi), and 'RBI.' When held against the light, the security thread on ₹1000, ₹500 and ₹100 can be seen as one continuous line. The ₹5, ₹10, ₹20 and ₹50 notes contain a readable, fully embedded windowed security thread with the inscription 'Bharat' (in Hindi), and 'RBI.' The security thread appears to the left of the Mahatma's portrait. Notes issued before the introduction of the Mahatma Gandhi Series have a plain, non-readable fully embedded security thread.

Latent Image: On the obverse side of ₹1000, ₹500, ₹100, ₹50 and ₹20 notes, a vertical band on the right side of the Mahatma Gandhi's portrait contains a latent image showing the respective denominational value in numeral. The latent image is visible only when the note is held horizontally at eye level.

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 Microlettering: This feature appears between the vertical band and Mahatma Gandhi portrait. It contains the word 'RBI' in ₹5 and ₹10. The notes of ₹20 and above also contain the denominational value of the notes in microletters. This feature can be seen well under a magnifying glass.

Intaglio Printing: The portrait of Mahatma Gandhi, the Reserve Bank seal, guarantee and promise clause, Ashoka Pillar Emblem on the left, RBI Governor's signature are printed in intaglio, i.e., in raised prints, which can be felt by touch, in ₹20, ₹50, ₹100, ₹500 and ₹2000 notes.

Identification Mark: A special feature in intaglio has been introduced on the left of the watermark window on all notes except ₹10/- note. This feature is in different shapes for various denominations and helps the visually impaired to identify the denomination. But, these shapes fade away as the currency gets older.

Fluorescence: Number panels of the notes are printed in fluorescent ink. The notes also have optical fibers. Both can be seen when the notes are exposed to the ultra-violet lamp.

Optically Variable Ink: This is a new security feature incorporated in the higher denominations notes with revised color scheme introduced in November 2000. The numerals on the obverse of notes are printed in optically variable ink viz., a color-shifting ink. The color of the numeral appears green when the note is held flat but would change to blue when the note is held at an angle.

See through Register: The small floral design printed both on the front (hollow) and back (filled up) of the note in the middle of the vertical band next to the Watermark has an accurate back to back registration. The design will appear as one floral design when seen against the light.

In the past, the Indian coins were manufactured with heavy metals. However, these traditional coins of different sizes have been discontinued by RBI. According to the Intelligence Bureau reports, the heavier coins of Indian rupees were smuggled across the Bangladesh border where they were melted and were used in creating razor blades and ornaments leading to acute shortage of these coins in India. In this situation, West Bengal was the worst affected state. The beggars who were smuggling the coins used to get a premium of 10-15% on the coins. This was an interesting way to make money out of money. For this reason, the Indian government reduced the size and changed the metal

to put an end to this fishy business. Gradually, the older coins were discontinued and taken back from the market. The next section discusses the motivation for this work.

1.3 MOTIVATION FOR THIS WORK

The seeds for this work were sowed in late 2006, when the author of this thesis, was cheated by receiving a counterfeit currency of ₹500 and had to resolve that issue by destroying that currency. This made a loss of ₹500, but that loss sparked a thought, that having been given two eyes if a person could be cheated then any financial cheating could happen to the blind people! From the experiences, it was learned that the currency identification, be it a coin or note, is a herculean task for the blind people. This laid down the foundation for this work.

In addition to this, in earlier days, as the previous section discusses, the coins were of different sizes and shapes and hence the identification was quite easy. Since 2011, as discussed in the previous section, RBI put an end to manufacture the coins of different sizes and introduced coins of almost same size and weight. This made the identification of coins more difficult for the blind people. The mixture of the old and the new coins makes the task tougher for them. Following are the new size and weights for the different coins as per the new regulations of RBI.

₹5 23mm 6g ₹10 27mm 5.62g ₹2 25mm 4.85g ₹1 22mm 3.79g

Along with the coins, the paper-based currencies have also been changed in their size with other features. After demonetization, the new currency notes are introduced with a smaller size which made the life of blind people worse [131]. Like ₹500 and ₹2000 notes are smaller in size than current ₹100 and ₹50 notes. Due to such minor variations in the size of the paper-based currency and frequent addition of new features to enhance the security, the identification for the same becomes more difficult than the coins. In addition to this, when the currency is counterfeit or torn out, the identification becomes, even more, difficult, for the blinds.

India, according to WHO reports (March 2017), has 12 million blind people who are $1/3^{rd}$ of the total 39 million people all over the world. Also, in India, the currency recognition tools are available to the Banks only who are neither affordable nor handy to a common man. To prevent the cheating and to serve the unprivileged people of the society, visually impaired people, this work has been carried out with a noble intention.

The next section discusses the problem statement, objectives of this work, the research contributions and possible applications of this work.

1.4 THE PROBLEM STATEMENT, OBJECTIVES, RESEARCH CONTRIBUTIONS AND APPLICATIONS

1.4.1 The Problem Statement

To design and develop a computer vision algorithm(s) that can recognize Indian currency denominations and translate it into Indian vernacular languages.

1.4.2 The Objectives

To achieve the noble goal, the following objectives are set:

1. To design and develop an algorithm(s) that can recognize the denomination of the Indian currencies.

2. To ensure that, along with denomination identification, it also checks if the currency is counterfeit or not.

3. To make the algorithm(s) lighter in terms of memory and time both so as to be usable for the handheld devices.

4. To develop the algorithm(s) in such a way so that it/they can survive the events like demonetization and can adapt the new currencies introduced.

