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# A Systematic Literature Review of Counterfeit Currency Detection using Modern Methods

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The escalating issue of counterfeit currency, fuelled by sophisticated printing and scanning technologies, poses a substantial threat to global economies, undermining financial systems and eroding public trust. Effective counterfeit detection has become imperative for mitigating this growing problem and safeguarding monetary integrity. This paper provides a comprehensive review of current and emerging methodologies in counterfeit currency detection, with a primary focus on image processing techniques. Key approaches, including Ultra Violet (UV) detection, polarization analysis, advanced edge detection, and machine learning algorithms, are explored in depth. Specific image processing techniques, such as the canny edge detection algorithm, image segmentation, and feature extraction, are analyzed for their effectiveness in identifying subtle differences between genuine and forged currency features. The paper also emphasizes the integration of these techniques into automated systems, which enhance accuracy, speed, and scalability in real-world applications. Leveraging both traditional and advanced technologies, this study proposes a robust framework for cost-effective, reliable, and scalable solutions in counterfeit detection, aiming to strengthen defences against increasingly complex forgeries.
**Keywords:** Counterfeit Detection, Image Processing, Machine Learning, Edge Detection, Optically Variable Ink, Pattern Recognition, Neural Networks, Chemical Analysis.

## 1. Introduction

Fake money discovery has become progressively refined, driven by headways in picture handling, AI, and particular security highlights. To really battle the expansion of phony notes, a thorough methodology is fundamental. This includes catching high-goal pictures of banknotes, pre-handling them to improve lucidity, and dissecting key elements like tone, shape, and surfaces utilizing v0arious picture handling methods. Furthermore, AI models, including Convolutional Brain Organizations (CNNs) and Strategic Relapse, are utilized to perceive inconspicuous examples and arrange notes with high exactness. High level security highlights, like Optically Factor Ink (OVI) and advanced watermarking, further brace the identification cycle. By incorporating these procedures, a strong framework arises, fit for recognizing valid cash from fakes with noteworthy accuracy.

## 2. Methodology:

### 2.1 Image Processing:

The picture handling approach for identifying fake cash starts with catching high-goal pictures of money notes. Introductory preprocessing steps center around lessening commotion and adjusting movement obscure to guarantee picture clearness [4]. Fundamental highlights, for example, variety shape, paper width, and chronic numbers are then removed utilizing strategies like variety examination and Optical Person Acknowledgment (OCR) [4]. To feature urgent elements, for example, edges and surfaces, the picture goes through separating. These highlights are contrasted and a reference dataset of veritable cash utilizing progressed picture acknowledgment and example investigation [14]. This approach resolves issues like commotion, movement obscure, and wasteful element extraction, prompting upgraded unwavering quality and exactness in distinguishing fake money [4][14]. By joining these strategies, the framework successfully recognizes true and phony notes.

### 2.2 Machine Learning:

The fake cash discovery framework utilizes progressed AI procedures, explicitly utilizing brain organizations, to examine and separate among certified and fake money. This approach includes preparing the organization on a dataset of pictures highlighting genuine and counterfeit notes, zeroing in on perceiving unobtrusive examples connected with security elements, for example, watermarks, security chains, 3D images, and miniature printing [14]. Among the AI techniques, Calculated Relapse has demonstrated profoundly exact (almost 100%) in characterizing money notes, beating Direct Discriminant Examination (LDA) [2]. When prepared, the brain network is coordinated into the framework to give continuous cash grouping and check, upgrading precision and proficiency in distinguishing fake cash.

### 2.3 Pattern Recognition Methodology:

Identifying fake money includes breaking down particular highlights of cash notes. The interaction begins by separating explicit locales of interest (returns on initial capital investment) from pictures of the notes and extricating extraordinary attributes like examples, tones, and surfaces [7]. These elements are then contrasted with a reference set of credible money to check for arrangement with certifiable examples. This examination decides if the

note is genuine or fake. High level strategies are applied to work on the exactness of this recognition, which improves the viability of recognizing certified cash and recognizing it from fake forms [11].

