ENERGY EFFICIENT RESOURCE OPTIMIZED DIGITAL WATERMARKING SCHEME FOR MOBILE DEVICES

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Dehradun

April 4th, 2016 (Durgansh Sharma)

Declaration

"I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which has been accepted for the award of any other degree or diploma of the university or other institute of higher learning, except where due acknowledgment has been made in the text."

Durgansh Sharma

Date:- 4th April, 2016

Place:- Dehradun

CERTIFICATE

This is to certify that the thesis entitled **"Energy Efficient Resource Optimized Digital Watermarking Scheme for Mobile Devices"** submitted by **DURGANSH SHARMA** to **University of Petroleum & Energy Studies** for the award of the degree of Doctor of Philosophy is a bona fide record of the research work carried out by him under our supervision and guidance. The content of the thesis, in full or parts have not been submitted to any other Institute or University for the award of any other degree or diploma.

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Table of Contents

ACKNOWLEDGEMENTS 2

Declaration 4

CERTIFICATE 5

EXECUTIVE SUMMARY 9

1. Chapter-I: Introduction 20

1.1. General Introduction 20

1.2. Digital Watermarking 22

1.3. Digital Image Watermarking 23

1.3.1. Digitization 23

1.3.2. Security of Data and Information 24

1.3.3. Steganography 24

1.3.4. Watermarking 24

1.3.5. Digital Watermarking 26

1.3.6. Image Watermarking 28

1.3.6.1. Fidelity 28

1.3.6.2. Robustness 29

1.3.6.3. Data Payload 29

1.3.6.4. Security 29

1.3.6.5. Computational Complexity 30

1.4. Classification of watermarking techniques 30

1.4.1. Public & Private Watermarking: 30

1.4.2. Asymmetric & Symmetric Watermarking: 30

1.4.3. Steganographic & Non-Steganographic watermarking: 31

1.4.4. Robust & Fragile Watermarking: 31

1.4.5. Visible & Transparent watermarking: 31

1.5. Soft Computing Techniques 32

1.5.1. Fuzzy Logic 32

1.5.2. Artificial Neural Network 32

1.5.3. Extreme Learning Machine 32

1.6. Android Framework 33

1.7. Motivation/need and overview 35

1.8. Objectives 37

1.9. Research Methodology 38

1.10. Chapter Scheme 39

2. Chapter-II: Review of Literature..41
2.1. Literature Review..41
2.2. Steganography and Cryptography..42
2.3. Watermarking Schemes Adopted: 42
2.4. Energy Efficiency or Power Consumption in Mobile or Smart Phones 48
2.5. Real Time/ Embedded Systems/ Computer Simulation and Mobile Application..51
2.6. Usage of Soft computing (Fuzzy Logic/ Genetic Algorithm/ ANN) in the field of image watermarking..54
2.7. ELM and its Applications 60
2.8. Applications of watermarking..61
3. Chapter-III: DMT Scheme (Phase-I): Optimized Framework for Digital Image Watermarking 65
3.1. DMT Scheme 65
3.2. Overview of Phase-I 65
3.3. Phase-I (HVS Modeling using Gray Scale Image) 66
3.4. Components of HVS 67
3.5. Algorithm: Watermark Embedding in Phase-I 77
3.6. Conclusion of Optimized Image Watermarking 83
4. Chapter-IV: DMT Scheme (Phase-II): Hardware Implementation and Simulation of image watermarking model. 84
4.1. Overview of Phase-II 84
4.2. Phase-II (Simulation of Image Watermarking Model) 84
4.3. BlueThresh() Thresholding Method..86
4.4. Conclusion of Simulink based real-time watermark embedding 91
5. Chapter-V: DMT Scheme (Phase-III): Realtime implementation image watermarking using Android Mobile phone 92
5.1. Overview of this chapter 92
5.2. Phase-II (Hardware Implementation)..92
5.3. Introduction of Modelling and Analysis 93
5.3.1. ELM Model..95
5.3.2. ELM Algorithm 96
5.4. Final DMT Model 97
5.4.1. Phase 3 (DMT Scheme) 98
5.4.2. Time Complexity of DMT Scheme (Stage wise and Overall):...........98
5.4.3. Final Workflow for Mobile App..100

6. Chapter-VI: Results and Evaluation 106
7. Chapter-VII: Conclusion and Future Scope of Work 120
8. References..121
9. Appendix-I: Images Captured using various Android based Mobile Phones ...130
Images Captured from LG P970 130
Images Captured from XIAOMI RedMI2 133
Images Captured from Karbonn Sparkle-V 137
Images Captured from Micromax Juice A-77...141
Images Captured from Lenovo K3 Note K50a40 147

EXECUTIVE SUMMARY

The augmenting attractiveness and convenience of digital manipulation is leading towards mischievous tampering and unlawful reproduction of multimedia content which has become difficult to detect. Digital Rights Management (DRM) has been a functional domain of research for the past few decades, aiming to stop pilferage and tampering in digital media content. Out of the most significant solutions available to get rid of this issue, digital watermarking is opted in various cases, it is a technology for embedding various types of ownership information in digital content to save its DRM.