5. To develop a test tool for the proposed algorithm(s) to ensure that the objectives are met.

Apart from the main objectives stated above, the other generic objectives in terms of research are:

1. To design and develop the algorithm(s) in such a way so that it/they remain(s) generic and can be used for feature detection and image classification for any images, not only the Indian currencies.

2. To improve or fusion any other existing technique(s) or algorithm(s) to achieve the goal.

1.4.3 The Research Contributions

Any image recognition process contains three phases, mainly: Preprocessing, Feature Extraction, and Classification. Through this research, every phase has been contributed with some novel or hybrid approaches. Following are the research contributions of this work:

1. A modified and improved GrabCut algorithm, *cGrab-Cut* (A Compromised GrabCut), for background removal in the preprocessing stage. It reduces the time consumption by 57% (For Android devices). This algorithm can be used to remove the background from the captured images as a part of preprocessing.

2. A Histogram and ORB based novel, generic and improved feature detector, *HORB*, to detect image features to improve the performance of the ORB. The performance of the *HORB* seemed to be nice with an average increase of 12.862% in accuracy against the ORB's 52.22%. It takes an average time of 2.335 seconds for image identification.

3. To further improve the performance of the ORB, a heuristic based approach, Ant Colony Optimization, has been used. This novel, generic and the ACO based ORB feature detector, *ACORB,* is developed, implemented and tested profoundly to prove its competency. It also shows an improvement in the accuracy of the ORB by 13.248% against the sole ORB's 52.22%, consuming less time of 2.283 seconds for image identification.

4. To further improve the performance of the partially visible objects, a novel, generic and a three-stage hybrid image classifier using Histograms, the ORB and Bag of Visual Features has been developed. It has been named as *HORBoVF*. The performance of the *HORBoVF* is outstanding with an average 91.541% accuracy and takes 2.452 seconds. The result shows that it serves as the motive of the development of this algorithm.

5. As narrated above that the attempt of the ACO based feature detector was a success. So the same, *ACORB*, has been used with a dynamic bag of visual features to develop another generic, novel and a two-stage classifier, the *ACORBoVF*. This approach uses the same dynamic bag of visual features as the *HORBoVF*, and hence, the final performance of the algorithm remains the same as the *HORBoVF* with little less time consumption of 2.4 seconds. Both the

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HORBoVF and the *ACORBoVF* can be used as generic classifiers for any images.

6. *Te₹₹ency (Tensor Currency)*, is a TensorFlow and Convolutional Neural Networks, a neural network of millions of images, based trained model and classifier for the Indian currencies. This has specifically been developed to evaluate the performance of the other two classifiers proposed above and to utilize the power of the CNN for image classification. This also gives a promising result of 87.215% accuracy taking 2.155 seconds for classification.

7. To carry out the testing for the proposed approaches, a dataset has been created, for each category of Indian currency denomination, consisting of an average 455 images for the small dataset (total 4552 images) and 1504 images for the large dataset (total 15042 images) for training purpose in classification. For the testing purpose, for each category of the Indian currency denomination, an average 182 fully visible images (total 1819 images) and 228 partially visible images (total 2284 images) have been used.

1.4.4 The Applications

The all algorithms have been designed in such a way so that they work not only for currency recognition but also for any other kind of image recognition and classification. Few possible applications of this work could be:

1. The improved *cGrab-Cut* can be used for Android-based vision applications for the background subtraction in the preprocessing stage.

2. The *HORB* and the *ACORB* can be used as improved feature detectors for image matching purposes.

3. The *HORBoVF* and the *ACORBoVF* can be used as improved classifiers for image labeling.

4. *Te₹₹ency* can be used for the Indian currency recognition.

5. These all algorithms have been developed and tested for Android devices also. So, they can be used in mobile vision applications for all handheld devices running on Android platform.

1.5 THE OVERALL ORGANIZATION OF THESIS

The overall thesis has been divided into nine chapters with a brief introduction of the chapter in the beginning and summary of the chapter at the end of each chapter. The first chapter, as discussed above, was about the evolution of the currencies, the Indian currencies, the motive behind this work and a brief introduction to the work, which has been carried out, in terms of the problem statement, objectives, research contributions and various possible applications of this work. The rest of the chapters are organized as under:

Chapter 2 gives a detailed analysis of the work carried out so far for currency or object detections across the globe and in India, as well, in the form of literature study. It also briefly tells about the tools and Apps available for the currency recognition purpose in the market. Finally, it describes various tools which have been used for this work.

Chapter 3 gives a brief introduction to the overall work carried out. Next, it shows the dataset details and the development and testing environment details. Finally, it describes the work for preprocessing of images in the form of an algorithm titled *cGrab-Cut* with its performance testing.

Chapter 4 introduces the ORB feature detector initially with its basic implementation. The second and third sections of the chapter give a detailed insight into the proposed feature detectors, the *HORB* and the *ACORB*, with testing and performance analysis.

Chapter 5 starts with a brief introduction about image classification and then the bag of words classification. The second section contains a detailed description of the two classifiers: the *HORBoVF* and the *ACORBoVF*. Finally, the chapter ends with the detailed result analysis of the two proposed classifiers.

Chapter 6 introduces the convolutional neural networks and TensorFlow technology. Next, it describes a TensorFlow based model, *Te₹₹ency*, followed by a detailed result analysis of the *Te₹₹ency*.

Chapter 7 concludes the work and gives a roadmap to the possibility of future work.

Chapter 8 lists out the publications that emerged through this research work.

Chapter 9 lists the references which have been used to carry out this research work.