### 2.4 Digital Watermarking:

Computerized watermarking is a procedure used to insert stowed away data into advanced content to check its genuineness and safeguard against falsifying. This technique includes embedding a remarkable, imperceptible code or example into the computerized picture of a money note. The inserted watermark is regularly intended to be vague to the unaided eye however perceptible utilizing particular programming or gear. This installed code can be utilized to approve the realness of the money note by contrasting it with the reference information base of certified notes. The watermarking system guarantees that each note conveys a novel identifier, which upgrades security and makes duplicating more troublesome. By coordinating these computerized markers, monetary organizations can actually follow and confirm the authenticity of cash, diminishing the gamble of fake cash flowing in the economy [3].

## 3. Feature Extraction:

Highlight extraction assumes a pivotal part in recognizing fake cash by distinguishing and breaking down unmistakable qualities of certifiable notes. The examination headings as for approaches on fake money discovery are determined as a stream graph in Figure 1. The interaction begins with computerized picture handling to catch and improve high-goal pictures of the cash. Picture division is then used to separate different districts of the note, like text, watermarks, and security strings, working with centered examination. During highlight extraction, remarkable properties like watermarks, miniature printing, security strings, and surface examples are distinguished and measured. These elements are then looked at against a data set of known fake qualities to confirm legitimacy. This procedure altogether works on the exactness of fake identification frameworks, guaranteeing viable security against counterfeit cash and keeping up with financial dependability [9].

### 3.1 Image Sensing:

Picture detecting includes securing and investigating pictures to distinguish fake money. This cycle uses a MATLAB GUI program that consolidates Watchful Edge Discovery innovation. The Shrewd Edge Discovery calculation processes the pictures to distinguish and feature edges, which are fundamental for recognizing explicit security highlights on the banknotes.

The framework upgrades its fake location abilities by incorporating Optically Factor Gadgets (OVDs) into the interaction. OVDs are progressed security includes that display extraordinary optical impacts, for example, variety changes and picture exchanging, which are trying to duplicate. This mix of picture securing, handling, and the examination of OVD highlights takes into consideration more solid identification of veritable versus fake cash [6].

### 3.2 Hyper Spectral Imaging:

Hyper Otherworldly Imaging (HSI) is utilized for recognizing fake money by catching

itemized phantom data from every pixel in a picture. This method includes a convenient, minimal expense HSI framework intended to catch pictures of Republic of China (ROC) banknotes. The framework changes over RGB pictures into ghostly pictures, giving an exhaustive examination of the banknotes' materials and elements. Three explicit locales of premium (returns for capital invested) are removed from the banknotes, and the mean dim worth (MGV) for every return for money invested is estimated. By contrasting the MGVs of fake and unique banknotes, the strategy groups the realness of the notes in view of the nitty gritty phantom information, offering a more exact and non-damaging methodology contrasted with conventional procedures like UV light location.

### 3.3 UV Detection Using NI-IMAQ:

UV Location Utilizing NI-IMAQ includes computerizing the recognizable proof of fake cash by using bright (UV) light to distinguish exceptional colors on banknotes that are apparent just under UV enlightenment. The money is put on a holder, enlightened with an UV source, and caught by a HD camera. The pictures are then dissected utilizing the Picture Procurement Research center Virtual Instrument Designing Workbench (IMAQ-LABVIEW) framework. These pictures are contrasted and a data set of veritable money pictures. On the off chance that the money matches, it is set apart as veritable with a green status; in any case, it is delegated fake and displayed with a red status [8].

### 3.4 Edge Detection Methodology:

The edge location approach includes using the watchful administrator to recognize edges in money pictures for fake discovery. The cycle starts with preprocessing the pictures to upgrade their quality, which works on the precision of the edge recognition. The Vigilant administrator is then applied, beginning with Gaussian smoothing to lessen clamor and forestall bogus edge recognition. Following this, the angle size and heading are registered to pinpoint regions with huge power changes, showing likely edges. Non-greatest concealment is then used to refine the edge location by limiting the identified edges to a solitary pixel width, eliminating less unmistakable edges. At last, edge following by hysteresis is utilized to hold the main edges while disposing of more fragile ones. This exhaustive methodology guarantees exact edge location, which is urgent for precisely recognizing veritable and fake money notes [12].

