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Counterfeit Currency Detection Technique using Image Processing, Polarization Principle and Holographic Technique

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Abstract- **The growing menace of fake and counterfeit currency is evident as newspaper reports of a huge cache of fake currency notes being seized appear every day. The advancements in the field of computers, photocopiers and scanners have made duplicating currency note very simple. The unsuspecting masses have no mechanism of differentiating the fake from the genuine. In our paper, we have included 2 kinds of mechanism to identify counterfeit currency. One is using Ultra Violet (UV) detection using lab view; the other is using the polarization of light when passed through the currency. Only if both the results are positive the output is positive.**

Keywords – National instruments-Image Acquisition (NI-IMAQ); Spin Coating; Cellulose Confirmation; Polarization; Ellipsometer; Holographic Pattern; Holographic Detection

I. INTRODUCTION

The battle to prevent counterfeiting has been ongoing since the Roman times. With the development of sophisticated printing techniques, the counterfeit currencies have become on- par with the original currency. One of the earliest methods was to use UV detection. It is based on the principle of detection of special kinds of inks that are only visible under UV light. Since this process is slow, automation is introduced using (NI-IMAQ). The polarization is based on the principle that, the Indian currency is not made of paper, but is a blend of cotton, paper and linen. Moreover the tree bark from which the currency is made is called the Balsam fig, which also contains a large percentage of cellulose. Cotton is the purest form of cellulose. Thus it is safe to say that Cellulose constitutes a considerable composition of the currency. Although the other ingredients will have some effect on the polarization angle, the polarization angle of the currency is almost close to that of cellulose, and the angle obtained by passing laser through the currency is unique thus it is made use of authentication of the original currency from the forged ones.

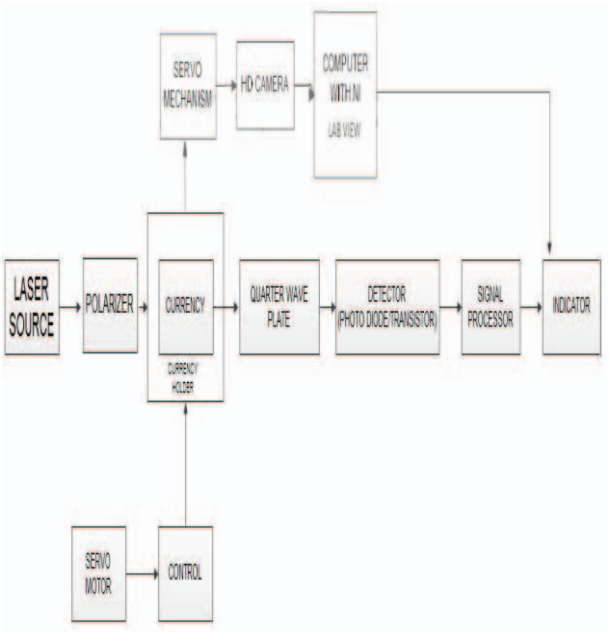

Figure 1. Basic design block diagram

II. UV DETECTION USING NI-IMAQ

The Indian currency is coated with special dyes that are visible only in UV light. With the advancements in technology, the counterfeit currency is coated with similar dyes that give positive results to UV test. The existing device which performs the UV test is capable of testing only one currency at a time, and the process is not automatic, as well as it requires humans to check the genuineness of the currency, which are prone to human errors. Using NI-IMAQ this process can be automated using a computer. The basic logic is developed using Image Acquisition-Laboratory Virtual Instrument Engineering Workbench (IMAQ-LABVIEW) (Figure 2). The images of the original currencies are fed to the computer at various angles, also images of various

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currencies at different ware & tear levels are also fed to the IMAQ database. The currency is initially placed on the holder which is driven by the servo mechanism and illuminated by the UV source. This currency is captured using an HD camera and the images are sent to IMAQ-LABVIEW. The current image is compared with the images of the original currencies from the database and if the currency is real the status glows green (Figure 3) else in red (Figure 4). The entire setup is show in figure 5.