The study reveals that communication has primarily been dominated by the usage of images in any context, furthermore, the use of digital media for images and video have some severe repercussions for the copyright control issues. This problem has further been intensified by the use of Internet and now the intensity is at peak with the use of smart mobile phones. Current trends are about posting and sharing the captured images almost instantly, it has raised the amount of data repository in web-servers saved in the form of images, photos and videos. Across the globe it has been observed a trend of exponential growth in the generation of images and video due to the provision of handy mobile devices with a built-in camera. The current way of distributing data, is leading towards unauthorized distribution in terms of copying the digital content. This technology offers advantage intelligently as compared to the old analog counterpart. Some of these advantages are data transmission, easy data editing of digital content, improved capability of lossless copying of the digital content. The main problem with the Internet enabled mobile device is the lack of control over sharing of the content – both for images and video data. The captured images and video can be used again in ways not envisioned by the owner of the material.

Primarily in the domain of this research work, visual content mainly images are focused upon with the objective of protecting its ownership attributes. Digitization of image leads to wider prospects in every domain ranging from medical imaging to architectural designs, various engineering

models, space and satellite imaging etc. but at the same time the protection of the originality of the performed work is utmost important, for that sake various techniques are evolved. Last few decades are the witness of exponential growth pattern in the generation of images and video due to the availability of handy mobile devices with a built-in camera. This improvement in the way of distributing data, also leads towards unauthorized distribution in terms of copying the digital content. Digitization of image leads to wider prospects in every domain right from medical imaging to architecture, engineering, space and satellite, imaging for astronomy or GIS, roadmaps, street views, augmented mode for resource identification etc. but at the same time the protection of the originality of the performed work is utmost important, for that sake various techniques are evolved. The digitization of the content has reduced the efforts to connect and collaborate amongst various users across the globe. But, at the other hand it has also increased the scope of vulnerable attacks on these contents specially images and videos.

Digital image watermarking is a method to authenticate the content through its ownership. It embeds an undetectable signature as a watermark in any digital file categorized as text, image, audio, video etc. It could be used for the authentication of the data file for tamper detection. Digitization of image enhances its prospects almost in every domain from medical imaging to architecture, satellite imaging, and space exploration etc.at the same time the protection of the originality is most important. The digitization of the content has reduced the efforts to connect and collaborate amongst various users across the globe. But, at the other hand it has also increased the scope of vulnerable attacks on these contents specially images and videos. The need of the digital signatures, especially the digital watermarking has potentially grown over the time to check image and video duplicity and piracy.

The interest and motivation towards the current research was invoked through the gaps analyzed in previous research work conducted in existing digital image watermarking techniques. Every research work provided insights, conclusion of their work done and scope of further enhancements were explored. During this process it was identified that there was a scope of implementing digital image watermarking in the real time environment, on a mobile device in such an optimized manner that it could be used by general public and that too keeping energy efficiency as a prime objective.

Initial phases of this research work, grayscale images were identified for digital image watermarking to take forward the research conclusions and scope of improvement provided by various researchers of similar domain and interest of research work. Insights were developed while applying digital image watermarking through most common technique of shifting LSB in the spatial domain following which, DCT based frequency transformation techniques on gray scale images like "Baboon", "Cameraman" and finally "Lena" was applied. These implementations and progressive outcome of the research work provided further motivation towards exploring new alternatives for upbringing the process of digital image watermarking, while improvising the speed of the process completion. The research work swiftly turned towards the usage of wavelets for accomplishing the process, which laid down the first objective for the research to be achieved. The usage of 2D-DWT towards implementation of single vector as watermark took a long time, but finally accomplishment of the same provided a big thrust and further enhanced the motivation towards the research work to be done, which required the understanding of implementing these frequency transformations in the most optimized manner.