### 3.5 Optically Variable Ink (OVI):

Optically Factor Ink (OVI) is a high-security include intended to deflect fake money. This ink shifts tone when seen from various points, making it challenging for forgers to reproduce. The innovation behind OVI includes extraordinary shades that modify their variety because of light communication, making a dynamic and difficult to-duplicate impact. This variety change is observable when the cash is shifted or seen under fluctuating lighting conditions. To check validness, the ink's variety moving properties are inspected; real notes will show reliable and anticipated changes, while fakes frequently neglect to precisely imitate these impacts. OVI's remarkable optical properties improve the strength of money check frameworks, making it a urgent component in current enemy of falsifying systems. Its capacity to give quick visual affirmation of realness forestalls the dissemination of fake notes and guarantees the honesty of monetary exchanges [3].

3.5.1. Pigment-Based Methods

Impedance Shades: These colors make variety shifts through obstruction impacts. They comprise of layers of various materials (frequently metallic) that mirror light in an unexpected way, contingent upon the point. The most well-known are pearlescent shades, which can create dynamic variety changes.

Chameleon Shades: These shades shift variety in light of the point of light and review point, like how certain chameleons change tone.

3.5.2. Dye-Based Methods

Thermo chromic Tones: These varieties change tone with temperature assortments, which can be gotten together with OVI influences. While not a fundamental part of OVI, they can further develop security features by noting contact or force.

Photochromic Tones: These varieties change tone when introduced to UV light. When facilitated into OVI, they add an extra layer of wellbeing that can be revealed under unambiguous lighting conditions.3.5.3. Covering Procedures

Layered Coatings: Applying various meager layers of various materials can upgrade the variety moving impact. Each layer can mirror various frequencies of light, delivering a more articulated shift.

Printing Strategies: Techniques like flexography, gravure, or screen printing can be utilized to apply OVI onto substrates like paper or plastic, guaranteeing exact command over the ink's thickness and application.

3.5.4. Nanotechnology

Nano-Organized Materials: Using nanotechnology, inks can be figured out with nanoparticles that upgrade the variety moving impact. These particles can control light at a tiny level, giving interesting optical properties.

3.5.5. Incorporation with Other Security Features

Holographic Components: Consolidating OVI with holographic components can make multifaceted security highlights. Multi dimensional images and OVI can cooperate, adding intricacy to the plan. Watermarking: Coordinating OVI with watermarking can give extra check techniques that are hard to imitate.

3.5.6. Laser and Etching Techniques

Laser Etching: Utilizing lasers to make fine examples or surfaces in the substrate can improve the optical impacts of the OVI, adding a material aspect to the visual security highlights. Miniature drawing: This procedure includes carving tiny examples on the substrate, which can influence how light connects with the OVI, making dynamic special visualizations.

3.6 Chemical Analysis:

Substance Examination is a vital system in fake cash location, zeroing in on the synthetic creation and properties of notes and coins to recognize certified money from fakes. Genuine

money is made utilizing explicit materials with exact substance creations that forgers frequently battle to repeat. Legal researchers use compound reagents to test for responses, for example, variety changes or fluorescence that are normal for authentic notes. Procedures like Infrared Spectroscopy (IR) or Raman Spectroscopy further improve the location interaction by recognizing special substance markers or inks. Furthermore, while forgers might mirror the visual appearance of safety includes, the compound properties of these highlights are a lot harder to precisely duplicate. By dissecting these perspectives, Compound Examination really uncovers disparities in fake money, making it a fundamental apparatus in legal examinations [11].

3.6.1. Spectroscopic Methods

Infrared (IR) Spectroscopy: Used to examine the exceptional unearthly finger impression of the paper and ink utilized in real money. Fake notes might have different synthetic structures.

UV-Vis Spectroscopy: Identifies fluorescence properties of inks and security include that is in many cases present in genuine banknotes yet missing in fakes.

3.6.2. Mass Spectrometry

Lattice Helped Laser Desorption/Ionization (MALDI) MS: Can distinguish explicit colors and shades utilized in banknote inks. This technique gives itemized data on the substance structure

3.6.3. Chromatographic Techniques

Elite Execution Fluid Chromatography (HPLC): Used to investigate the ink sythesis of banknotes, distinguishing explicit colors that are one of a kind to legitimate money.

