Image Processing Based Feature Extraction of Bangladeshi Banknotes

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***Abstract* — Counterfeit currency is a burning question throughout the world. The counterfeiters are becoming harder to track down because of their rapid adoption of and adaptation with highly advanced technology. One of the most effective methods to stop counterfeiting can be the widespread use of counterfeit detection tools/software that are easily available and are efficient in terms of cost, reliability and accuracy. This paper presents a core software system to build a robust automated counterfeit currency detection tool for Bangladeshi bank notes. The software detects fake currency by extracting existing features of banknotes such as micro-printing, optically variable ink (OVI), water-mark, iridescent ink, security thread and ultra-violet lines using OCR (Optical Character recognition), Contour Analysis, Face Recognition, Speeded UP Robust Features (SURF) and Canny Edge & Hough transformation algorithm of OpenCV. The success rate of this software can be measured in terms of accuracy and speed. This paper also focuses on the pros and cons of implementation details that may degrade the performance of image processing based paper currency authentication systems.**

Keywords* — *OCR; PCA; Eigen Object Recognizer; Fisher Faces; LBPH; Contour Analysis; SURF; Canny Edges

I. Introduction

Currency counterfeiting is as old as the start of coinage around the world. The paper currencies are the center of target to counterfeiters [1].Counterfeit detection is mainly executed based on the Chemical or Physical properties of paper currencies. The counterfeiters nowadays, can evade the chemical property & physical feature based counterfeit paper currency detection system due to technological advancement. Moreover, the unavailability, high cost, poor accuracy and lack of user-friendliness leads these fake detection tools to a least acceptance situation among the end-users [2]. That is why, feature based counterfeit detection system is now the focus of active research [3]. Throughout this paper, the methodology of image processing based extraction of the existing features of Bangladeshi banknotes are depicted in details to demonstrate the feasibility of software assisted counterfeit currency detection system. The implemented software encompasses some high end technologies like Optical Character Recognition, Face Recognition, Speeded UP Robust Features, Contour Analysis and Canny Edge & Hough transformation algorithm of high performance, cross platform and open-source OpenCV library [4]. As a result, the software core performs flawlessly and detection rate tends to 100% in each selected features of banknotes. Some challenges that persist involves in tight hardware requirements to create the environment for extracting features of paper currency, is also explained in this paper. However, this challenges can be mitigated easily by adopting some of our proposals relates with manufacturing standard of Bangladeshi banknotes.

II. Problems with Fake Currency

Currency counterfeiting is called the oldest crime of the world. Now a days no country is immune from the problem of counterfeiting of its currency notes. Counterfeiters make fake currency and circulate these in all possible places.

A. Statistics:

US Secret Service officials claim that on average, up to $7.8 Million in counterfeit dollars of "Supernotes" quality are confiscated each year [5]. Not only in developed country but also developing countries like Bangladesh having serious problems because of counterfeiting. In This country, Fake notes worth Taka 5,000 crore, in denominations of Taka 500, are being released everyday and about Taka 200/250 million (20/25 crore) in each month ([6], [7]). Statistics shows that, in every fiscal year counterfeiting is increasing shockingly. Here is a chart of detected counterfeit money of the last four fiscal years of some countries. The quantity relates with the detected fake currencies only, but not with all the amount that is circulated all the year round.