The research work further advanced while understanding the ways of applying DCT for HVS (Human Visual System) on a gray scale image. That process further required an intelligent soft-computing engine to decipher the image in the way a human eye perceives. Furthermore, the factors and attributes were needed to be identified as the sensitivities in the domain of Luminance, Edge Detection, and Contrast. Image processing functions were explored to identify and extract these basic parameters from any static gray scale image. Those functions were implemented on the gray scale images of "Lena" and extracted the desired factors to further work upon while sharing these parameters to the fuzzy inference engine. Next stage was to tune that engine by designing a set of rules which can be applied on the input parameters extracted from the image under observation.

Further, this research work identified and focused upon optimized robust image watermarking technique to model the Human Visual System (HVS) using Fuzzy Logic which was most appropriate in identifying and implementing the rules of deciphering the image parameters extracted from the image under observation. The proposed Fuzzy Inference System was trained by logical inference rules considering HVS features namely luminance sensitivity, edge sensitivity and texture or contrast sensitivity. Then, the fuzzy network computed the image block wise in a block size of 8x8 pixels for producing a single output weighting factor which is used to embed unique machine identification parameters as watermark for authorization and verification of the original image.

The robustness of the watermark embedded during the initial research work of embedding watermark using Fuzzy Inference System for implementing HVS, was checked by Stirmark image processing attacks, which are a proven set of 7 attacks to be applied on the watermarked image to check its robustness on behalf of defined parameters as mentioned.

(1) Counterclockwise rotation of 900.

(2) Dithering of color levels from 256 to 16-color

(3) Gaussian Blur (Radius = 1.0 units)

(4) Brightness and Contrast operation (each 15%)

(5) Median Filtering (Filtering aperture = 3 units)

(6) 10% Gaussian Noise addition

(7) Jpeg compression (QF=90).

Computed value of the similarity evaluating function i.e. SIM(X, X*) parameter, for the image concluded it as good watermark recovery process. The values of MSE and PSNR after bearing the attacks were reflecting the robustness of image watermarking algorithm used during the process.

Further, motivation from the results led the research work to redesign the threshold process for one of a channels extracted from RGB image. High frequency channel i.e. Blue channel was chosen as the nearest appealing color for registering the threshold of the subject as image. Keeping all other settings, the same, research work further move to apply it on an RGB image. An RGB image was captured using a webcam of 1.3 Mega Pixel capacity then reduced to 640x480 pixels, captured image was used for re-implementation of the process, but this time blue channel was extracted and this layer was used as the base layer as a grayscale image to be used for visible image watermarking. The process went successful and the colored image got watermarked with a visible label on it.

This outcome further motivates the research to check this process in a real-time environment. Thus, a simulated environment was created using SIMULINK and for capturing image in real-time, webcam as a capturing device was used. Label was created using Text valued as name of the subject and the date of capturing the image was kept as automated label generated in real-time through system clock. It was a breath-holding moment while executing the algorithm in real-time and image was captured through webcam, then after processing a watermarked image was shown, furthermore the watermarked and original images were compared showing acceptable results as the outcome of MSE and PSNR. Most of the parameters generated while executing the algorithm gave satisfactory results, and the time taken by process was reduced to 12 seconds from 35 seconds, it was again a motivating factor for the research work to move on for the next step of realtime implementation of image watermarking.

As the research work redirected towards hardware implementation of the same, it required a lot of expertise for designing after selecting the right components to be used in this case. Various development kits with DSP or Microcontroller and camera from Texas Instruments (TI) with Leopard Imaging which provided the Time-to-Market camera development kit with seamless interface to a TI DM6446 and DM355 DaVinci digital media processor EVM through DM355 Adapter Board (LI-355A). LI-5M01 is a high-resolution digital camera board and it incorporates an Aptina 1/2.5-inch CMOS digital image sensor MT9P031, with an active imaging pixel array of 2592H x 1944V having a capacity of (5038848 pixels) i.e. 5.0 Megapixel. The LI-5M01 Camera Board produces extraordinarily clear, sharp digital pictures, and it is capable of capturing both continuous video and single frame, which makes it the perfect choice for digital video cameras and surveillance camera, using its software development IDE. Furthermore, National Instruments (NI) development kit with LabVIEW 7.1 VISION and a webcam were explored, but both of the embedded options didn't serve the purpose for this research work of getting implemented in a mobile device, it had only one option to be used a separate gadget, thus the research direction was reframed to be used with built-in capacity of a mobile phone with camera.

The present work is proposing the design and implementation of a scheme which can be used for digital watermarking in a real time while capturing the image using mobile device, though augmenting computing resources and maintaining energy efficiency for mobile devices while optimal utilization the resources available in that converged machine.