Slender Layer Chromatography (tender loving care): A fast technique to isolate ink parts and contrast them and real examples.

3.6.4. Electrochemical Methods

Potentiometric Sensors: Can distinguish explicit particles or mixtures in inks or paper that are normal for genuine cash.

Voltammetry: Breaks down electrochemical properties of inks, which might contrast among real and fake notes.

3.6.5. Gravimetric Analysis

Weighing and analyzing the paper's composition and thickness can help determine authenticity, as counterfeit notes often use different materials that do not match the specifications of real currency.

3.6.6. Thermal Analysis

Thermo gravimetric Examination (TGA): A Measures weight change in the money test as it is warmed, distinguishing the organization of the paper and inks, which can vary from bona fide notes.

3.6.7. X-ray Techniques

X-beam Fluorescence (XRF): Non-horrendous examination that can decide the essential organization of banknotes, uncovering contrasts in materials utilized among certifiable and fake notes.

3.6.8. Microscopy Methods

Checking Electron Microscopy (SEM): Gives high-goal pictures of the paper and ink, taking into account assessment of the microstructure and surface elements novel to real money.

Optical Microscopy: Can uncover highlights like miniatures printing that are in many cases missing in fake notes.

3.6.9. Field-Portable Methods

Compact gadgets for spectroscopy or chromatography consider fast, in-field testing of thought fake notes, making it more straightforward for retailers and policing confirm money on the spot.

3.6.10. Colorimetric Methods

Variety Change Discovery: Utilizing compound markers that change variety because of explicit inks or medicines can assist with recognizing fakes rapidly.