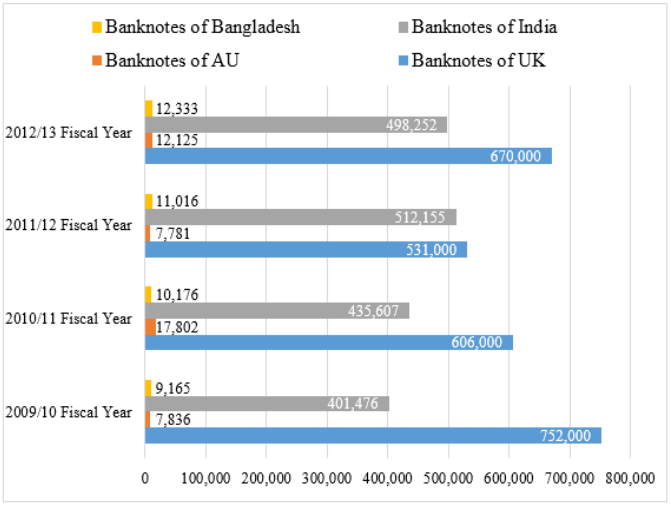

Fig. 1. Statistics on detected counterfeit banknotes ([8]-[12])

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Here is another chart of counterfeit money in per million which was detected in 2013 in some countries.

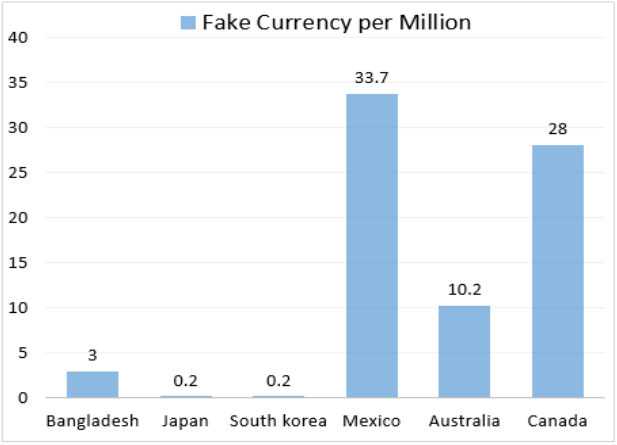


Fig. 2. Counterfeit currency/million banknotes in 2013 [13]

B. Attack Surface:

The machines that are used to detect fake currency are high in cost and not available to all. That is why, counterfeiters pick the fields like un-educated people, lack of proper knowledge about fake currency and busy business areas which are not consuming fake currency detector machines. Some attack surfaces are Eid market, Cattle market, Kitchen Market, Hawker market, Shopping mall, Bus terminal, Railway station, Launch terminal, Grocery store, Restaurant, Convenience store, Liquor store are ideal where counterfeit currency is circulated frequently.

C. Sufferers:

The actual sufferers from counterfeit currency are common people. Such as new comers in the big cities, age old shopkeepers, poor villagers, farmers face this problem most.

D. Economic Loss:

Currency Counterfeiting is such a crime that can make a country's economy paralyzed. Because of counterfeiting every country faces numerous problems. Day by day forging is increasing and gruesomeness of this crime is crossing the limit. It makes Global Economic recession and imbalance. Some effects of counterfeiting are as follows.

1) Spike inflation and devaluation of currency:

Counterfeiting makes the circulation of paper currency more than there should be. So, the price of common goods, food & housing increase exceedingly. This erodes the purchase capability of mass people. As a result, they have to spend a lot of extra money to buy essentials. So, the inflation leads to a dreadful turmoil. It makes the devaluation of currency ([14], [15]).

2) Low savings:

As people are used to buy all their essentials with extra money, they left nothing or a few for savings. This excessive price of goods makes people's savings rate to a least frequency. Eventually, the national Economy stumbles for want of adequate investment.

3) Dumping of goods at cheaper rates:

Inflation & devaluation of currency together can capitalize other countries which may then dump inferior quality goods in the market comparatively at a cheaper rates than the native products of a country. These products can capture a good market place. Because people can get their product as per their affordability. Ultimately, it damages a country's economy [14].

4) Loss in national economy:

As the national investment decrease, government has to snip social spending like healthcare, infrastructure, education etc. Government has to take grandiose loan to implement the manifesto and at the same time the fiscal deficit widened. To trim excess money from economy, the central bank has to hike up the interest rate. So, the loans become costly and business industries halt their expansion plans. They also pass on the extra borrowing cost to the consumers at the cost of the demand and so purchasing slows down. Foreign investors withdraw investments from the capital market. Thus, foreign exchange reserves come down [15].