The challenges portrayed in this work were to reconstruct the algorithm as an application on a well-defined mobile operating environment. The research work need to choose from various platforms available for the needful transformation and Microsoft Windows CE and Windows Mobile 6.0 were there available for Mobile development. IOS version 4 was also well established, but it was a closed framework, and accessing libraries for the development was a costly affair. Then the nearest to its performance was Android and version 2.2 (Froyo) was a successor of well-established version 1.6 (Donut) and 2.0 and 2.1 (Eclair) and Linux based open framework. This research work initiated the development of a Mobile App using Eclipse as an IDE which was inspired by Smalltalk-based VisualAge a family of integrated environment and initially Android 2.2 based target device LG Optimus Black (P970)

List of Abbreviations

Abbreviation	Meaning
ANN	Artificial Neural Network
BPN	Back Propagation Network
CONSEN	Contrast Sensitivity
DCT	Discrete Cosine Transformation
DMT	Digital Mobile Transcendence
DRM	Digital Rights Management
DWM	Digital Watermarking
DWT	Discrete Wavelet Transformation
EDGSEN	Edge Sensitivity
ELM	Extreme Learning Machine
FIS	Fuzzy Inference System
HVS	Human Visual System
IDCT	Inverse Discrete Cosine Transformation
IDWT	Inverse Discrete Wavelet Transformation
IMEI	International Mobile Equipment Identity
LumSEN	Luminance Sensitivity
RGB	Red Green Blue Channel
TWESEVIR	Fuzzy Inference Engine of 27 rules
MAC	Medium Access Control
MSE	Mean Square Error
PSNR	Peak Signal to Noise Ratio
SIM	Similarity Index Measurement
SLFN	Single hidden Layer Feed forward Network
SSIM	Structural Similarity Index Measurement
SVD	Singular Value Decomposition
WBC	Watermarked image in Blue Channel
WEIFAC	Weighting Factor

List of Figures

Figure 1-1: A typical watermarking scheme for WM Embedding and Recovery. 28
Figure 1-2: Android Framework....33
Figure 3-1: Fuzzy Values for Luminance Sensitivity....68
Figure 3-2: Fuzzy Values for Edge Sensitivity....69
Figure 3-3: Fuzzy Values for Contrast Sensitivity....71
Figure 3-4: Fuzzy Values for Weighting Factor (W)....73
Figure 3-5: Fuzzy Model for HVS....73
Figure 3-6: Most Frequently Fired Rules in the Fuzzy Rule Engine....78
figure 3-7: Write Label....79
Figure 3-8: Read Label....79
Figure 3-9: MSE and PSNR calculation of attacked images....83
Figure 4-1: SIMULINK MODEL FOR REAL-TIME WBC....90
Figure 4-2: PROFILE SUMMARY OF SIMULINK BASED REAL-TIME WBC...90
Figure 4-3: Original Image Captured in Realtime....91
Figure 4-4: Watermarked Image in Blue Channel....91
Figure 5-1: Hardware implemntation of DMT scheme....93
Figure 5-2: Final Workflow....100
Figure 5-3: Flowchart for Watermark Embedding....101
Figure 5-4: Flowchart for Watermark Extraction....102
Figure 5-5: Landing Layout....104
Figure 5-6: Step 1....104
Figure 5-7: Step 2....104
Figure 5-8: Step 3....104
Figure 5-9: Step 4....104
Figure 5-10: Step 5....104
Figure 5-11: Original Image....105
Figure 5-12: Watermarked Image....105
Figure 5-13: Storage Path....105
Figure 5-14: Overall Energy Consumption by Camera App....105
Figure 5-15: Energy Consumption by LCD for Camera App....105
Figure 5-16: Energy Consumption by CPU for Camera App....105
Figure 9-1: durgansh359704042100234_02_06_2013_18_10_15_683....130
Figure 9-2: durgansh359704042100234_02_06_2013_18_11_09_374....131
Figure 9-3: durgansh359704042100234_04_04_2013_23_22_22_495....131
Figure 9-4: durgansh359704042100234_05_07_2013_16_31_07_442....132
Figure 9-5: durgansh359704042100234_06_09_2013_15_15_59_207....132
Figure 9-6: 07_02_2016_15_21_39_129....133
Figure 9-7: 07_02_2016_15_21_39_129encrypted....133
Figure 9-8: 07_02_2016_15_26_40_478....134
Figure 9-9: 07_02_2016_15_26_40_478encrypted....134
Figure 9-10: 07_02_2016_15_23_34_643....135
Figure 9-11: 07_02_2016_15_23_34_643encrypted....135
Figure 9-12: Screenshot of Encrypted Image showing the details of XIAOMI........136
Figure 9-13: 18_02_2016_00_12_24_27....137