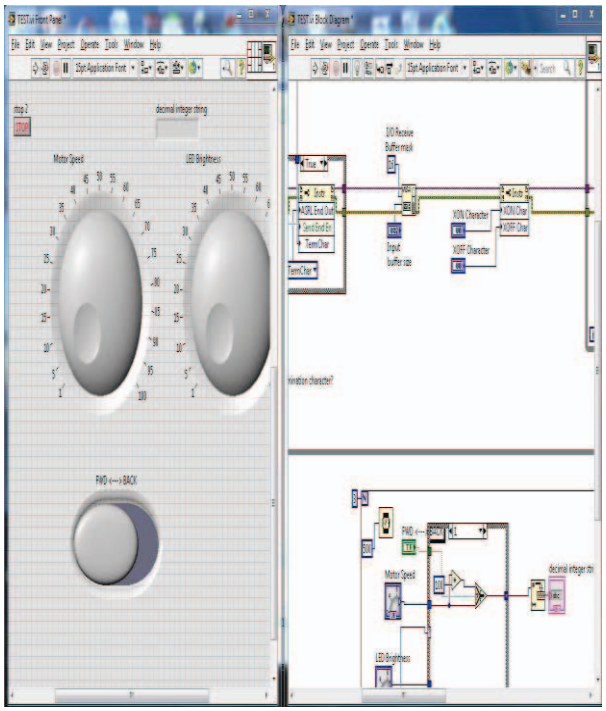

Figure 2. Front panel & Block diagram of the detection process

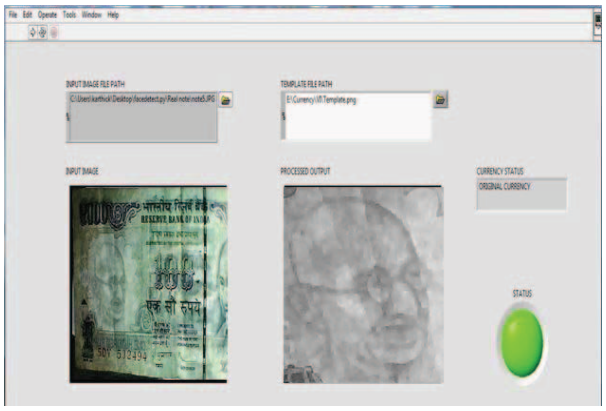

Figure 3. Output for original currency

Figure 4. Output for fake currency

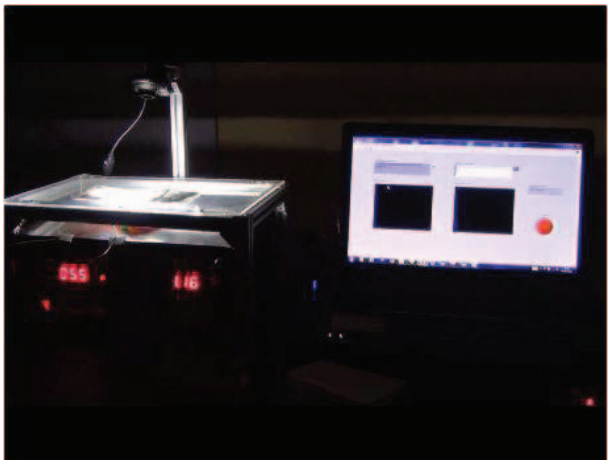

Figure 5. Overall Setup

III. POLARIZATION ANALYSIS AND WORKING

The Indian currency is not made of paper but is a blend of paper and cloth. The paper used for making the currency is made from the balsam fir tree. The currency contains 30-40% cotton. Cotton is the purest form of cellulose and is present as cellulose I in it. Cellulose I am crystalline at room temperature and becomes amorphous when heated to 340F [9]. When cotton is manipulated or subjected to various chemical processes in order to convert it into fiber, the cellulose I is converted to cellulose II or III or IV, which are also crystalline. Thus by measuring the polarization properties of cellulose I, II, III and IV, we can extend it to the property to the currency [10]. Since the currency is translucent, it is necessary to use a monochromatic laser more than 2mW to obtain a beam powerful enough for the photo detector to detect and the laser must not be more than 5mW, as it might burn the currency.

Figure 6. Experiment to confirm the presence of Cellulose in the currency

Figure 7. Spin Coating of Currency

The polarization compensator is used to measure the circular and elliptical polarization. The 7 types of currencies require polarizer at different angles and this is achieved by using a servo motor controlled by the micro controller. Depending upon the data fed into the micro controller, the servo motor makes its movement and the appropriate polarization is achieved. Since the light coming out of a translucent material [1] is of less intensity, we use a highly sensitive photo detector-amplifier array to measure the intensity. Since maximum intensity is obtained when the plane of polarization is parallel to the plane of vibration, this method is used to determine the genuineness of the currency. The light from the laser, after passing through the polarizer is passed through the currency. To ensure the simplicity of the circuit and the ease of operation, the currency holder is aligned in such a way that it will be oriented along the Brewster's angle. The quarter wave plate will convert the elliptical polarization into linear polarization and the final output will be measured by the photo-transistor circuit and amplifier. The output directive determines whether the currency is genuine or not. The Brewster's angle will be different for different currencies (10, 20, 50, 100, 500, and 1000) and the servo mechanical arrangement will align the currency holder accordingly. Since Brewster's angle of a very small magnitude is being dealt with here, a very high response photo diode is required.