5) Loss of public confidence:

People lose their trust on money and the economy of residing country. So, in order to avoid any kind of encounter with counterfeit money, they may start making demands of their payments to be made in some other, more stable currency. This may further destabilize the country's overall economy [14].

III. Limitations of Existing Fake Currency Detection Systems

Technology is developing very faster day by day. Now-a-days using many advanced technology forgers are producing fake currency [16]. There are many devices to detect the fake notes. But, only some specific institutions can make use of these devices. Actually, there are some limitations of these tools. Some of them are depicted in the followings.

A. Cost:

To detect fake currency accurately, a detector machine has to check few features. Most of the detector devices that can recognize currency accurately from multiple features are very high in price [16].

B. User Friendliness:

Some machines are not user friendly because of their hard and fast operational requirements. As users cannot use the machines properly, the goal cannot be achieved.

C. Availability:

The center of target of counterfeiters are general people. But fake currency detector devices are not available everywhere because of high cost and affability. Moreover, these devices are not available in rural areas.

D. Poor Detection Rate:

Some fake currency detector devices like detector pen, light are low in price. So, people can buy those tools easily. But

these tools are mainly single feature dependent which is not reliable. Because, counterfeiters may easily evade single feature of paper currencies [16].

E. Too much Efficiency Overhead:

Though some institutes have detector devices but there is a lot of scarcity of skilled person to operate the devices. Hence, it creates a great efficiency problem in terms of fake currency detection.

F. Fast Adoption of New Technology in Bank Notes:

Security features of the bank-notes changes very frequently to keep pace with the advancement of technology. But devices that use existing features of bank notes fails to adapt with newly added features of paper currencies. That is why, consumers of the devices have to purchase new machines that are completely hardware dependent, each time the feature changes.

IV. Proposed Solution Model

A. Target Features of Bank Notes:

Fake currency detection system varies depending on specific features of bank notes of a country [16]. For Bangladeshi bank notes following features are considered. Here, for testing purpose BDT 1000 has taken.

1) *Micro-printing*
2) *Watermark*
3) *Optically Variable Ink*
4) *Iridescent Ink*
5) *Security Thread*
6) *Ultraviolet Lines*

B. Reasons of Selecting this Features:

Micro-printing is the most common & robust feature of Bangladeshi Banknotes. Micro letters cannot be visible without magnifying glass or appropriate focusing of camera. It is actually very tough to replicate in fake notes by following normal printing process. It necessitates very high cost. OVI is another costlier ink which is impossible to forge through printers or ordinary printing machines. In real notes, the printing quality of watermark is very good, unblemished & perfect. That is why, it is hard to clone for the counterfeiters. The stitching technique of security threads in banknotes makes it a very unique feature. The forgers cannot copy the stitching technique of security threads and so the pattern around the security thread is clearly identifiable. The existence of Ultraviolet Lines in banknotes creates a new dimension in anti-counterfeiting. The above mentioned features of Bangladeshi banknotes gives it a solid foundation against counterfeiting [17]. Therefore, those features are chosen to perform forgery detection.

Here is a table that represents the existence of those features in various Bangladeshi Banknotes based on which the experiment is undertaken.

TABLE I: Security Feature's Availability Among Notes

Features	Availability Among Notes
1. Micro-printing	5(2014),10,20,50,100,500,1000
2. Watermark(The portrait of Sheikh Muzibur Rahman)	5(2014),10,20,50,100,500,1000
3. Optically Variable Ink	100,500,1000
4. Iridescent Stripe	1000
5. Security Thread	All notes
6. Ultraviolet Lines	100,500,1000

[18]

C. Project Architecture:

This project comprises a Hardware layer by which necessary images of bank notes is captured within different lighting condition, a software core that performs whole detection process and a filtration layer that separates the currencies based on the prediction provided by the software core. Fig.1 illustrates this architecture.