Figure 9-14: 18_02_2016_00_12_24_27encrypted 137
Figure 9-15: 18_02_2016_00_12_43_45 138
Figure 9-16: 18_02_2016_00_12_43_45encrypted 138
Figure 9-17: 18_02_2016_00_13_17_68 139
Figure 9-18: 18_02_2016_00_13_17_68encrypted 139
Figure 9-19: SCREENSHOT OF ENCRYPTED IMAGE SHOWING THE DETAILS OF KARBONN 140
Figure 9-20: 25_06_2015_16_01_19_370 141
Figure 9-21: 25_06_2015_16_01_19_370encrypted 141
Figure 9-22: 26_08_2015_11_44_05_807 142
Figure 9-23: 26_08_2015_11_44_05_807encrypted 142
Figure 9-24: 26_08_2015_11_42_23_318 143
Figure 9-25: 26_08_2015_11_42_23_318encrypted 143
Figure 9-26: 30_11_2015_11_03_53_713 144
Figure 9-27: 30_11_2015_11_03_53_713encrypted 144
Figure 9-28: 24_11_2015_21_09_24_74 145
Figure 9-29: 24_11_2015_21_09_24_74encrypted 145
Figure 9-30: SCREENSHOT OF ENCRYPTED IMAGE SHOWING THE DETAILS OF MICROMAX JUICE A-77 146
Figure 9-31: 31_01_2016_15_12_58_40 147
Figure 9-32: 31_01_2016_15_12_58_40encrypted 147
Figure 9-33: 26_01_2016_13_44_51_20 148
Figure 9-34: 26_01_2016_13_44_51_20encrypted 148
Figure 9-35: SCREENSHOT OF ENCRYPTED IMAGE SHOWING THE DETAILS OF LENOVO K50a40 149

List of Equations

Equation 3-1: Discrete Cosine Transformation 67
Equation 3-2: LUMSEN COMPUTATION 68
Equation 3-3: EDGSEN - Threshold using greythresh() 68
Equation 3-4: Image Threshold 69
Equation 3-5: Discrete Probability Density Function 69
Equation 3-6: Computation of Class Variance 70
Equation 3-7: Calculation CONSEN 70
Equation 3-8: Expression for the nth moment 71
Equation 3-9: Mean of Average Intensity 71
Equation 3-10: Standard Deviation of Average Contrast 71
Equation 3-11: Variance of Average Contrast 71
Equation 3-12: Third Moment 72
Equation 3-13: SMOOTHNESS 72
Equation 3-14: UNIFORMITY 72
Equation 3-15: Entropy - The measure of randomness 72
Equation 3-16: Function for HVS 73
Equation 3-17: Phase-1 Watermark Embedding 77
Equation 3-18: IMAGE Similarity Check 81
Equation 4-1: DCT for differential equations 85
Equation 4-2: DWT Equation 85
Equation 4-3: Class Variance 88
Equation 4-4: Class Probability 88
Equation 4-5: Class Means 88
Equation 4-6: Individual Class Variance 88
Equation 4-7: Total Variance 89
Equation 4-8: Recursion for computation of final value 89
Equation 5-1: RGB to YUV Conversion 94
Equation 5-2: YUV to RGB Conversion 95
Equation 5-3: SLFN Activation Function for N training data 95
Equation 5-4: Rewritten for all N equations 95
Equation 5-5: Matrix Variables for N training sample 96
Equation 5-6: Training Set 96
Equation 5-7: Overall Time Complexity of DMT Scheme 99
Equation 5-8: RGB to YUV Conversion 101
Equation 5-9: YUV to RGB Conversion 102

List of Tables

Table 3-1: HVS based 27 Rules for Fuzzy Inference System....................................73
Table 6-1: Data table for various images captured 110
Table 6-2: Model Summary for the images captured 115
Table 6-3: Model Summary for the images captured for df2 and significance.........116
Table 6-4: ANOVA calculated for the images captured..117
Table 6-5Significance of coefficients against all the factors used for images captured 118

1. Chapter-I: Introduction

This chapter introduces and describes various methods of digital image watermarking though sections and sub-sections used in this research work.

1.1. General Introduction

This digital era, has transformed the human thoughtfulness through the ubiquitous network environment, which has stimulated the rapid distribution of digital multimedia files. Entire population of mobile users and its service handlers are enthusiastic to experience the convenience and advantages that internet as a superset of networks has provided. Entire population of this category enjoys to share innumerable media information in a rather most economical mode, without any cognizance of possibly breaching copyrights.