IV. SPIN COATING AND ELLIPSOMETRIC ANALYSIS

In order to prove that the currency consists of cellulose, the currency is mixed with lithium chloride [4] and dimethyl acetamide and heated to 70^{o}C in the presence of nitrogen gas (figure 6). It is found that the cellulose disintegrates leaving behind the currency in the form of a pulp [5]. To find the polarization angle the currency is spin coated [6] at 2000RPM onto a silicon wafer (figure 7) and is tested using an Ellipsometer. The Ellipsometer works on the principle of the differential reflection by the currency and the silicon surface. The thickness of the currency is calculated to be 100microns [11] and this data is fed to the computer connected to the Ellipsometer [7] (figure 8) . Thus the refractive index of the currency is found with which the Brewster's angle of the currency is determined.

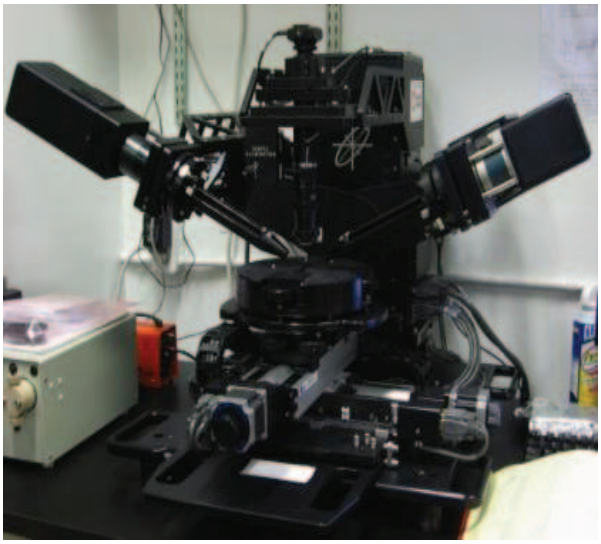

Figure 8. Ellipsometer analysis of currency

V. MATHEMATICAL VERIFICATIONS

A. Polarizability of cellulose:

The refractive index of cellulose at a wavelength of 633nm is 1.468. We can calculate the Abbes number V_d/V_e for cellulose from the following formula

$V_d = (n_d-1) / (n_F-n_C) = 54.22$, where

nd: 0.58756 μm (wavelength of Yellow helium line)

n_F: 0.48613 μm (wavelength of Blue hydrogen line)

n_C: 0.65627 μm (wavelength of Red hydrogen line)

$V_e = (n_e-1) / (n_{F'}-n_{C'}) = 54.71$, where

n_e: 0.54607 μm (wavelength of Green mercury line)

$n_{F'}$: 0.47999 μm (wavelength of Blue cadmium line)

n_C : 0.64385 μm (wavelength of Red cadmium line)

This proves that cellulose is transparent and is capable of transmitting and reflecting light.

B. Determination of Angle of Polarization in Indian Currency:

By calculating the reflectance coefficient for cellulose currency note the polarization angle can be determined. Cellulose polarizes in 2 different ways-linear and elliptical. The linear polarization is mathematically expressed as

$E_y = E \sin(kx-wt)$ (1)

$E_z = E \sin(kx-wt)$ (2)

E_y: Electric field intensity along the y axis (Ordinary ray)

E_z: Electric field intensity along the z axis (extraordinary ray)

E: amplitude of the electric field

K: wave number

w: angular frequency(radians per second)

x: displacement along the x axis (electromagnetic wave is travelling in the x direction)

t: time(seconds)

after passing through the test material, the change in the electric field vector can be expressed as

$E_y = E \sin(kx-wt)$ (3)

$E_z = E \cos(kx-wt-A)$ (4)

A: phase difference of the waves along z and y-axis

Where the polarization is decided by the phase difference A

$E_y = E \sin(kx-wt)$ (5)

$E_z = E \cos(kx-wt+\pi/2)$ (6)

$E_y = E \sin(kx-wt)$ (7)

$E_z = E \cos(kx-wt+3\pi/2)$ (8)

Finally the polarization angle is a function of wavelength of light used, refractive index of the material and the angle of incidence.