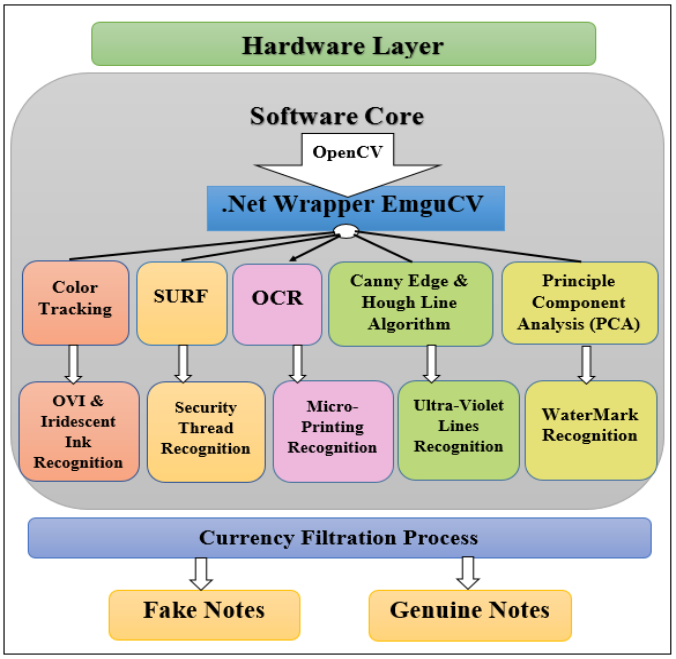


Fig. 3. Project architecture

D. Control Flow:

The software starts performing based on six images of a single note. The first and most important state is OCR that has to be passed to be a genuine note. Because, almost all Bangladeshi banknotes of 2014 has the micro-printing feature. If any note passes this state then a feature counter starts which counts the success points of each banknotes. As, the software is capable of detecting six security features of bank notes, the final state of this software will pass the notes as genuine only which can gain at least 4 success points that means greater than or equal to 66.67% including OCR. This is because, each of the six features are strong enough to fight against counterfeiting. But, sometimes printing quality and rough usage can make the security features of genuine banknotes fade. That is why 1 or 2

selected features may not be detected accurately. Fig.2 is the pictorial representation of the whole software's control flow. The implemented software proves the control logic of the whole project and the robustness of this project is clearly plausible in later on.