The exponential usage and convenience of digital media manipulation is extending its direction to the damaging usage while tampering unlawfully with its integrity. With the advent of such events of mischief, and incorporation of digital techniques for serving the tenacity towards achieving illegitimate aims and intentions. Digital Rights Management (DRM) has been a well-designed realm of research for the past few decades, aiming to halt pilferage and tampering in digital media content. Out of the most significant solutions available to get rid of this issue, digital watermarking was determined in various cases, it is a technology for embedding various types of ownership information in digital content to save its DRM.

The trends of communication have primarily been dominated by the usage of images in any context, furthermore, the use of digital media for images and video have some severe repercussions for the copyright control issues. This problem has further been intensified by the use of Internet and now the intensity is at peak with the use of smart mobile phones. Current trends are about posting and sharing the captured images almost instantly, it has raised the amount of data repository in web-servers saved in the form of images, photos and videos. Across the globe it has been observed a trend of exponential growth in the generation of images and video due to the provision of handy mobile devices with a built-in camera. The current way of distributing data, is leading towards unauthorized distribution in terms of copying the digital content. This technology offers advantage intelligently as compared to the old analog counterpart. Some of these advantages are data transmission, easy data editing of digital content, improved capability of lossless copying of the digital content. The main problem with the Internet enabled mobile device is the lack of control over sharing of the content – both for images and video data. The captured images and video can be used again in ways not envisioned by the owner of the material.

Primarily in the domain of this research work, visual content mainly images are focused upon with the objective of protecting its ownership attributes. Digitization of image leads to wider prospects in every domain ranging from medical imaging to architectural designs, various engineering models, space and satellite imaging etc. but at the same time the protection of the originality of the performed work is utmost important, for that sake various techniques are evolved. Last few decades are the witness of exponential growth pattern in the generation of images and video due to the availability of handy mobile devices with a built-in camera. This improvement in the way of distributing data, also leads towards unauthorized distribution in terms of copying the digital content. Digitization of image leads to wider prospects in every domain right from medical imaging to architecture, engineering, space and satellite, imaging for astronomy or GIS, roadmaps, street views, augmented mode for resource identification etc. but at the same time the protection of the originality of the performed work is utmost important, for that sake various techniques are evolved. The digitization of the content has reduced the efforts to connect and collaborate amongst various users across the globe. But, at the other hand it has also increased the scope of vulnerable attacks on these contents specially images and videos.

Digital watermarking techniques have been developed to protect the copyright of media signals. The objective of this chapter is to provide a review and background about the digital watermarking, its definition, concept and the main contributions in the domain of digital image watermarking. The chapter begins with a universal view of digital data, the Internet and its effectiveness over the content provisioning and its distribution as multimedia content over various portals, blogs, Social Media, E-commerce sites and Mobile Apps over different mobile platforms. It also focusses on the future prospective of the digital image watermarking, and upcoming methodology adopted and proposed through this research work.

1.2. Digital Watermarking

Digital watermarking is a technology for embedding various types of information in digital content primarily in the domain of visible content mainly images in the context of this research work, with the concept of protecting its ownership attributes. Digitization of image leads to wider prospects in every domain ranging from medical imaging to architectural designs, various engineering models, space and satellite imaging etc. but at the same time the protection of the originality of the performed work is utmost important, for that sake various techniques are evolved.

The use of digital media for images and video have some severe repercussions for the copyright control issues. Nowadays, the image is in the digital ecosystem, high quality processing software but yet economical can be used to manipulate the image and videos especially with the memories becoming so inexpensive. This problem has further been intensified by the use of Internet and now the intensity is at peak with the use of mobile phones. The main problem with the Internet enabled mobile is the lack of control over sharing of the content – both for images and video data. The captured images and video can be used again in ways not envisioned by the owner of the material. Digital watermarking embeds an imperceptible signature as a watermark in any digital file categorized as text, image, audio, video etc. It could be used for the authentication of the data file for tamper detection.

1.3. Digital Image Watermarking

1.3.1. Digitization

Prior to digitization, signals were created as analog by nature and communicated through analog medium. There were various constraints in term of speed of transmission, re-usage of these signals etc. Digitization enabled the process of transforming analog data into digital information while overcoming all the specified constraints.

This process comprises of converting each and every piece of data and preserve it in the form of [0 and 1] digital signals. Entire data stream comprises of zeroes and ones with data packets divided in two parts i.e. header which contains formatting instructions and actual data stream, which contain the actual piece of information converted and to be preserved or stored in the hard disk available with the computer as desktop, laptop or server in the cloud.