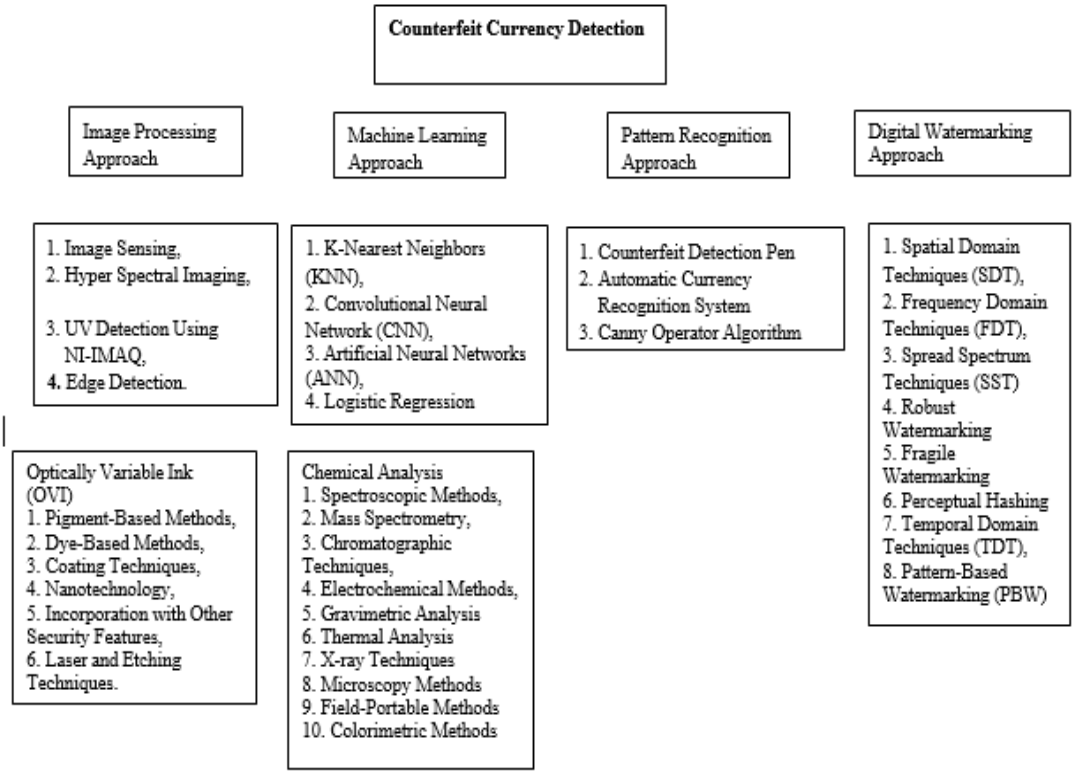


Fig: 1 Various Approaches on Counterfeit Currency Detection

## 4. Algorithms:

### 4.1 K-Nearest Neighbors (KNN):

The K-Closest Neighbors (KNN) calculation is used for recognizing fake cash through picture handling strategies. KNN capabilities by contrasting highlights removed from pictures of money notes — like tone, shape, and paper width — with those in a pre-laid out dataset. It utilizes Euclidean distance to check the comparability between the highlights of another cash note and those in the dataset. For each new note, KNN distinguishes the "k" closest neighbors in view of these distances and arranges the note as per the larger part class among these neighbors. This technique is especially viable for little datasets, as KNN can accomplish high precision without requiring a conventional preparation stage. In any case, difficulties, for example, computational intricacy with bigger datasets and the nature of component extraction should be addressed to keep up with solid arrangement execution [4].

### 4.2 Convolutional Neural Network (CNN):

Convolutional Brain Organizations (CNNs) are pivotal for identifying fake cash because of their high level picture acknowledgment capacities. CNNs naturally gain and concentrate complex highlights from pictures through a multi-facet engineering. This engineering incorporates convolutional layers that distinguish fundamental highlights like edges, surfaces, and perplexing examples novel to veritable money, for example, watermarks and miniature printing [13], [14]. The CNN is prepared on a thorough dataset containing both real and fake notes, permitting it to learn and order highlights characteristic of validness. In the wake of preparing, the CNN productively dissects and recognizes genuine and counterfeit money notes in light of the learned examples. This strategy upgrades the precision and dependability of fake identification via computerizing highlight extraction and order processes, making it an amazing asset in frameworks like the Verinote Counterfeit Cash Discovery Framework [14].

### 4.3 Artificial Neural Networks (ANN):

Fake Brain Organizations (ANN) is utilized for distinguishing fake cash through a purposeful picture handling and example acknowledgment approach. The cycle starts with catching high-goal pictures of cash notes and extricating a District of Revenue (return for money invested) that spotlights on significant elements. High level picture handling strategies are then applied to these returns on initial capital investment to improve and channel the pictures, featuring separating attributes like examples, varieties, and text. The refined pictures are taken care of into an ANN model, which imitates the brain construction of the human cerebrum to learn and perceive designs. Via preparing on a dataset involving both veritable and fake notes, the ANN model proficiently groups the info pictures as credible or counterfeit. This technique works on the framework's precision in recognizing fake money and guarantees reliable confirmation [7].

### 4.4 Counterfeit Detection Pen:

The fake recognition pen is an instrument used to distinguish counterfeit money by dissecting the paper creation. It contains iodine, which responds with starch found in certifiable money paper. At the point when the pen is applied to a genuine note, the iodine responds with the starch, bringing about a variety change to golden or brown. Interestingly,

fake notes frequently need starch, making the iodine stay unaltered or become dark. This strategy considers a fast and straightforward check of money legitimacy, however it may not distinguish a wide range of fake notes, especially those produced using paper that copies the properties of certifiable cash [3].

### 4.5 Automatic Currency Recognition System:

The Programmed Cash Acknowledgment Framework recognizes fake notes through a multi-step picture handling approach. It starts by obtaining a computerized picture of the money, and switching it over completely to grayscale to work on the information. Edge recognition calculations recognize key highlights and limits on the note. Then, include extraction disengages particular credits like examples and security markings. The framework then fragments the picture into explicit areas of interest for additional investigation. By contrasting these elements and those of realized veritable notes put away in a data set, it evaluates the money's legitimacy. The eventual outcome demonstrates whether the note is veritable or fake and distinguishes its group. This robotized cycle further develops identification proficiency and exactness, making it significant for applications like ATMs and mechanized candy machines, where fast and dependable money confirmation is urgent [1].