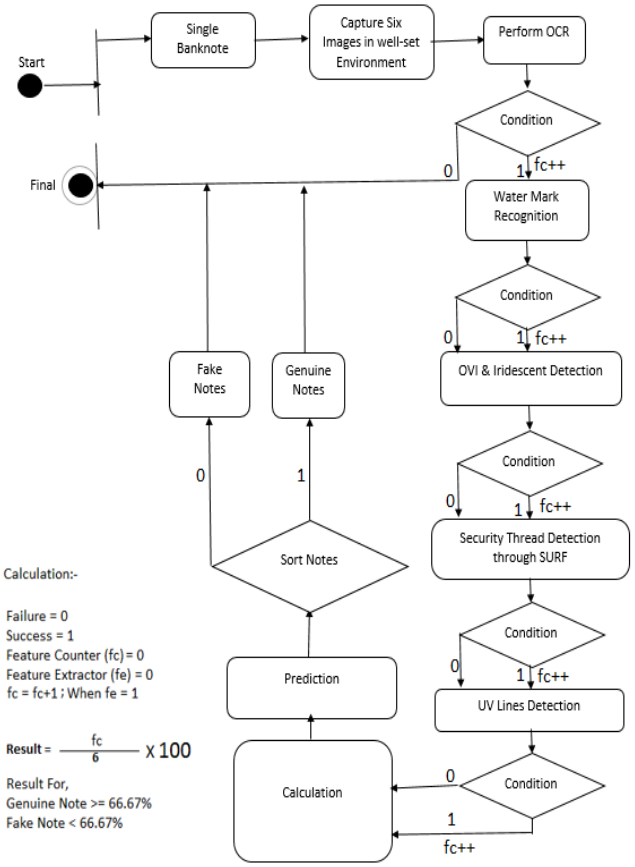


Fig. 4. Control flow diagram

V. How it Differs from Other Systems

The whole project is different from existing fake detection tools like chemical property based tools, color density measuring tools and most importantly single feature based tool like UV light pen tool [17]. To accurately identify a single note as genuine the implemented software requires at best 3 seconds. This required time can be reduced by removing 1 or 2 security features of banknotes from the calculation of this project. Because each of the features are strong enough to maintain the security of bank notes. Users will easily afford this system as the price of the software and hardware comprise comparatively very low cost, operationally fast, easy to use, efficient & accurate.

VI. Software Specifications in Details

A. Core Functionalities:

1) Micro letters recognition through optical character recognition (OCR):

Micro-printing is the most powerful feature of Bangladeshi banknotes. The micro-letters on the banknotes are "BANGLADESH BANK", "500 TAKA", "1000 TAKA" etc. repeatedly in 1000 & 500 BDT. But, to do OCR micro-letters containing "BANGLADESH BANK" is ideal ([19], [20]). That is why, those letters are chosen in this context. The required environment & result relates with OCR are as follows.

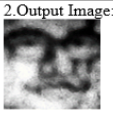
TABLE II: Micro Letters Recognition

Inputs	Software's Tuning	Hardware Requirement	Result
1.Bgr Image containing micro printing 	1.Adaptive Threshold Block Size : 300	1.Highly Zoomed USB2.0 Camera	1.Time:1800-2400 milliseconds 2.Output image: 
	2.Canny Threshold & Threshold Linking : 206	2.Light Environment	
	3. Brightness : 90%	3.Black Box For Noise Reduction	
	4.Contrast : 100%		3.Accuracy : 100%
	5.Sharpness : 100%		
	6.Zoom Scale : 2.5		
	7.Input Image DPI : 600		
	8.Input Image Format : .TIFF		

2) Watermark recognition through principal component analysis (PCA) & Eigen object recognizer:

Watermark containing the portrait of Bangabandhu Sheikh Muzibur Rahman (Father of the Nation) is chosen to perform face detection and recognition using Principal Component Analysis (PCA) ([21], [22]). Moreover, 3 Classifiers known as the Eigen Classifier, the Fisher Classifier and the Local Binary Pattern Histogram Classifier (LBPH) are implemented to compare the face detection and recognition accuracy [23]. Both the Eigen & Fisher Classifiers are suitable for face detection only but not for recognition. Because, both of them performed poorly for unknown faces like fake ones. In contrast, the LBPH classifier is ideal for face recognition. The specification table for Water mark detection and recognition is as follows.

TABLE III: Water-mark Recognition

Inputs	Software's Tuning	Hardware Requirement	Result
1. 10 Training Images 	1.Eigen Threshold: 2000	1.Highly Zoomed USB2.0 Camera	1.Time: 221 milliseconds
		2.Nested Light Environment focused on Watermark Only	2.Output Image: 
2.Input Image : 		3.Black Box For Noise Reduction	3.Recognition Accuracy: 100%
			4.Eigen Distance:45

3) Optically variable ink & iridescent ink recognition through color based contour analysis:

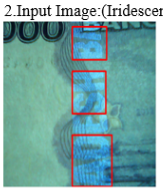
Optically Variable Ink (OVI) feature differs in 100,500 and 1000 TAKA notes. In 500 &1000 taka notes, Green and