These properties have revolutionized the ways of creating, storing, updating, deleting, transferring data amongst various users via different devices or machines. Entire communications media has been transformed into various different forms of data and further analysis of data and its utilization has transformed itself into information. Both, data and related information has been applied and updated knowledge base which in turn is updating intelligence amongst machines around us. Gradually, this initiation in the process of transforming machines into intelligent devices through soft-computing and embedding self-evolving intelligent algorithms and protocols into their hardware. Even though reduction in the power consumption of used applications or apps in any mobile device has been a tenet for their design. Energy efficiency and optimal utilization of all the computing resources for an app are needed to be the prime concern

1.3.2. Security of Data and Information

Data is also described as raw facts, and in the form of digital data it takes the shape through the help of digital signals in the form of '0' and '1'. Each and every type of data has been described using bit streams of 0 and 1. Data sets are identified through their format and permissions applied on them, which is also in the form of 0 and 1.

Information is also known as processed data which is mapped with any entity, and it is most powerful thing in this world now days. Most of the technologies are related to take care of important information only, and thus it needs security as their prime objective. Digital images are being the most adopted way and media of communication. Thus, their security for the sake of ownership and confidentiality in many cases are need to be assigned a prime focus while designing any application to capture the images in this vulnerable digital world.

1.3.3. Steganography

Information and its usage for every entity has been an issue in digital age and Steganography has been used for covered writing, which is essentially required in various digital application. As known steganography is the art and science of communicating the messages in such a way that its presence remain undetected [1]. Simple techniques of steganography have been transformed for their increasing usage for files in an electronic format with merger of new techniques for information hiding in electronic media [2].

1.3.4. Watermarking

It is a branch of steganography, where all objects of the host digital content are marked with the same way. It creates a uniformity in hiding the information and has been used mostly with digital images, audio, video and multimedia contents. Digital watermarking embeds an undetectable signature as a watermark in any digital file categorized as text, image, audio, video etc. It could be used for the authentication of the data file for tamper detection [3]. Watermarks are mainly divided through their distinct property of being visible or perceptible and invisible or imperceptible. They are being mainly categorized through spatial transformation techniques, frequency transformation techniques, hybrid techniques where spatial or/ and frequency transformation is supported by soft computing techniques [4]. Primarily the image watermarking schemes were applied on gray scale images through secure spread spectrum [5].

The use of digital media for images and video sequences has some serious implications for the copyright control issues. Now-a-days, the image is in the digital environment, very low cost but high quality processing software can be used to manipulate the image and videos especially with the memories becoming so cheap. This problem has further been aggravated by the use of Internet. The main problem with the Internet is the lack of control over reuse of the content – both for images and video data. The captured images and video can be used again in ways not intended by the copyright owner of the material.

The need of the digital signatures, especially the digital watermarking has potentially grown over the time to check image and video duplicity and piracy. The present work is focused on the basic study of various techniques of digital watermarking presently being researched worldwide in general and on spread spectrum based watermarking algorithms in particular.

Work in the area of digital watermarking is challenging as it demands good understanding of multimedia signal processing, communication theory, high level programming skills etc., to create a watermark that is not perceivable (transparent) yet robust to signal processing methods that attempt to separate or remove the embedded bits without perceivably degrading the original data quality.

One of the earlier uses of the digital watermarking was the IBM scheme which was nothing but a visible watermark scheme. Although a visible watermark has some good characteristics, it is also true to say that what is really needed is an invisible watermark scheme that could be used for any application. The requirements of a watermarking scheme for copyright protection purposes are as follows:

- The image must not be visibly degraded by the presence of watermark while at the same time; a unique identifier with high information content is produced.
- The mark must be readily recoverable by some form of comparison with the original image.
- The mark must be strongly resistant to detection and decoding without access to the original image. It must be strongly resistant to attacks and it should cause a significant loss of image quality for it to be destroyed.
- In addition, the watermark must be tolerant to reasonable quality lossy compression of the image.

Since 1995, the emphasis on recovery was through the access of original image i.e., incomplete watermark recovery. But, the focus now shifting to various techniques that doesn’t require access to the original image leads to blind watermarking.

1.3.5. Digital Watermarking

To complete the high level classification of digital watermarking schemes, robust watermarks are those designed to withstand accidental and malicious attacks while fragile watermarks have just the opposite characteristics and are used to detect tampering. Therefore, a watermark can be fragile/ robust, complete/ incomplete, and visible/ invisible. The following figure 1 shows a typical process flow for a watermarking system, where, the original image is subjected to frequency transform typically a discrete cosine transform (DCT) and then some aspects of the transform domain coefficients are modified in order to embed the watermark information. After all the needful steps, finally, the inverse transform is applied in order to generate the signed version of the original image that contains the watermark. It depends on the work flow regarding distribution of the images using media, if the original image itself contains watermark and a blind watermarking technique has been used, then the same image can be distributed, whereas, if your watermarking scheme is generating one watermarked image along with the original image, then it is advised to distribute the watermarked image.