C. Determination of Brewster's Angle:

The Brewster's angle can be calculated through the simple formula

$_B = \tan^{-1}(n2/n1)$

Where "$_B$" is the Brewster's angle,

n2 = refractive index of the currency note,

n1= refractive index of air (n1=1).

Since the refractive index of cellulose is already known (@633nm n=1. 4687) the Brewster's angle is around 55.78^o or 0.98rad. It is assumed that when the refractive index of currency is calculated, it will be equal or close to the above mentioned values.

VI. HOLOGRAPHIC DETECTION TECHNIQUE

Since the concept of holography has not yet been included in the Indian currency, a system to determine the originality of the currency through holographic detection has been introduced. The basic concept of a hologram is that when 2 laser sources interfere on the recording medium, a unique random interference pattern is created, which under no circumstances can be reverse engineered. Such A unique sticker can be developed by the government and its authenticity can be checked by using a holographic detector. The holographic detector determines the originality by using the depth and the colour patterns along with the text impregnated in the holographic sticker. The sticker is not stuck to the currency later on, but is incorporated during the construction process. Thus the laser light from the laser source is made to fall on the currency incorporated with holographic sticker which reflects the light from the sticker, this light falls on the holographic detector whose values is fed to the comparator which check the values obtained from the holographic detector with the reference value and provides the result weather or not the currency is fake or genuine (figure 9).

A Small set back in this technique is that the initial sample preparation of the holographic sticker is a bit costly, but the subsequent replication of the sticker from the source and incorporation with the currency is very cheap and easy, making this technique the most simplest and effective method in the detection of counterfeit currency.

Further, for better reliability, other counterfeit detection techniques such as magnetic ink method, Infrared based detection methods can be incorporated with this device. Thus making it a fool proof or a failsafe device to detect counterfeit currency.

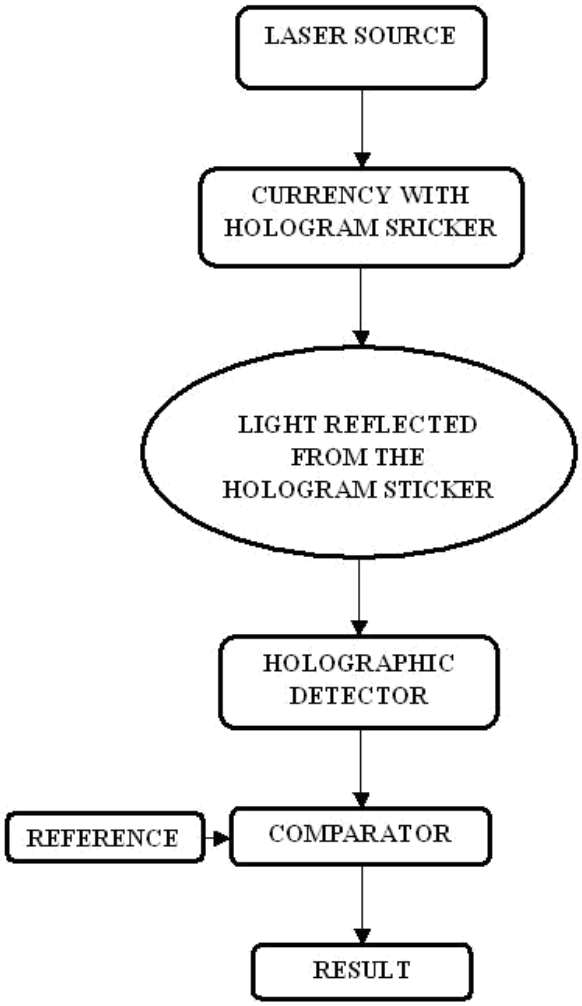

Figure 9. Block diagram of holographic setup

VII. CONCLUSIONS

The above mentioned methods of counterfeit detection are far more superior to those which already exist, in terms of accuracy, reliability and automation. Further this technique can also be used in detection of original and counterfeit documents.

Polarization technique that is used in this detection process is based on the physical property of the currency and thus making the above proposed method more reliable than the existing chemical property based detectors such as UV detector, Magnetic Ink detector, etc. This method is dynamic and can be incorporated with the existing methods to make the counterfeit currency detection more accurate. Thus the Counterfeit currency Detection Technique using image processing, polarization principal and Holographic technique can be claimed as an innovative approach in detecting the counterfeit currency based on its physical property.

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