Golden colors are reflected with variation of light source. Similarly, Green & Magenta colors are reflected for 100 taka note. As, those colors have specific range of HSV (Hue, Saturation, Value) colors, this software requires training with specific HSV color range [24]. That is why, HSV input images are required for finding contours to detect the existence of OVI & Iridescent Ink [25]. However, this software is now capable to detect the existence of OVI & Iridescent Ink of 1000 Taka notes. In 1000 taka notes, Light Blue color is reflected with 30 to 45 degree angle between the note & light source which ensures the presence of Iridescent Ink. Finally, contour area is evaluated around the OVI & Iridescent ink region to display the detected portion of paper currency [26]. This Feature extraction is solely done with 1000 taka notes. The requirement table represents the specific HSV color ranges as well as software tuning values.

TABLE IV: HSV COLOR RANGES

OVI & Iridescent Ink Colors	HSV Color Ranges		
		Low	High
Golden	Hue	21	56
	Saturation	34	255
	Value	76	255
Dark Green	Hue	35	79
	Saturation	20	255
	Value	76	255
Light Blue	Hue	93	153
	Saturation	0	255
	Value	144	255

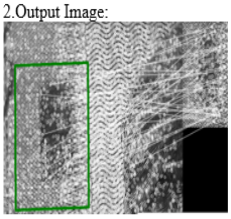
TABLE V: OVI & IRIDESCENT INK RECOGNITION

Inputs	Software's Tuning	Hardware Requirement	Result
1.Input Image:(OVI)  2.Input Image:(Iridescent) 	1.Minimum Contour Area: 1800	1.USB2.0 Camera In Normal Mode	1.Time:20-28 milliseconds
		2.Black Box For Noise Reduction	2.Output Image:(OVI)  3.Output Image:(Iridescent) 
		3.Normal Lighting Environment	4.Accuracy:100%
			5.Resulting Contour Area: above 17000

4) Security thread recognition using speeded up robust features (SURF):

Security Thread is a common feature in almost all Bangladeshi banknotes. The pattern of art work around the security thread & stitching technique makes it a very unique feature of paper currencies. The gap between the two stitched portion of security thread containing the art work & the logo of Bangladesh Bank with "১০০০ টাকা" inscription clearly differentiate the genuine notes from the forge notes. To detect counterfeiting, an image containing the genuine portion of security thread with art work is provided as model image. After that, matching points are retrieved through SURF with its homographic points based on that model image [27]. Actually, a lot of challenges need to overcome to extract this feature because of the printing quality of bank notes. The security thread can be a most robust feature for the feature based counterfeit detection systems, if the printing quality of bank notes can be preserved strictly. The necessary details for this feature extraction are as follows.

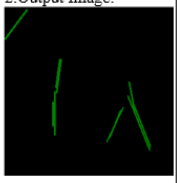
TABLE VI: SECURITY THREAD RECOGNITION

Inputs	Software's Tuning	Hardware Requirement	Results
1.Input Image:  2.Model Image: 	1.Hessian Threshold: 500	1.Medium Zoomed USB2.0 Camera	1.Time: 371 milliseconds
	2.Extended Flags: False	2.Normal Lighting Environment	2.Output Image: 
		3.Black Box for Noise Reduction	
			3.Accuracy :100%

5) Ultraviolet visible lines recognition through "Canny" & "Hough transformation" algorithm:

Ultraviolet light visible straight and curved lines are a most powerful feature of banknotes. UV lines are randomly placed throughout the whole banknote. But, detecting UV lines is very challenging because of numerous colorful art-works presents in the bank notes makes it noisy surface to perform Canny & Hough transformation algorithm. To reduce and avoid extra noise, white portion of banknotes containing the Watermarks is chosen in this context. First of all, edges are detected through Canny edge detection algorithm [28]. That is why, Canny Threshold-180 & Canny Threshold Linking-120 is used. After that, UV lines are detected through Hough transformation algorithm based on the edges that are retrieved from Canny algorithm [29]. The necessary details of software & hardware that is used to detect UV lines are as follows.