### 4.6 Logistic Regression:

Strategic Relapse is a strong measurable characterization strategy used to separate among fake and certified money. The model applies a strategic (sigmoid) capability to a straight mix of info highlights, bringing about likelihood esteem somewhere in the range of 0 and 1. This worth addresses the probability that the information is fake. Via preparing on named information, Strategic Relapse learns the connection amongst highlights and the twofold result. In cash verification, elements can incorporate picture based or substance qualities. The paper reports that Strategic Relapse accomplished a noteworthy precision of almost 100% in distinguishing fake cash, outperforming Straight Discriminant Examination (LDA). Its key advantages incorporate high interpretability and computational proficiency, settling on it a powerful decision for fake discovery [2].

### 4.7 Mean Gray Value (MGV):

The Mean Dim worth (MGV) calculation computes the typical dim degree of pixels inside unambiguous locales of premium (returns on initial capital investment) on a banknote. The interaction includes separating three returns for capital invested from hyper ghastly pictures of the banknotes. For every return for capital invested, the dark levels of all pixels are found the middle value of to acquire the MGV. This worth measures the force or reflectance inside the return for money invested and helps with separating among veritable and fake banknotes by contrasting MGVs of different examples [5].

### 4.8 Canny Operator Algorithm:

The Vigilant Edge Recognition calculation, fundamental for exact picture examination, works through a multi- stage cycle to recognize edges in pictures. At first, the calculation computes the angle of the picture to recognize huge force changes, which show potential edges [6]. Following this, non-most extreme concealment refines the edge identification by diminishing out the edges and eliminating pixels that don't comprise part of an edge [10].

The last step includes edge following by hysteresis, where two limits — high and low — is applied to conclude the edge map. Solid edges are set apart by angles over the high limit, while more fragile edges are incorporated provided that they interface with solid edges, guaranteeing powerful and exact edge recognition [6] [10]. This strategy is especially valuable for examining security highlights like the Optically Factor Gadget (OVD) in fake recognition, guaranteeing nitty gritty and dependable picture examination.

Computerized watermarking includes inserting data into advanced media (like pictures, sound, or video) to safeguard copyright, confirm genuineness, or pass on data. Here are a few normal strategies for computerized watermarking.

4.9 Spatial Domain Techniques

Least Huge Piece (LSB) Addition: This technique modifies the most un-critical pieces of the pixel values in a picture or the example values in sound. It's basic and quick however can be handily recognized and taken out.

4.10 Frequency Domain Techniques

Discrete Cosine Change (DCT): Watermarks are implanted in the DCT coefficients of a picture. This technique is powerful against different goes after like pressure and trimming.

Discrete Wavelet Change (DWT): Like DCT, DWT isolates the picture into various recurrence parts, considering more adaptable watermark installing.

4.11 Spread Spectrum Techniques

Watermarks are spread over a great many frequencies, making them hearty against commotion and pressure. This technique can be applied to both sound and pictures.

4.12 Robust Watermarking

Intended to endure purposeful assaults or changes (like pressure or trimming). Procedures frequently consolidate recurrence and spatial techniques to upgrade strength.

4.13 Fragile Watermarking

Assuming the media is messed with; the watermark is annihilated, showing that the substance has been adjusted. This is valuable for legitimacy confirmation.

4.14. Perceptual Hashing

A strategy where a hash is made from the media that mirrors its substance. Any modification in the media changes the hash, considering content check.

4.15 Temporal Domain Techniques

Utilized essentially in video watermarking, these procedures implant watermarks in the time area, adjusting the edge rate or timing of specific casings to convey watermark data.

4.16 Pattern-Based Watermarking

Uses unmistakable examples or surfaces in pictures to pass on watermark data, which can be outwardly discernible or stowed away.

## 5. Conclusion:

The diverse way to deal with fake money location, joining picture handling, AI, and high level security highlights, gives a strong tool stash to guaranteeing the credibility of banknotes. Picture handling strategies, for example, edge discovery and element extraction improve the capacity to distinguish unmistakable qualities, while AI calculations, including CNNs and Calculated Relapse, offer high level example acknowledgment and order abilities. The consideration of safety highlights like OVI and advanced watermarking adds layer of check, making it progressively hard for forgers to reproduce. This far reaching and incorporated approach not just works on the exactness and dependability of money confirmation yet in addition reinforces the general security foundation against duplicating. The nonstop refinement and utilization of these innovations are crucial for keeping up with monetary honesty and protecting financial frameworks.

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