TABLE VII: ULTRAVIOLET VISIBLE LINES RECOGNITION

Inputs	Software's Tuning	Hardware Requirement	Result
1.Input Image: 	Hough Line Parameters: a. Threshold: 20 b. Gap Between lines: 10 c. Minimum Line Width: 30	1.LED light	1.Time: 5 milliseconds
		2.Dark environment	2.Output Image: 
			3.Accuracy:100%

B. Reliability of Selected Features:

To recognize micro-printing, watermark, security thread, OVI & Iridescent ink, ultra-violet lines of bank notes, open source Tesseract OCR engine, Principle Component Analysis based Eigen object recognizer, SURF, Contour Analysis and Canny Edge & Hough transformation algorithms are used

respectively. World's best open source OCR engine that was introduced by Hewlett Packard and now, it is under development by Google is used to perform OCR. It is renowned for its accuracy [30]. All of the above mentioned features are well documented. The structure & performance proves the reliability of these features of OpenCV.

C. Test Result Comparison between Genuine & Fake Notes:

A pictorial comparison of 6 selected features based on the outputs between genuine and fake notes which are extracted from the software are as follows.

TABLE VIII: MICRO LETTER TEST

Micro Letters Recognition (Genuine Note)	Input Image: 	Output Image:  BANKBANGLADESHBANKBANGLADESHBANKIAI
Micro Letters Recognition (Fake Note)	Input Image: 	Output Image: *No text found*

TABLE IX: WATER-MARK TEST

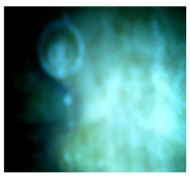
Watermark Recognition (Genuine Note)	Input Image: 	Output Image: 
Watermark Recognition (Fake Note)	Input Image: 	Output Image: *No face detected*

TABLE X: OVI TEST

OVI Detection (Genuine Note)	Input Image : 	Output Image : 
OVI Detection (Fake Note)	Input Image : 	Output Image : 

TABLE XI: IRIDESCENT INK TEST

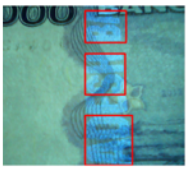
Iridescent Ink Detection (Genuine Note)	Input Image : 	Output Image : 
Iridescent Ink Detection (Fake Note)	Input Image : 	Output Image : 

TABLE XII: SECURITY THREAD TEST

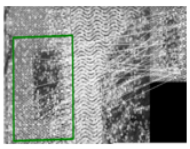
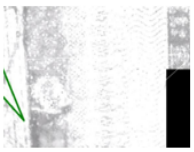
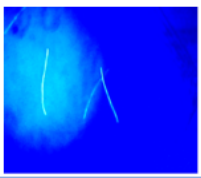
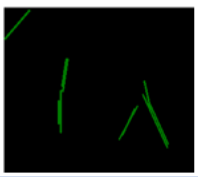
Security Thread Detection (Genuine Note)	Model Image: 	Input Image: 	Output Image: 
Security Thread Detection (Fake Note)		Input Image: 	Output Image: 

TABLE XIII: UV-LINES TEST

UV-Lines Detection (Genuine Note)	Input Image: 	Output Image: 
UV-Lines Detection (Fake Note)	Input Image: 	Output Image: 

D. Development Environment:

1) Framework details:

Intel's OpenCV library is the building block of this software. As, the development platform of this software is .Net, OpenCV's .Net wrapper cross platform EmguCV library is used in this context [31].

2) IDE: Visual Studio: 2013

3) Language: C#

4) .Net Platform: 4.5

5) Target CPU Platform: 32 bit

VII. Necessary Hardware Support

The software core needs a black box to reduce extra noise, a stand for holding the note in exact position under the light source, a USB2.0 web camera with a frame rate of 30fps, different LED lights etc. Most of the mentioned hardware parts are home made.

VIII. Applicable Environment of this Software

The applicability of this system can grasp a broader context than the explanation. This system can be useful in places where fake currency is a matter of great concern. The application domain of this system is mainly two types.

A. Personal:

Anyone can use it personally to satisfy his quest relates with the fear of being forged from fake notes.

B. Commercial:

To check the printing quality of banknotes in currency printing-press, banks, corporations, companies, educational institutions and organizations, hospitals, markets, shopping malls and security forces can use it.

IX. Feasibility Study

The feasibility of this project is evaluated based on three important factors which includes user-friendliness, cost analysis and business values.

A. User friendliness:

A system that is completely controlled by a software is much friendlier to use than others for the end users. The proposed software have high operational feasibility. Everyone will be able to use this software to detect or check their money easily by connecting the device with a computer.

B. Cost Analysis:

To evaluate economic feasibility, cost analysis and benefits associated with the proposed project including software and hardware needs to be measured first. Software cost for this project is completely null. Because it is implemented using some open source libraries. Hardware cost is also very low because of the components that are used to make the hardware part of this device encompasses simple LED lights, a stand to hold bank notes and a USB 2.0 Camera of 600 BDT only.

C. Business Values:

This software will help to detect fake currency more accurately with a minimal device cost. Therefore, removing fake notes from circulation will be easy. Ultimately, it will help to stabilize the national Economy. The problems that are related with counterfeit currency like inflation, devaluation of money, price hike of common goods and most importantly loss in national economy can be mitigated drastically by adopting software assisted counterfeit paper currency detection system.

X. Challenges

A. Hardware Adaptation:

The distance between camera and bank notes must be fixed as well as with the same angle and height. If the distance changes randomly beyond the range, then appropriate image cannot be captured. Without exact images specific feature extraction cannot be possible. Moreover, camera's physical zoom must be same to detect Micro-printing, Security Thread, Ultra-Violet Lines & Watermark and for OVI & Iridescent color detection another zoom scale must be ensured. However, problems with feature specific fake currency detection systems are related with distance scaling, color, printing technique etc. [32].

B. Feature Specific Limited Group of Bank Notes:

All the experimented features are not currently available in all the Bangladeshi bank notes. That is why only limited number of bank notes can be tested.

C. Tight Test Environment (Luminosity & Noise):

The light plays a vital role to feature extraction. In case of watermark recognition, OVI & Iridescent detection and UV lines detection lights must be used from different specific positions and ranges. To avoid noise due to unanticipated light, black box must be used.

D. Printing Quality:

In some real bank notes security threads are printed over micro-letters. This is a big printing fault which may degrade all the feature based paper currency detection systems. Moreover, UV lines must be put largely on the white watermark portion of Bangladeshi banknotes so that it can serve the purpose of UV lines detection easily. So, every note must be printed in a strict standard way.

E. Rough Usage of Banknotes:

Sometimes rough usage make the paper currency too noisy & fade to detect by using image processing.

F. Software Bindings:

To extract all the six features of bank notes, software tuning values from the above mentioned tables must be followed.

XI. Future Work

A. Micro Controller Based Embedded Software Design:

To implement this software using micro-controller so that it can integrate with various embedded devices.

B. Hardware Complexity Minimization:

The complexity that arises during real time fake currency detection due to hardware components will be resolved in future up-gradations.

C. Bengali Language Support:

Bengali Character support in OCR systems of this software will be implemented in future versions.

D. *Support for All Kinds of Bangladeshi Bank Notes & Other Foreign Currencies:*

Support for all kinds of Bangladeshi bank notes and other foreign currencies like dollar, pound, Indian rupee etc. will be provided.

XII. CONCLUSION

In this paper, we have presented a core software that is able to identify fake currencies from images. The software can be used to build a complete system (hardware and software) to combat against counterfeiting. Even though the project has some limitations relating to hardware and printing standard of Bangladeshi paper currency, it can be a substantial threat against currency counterfeiting.

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