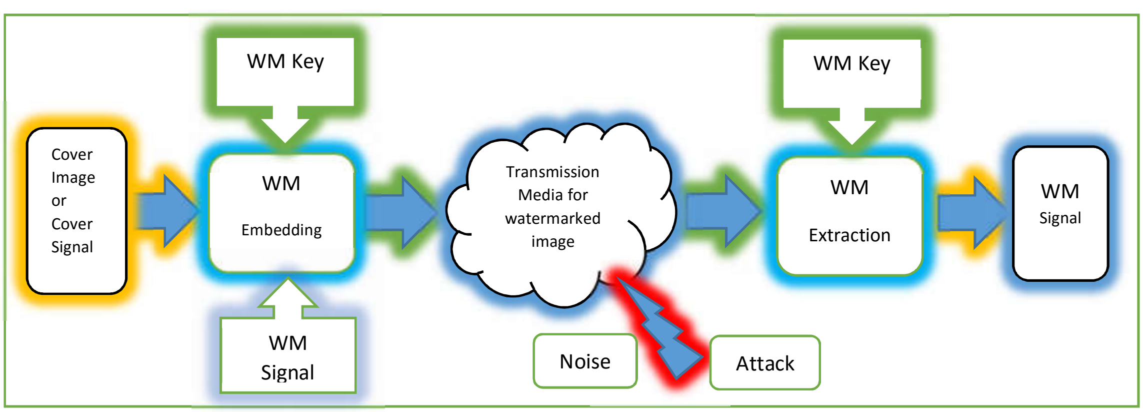


FIGURE 1-1: A TYPICAL WATERMARKING SCHEME FOR WM EMBEDDING AND RECOVERY.

To recover the watermark, both the original and signed images are transformed which allows the transform domain coefficient modifications to be established by comparing the transformed original and signed images. Only a simple modification is required to turn an incomplete system into a complete system, namely to establish relationships amongst the coefficients such that only the signed image itself is required.

There are also watermarking schemes that operate directly on the original image without first transforming it using DCT, DFT, or DWT. Typically, these schemes use pseudo random noise sequences that have been modified by the watermark information in a similar way to direct sequence spread spectrum techniques, analyzed in the present work. While doing so, in order to survive lossy compression, any robust system must be careful to control the spatial frequency spectrum of the embedded watermark information and this is the basic reason in operating in the spatial frequency domain.

1.3.6. Image Watermarking

The requirements for image watermarking can be treated as characteristics, properties or attributes of image watermarking. Different applications demand different properties of watermarking. Requirements of image watermarking vary and result in various design issues depending on image watermarking applications and purpose. These requirements need to be taken into consideration while designing watermarking system. There are basic five requirements as follows:

1.3.6.1. Fidelity

Fidelity can be considered as a measure of perceptual transparency or imperceptibility of watermark. It refers to the similarity of un-watermarked and watermarked images. This perspective of watermarking exploits limitation of human vision. Watermarking should not introduce visible distortions as it reduces commercial value of the watermarked image.

1.3.6.2. Robustness

Watermarks should not be removed intentionally or unintentionally by simple image processing operations Hence watermarks should be robust against variety of such attacks. Robust watermarks are designed to resist normal processing. On the other hand, fragile watermarks are designed to convey any attempt to change digital content.

1.3.6.3. Data Payload

Data payload is also known as capacity of watermarking. It is the maximum amount of information that can be hidden without degrading image quality. It can be evaluated by the amount of hidden data. This property describes how much data should be embedded as a watermark so that it can be successfully detected during extraction.

1.3.6.4. Security

Secret key has to be used for embedding and detection process in case security is a major concern. There are three types of keys used in watermark systems: private-key, detection-key and public-key. Hackers should not be able to remove watermark with anti-reverse engineering research algorithm.

1.3.6.5. Computational Complexity

Computational complexity indicates the amount of time watermarking algorithm takes to encode and decode. To ensure security and validity of watermark, more computational complexity is needed. Conversely, real-time applications necessitate both speed and efficiency.

1.4. Classification of watermarking techniques

Digital Watermarking techniques can be classified in a number of ways depending on different parameters. Various types of watermarking techniques are enlisted below. Each of the different types mentioned below have different applications.

Inserted Media Category: watermarking techniques can be categorized on the basis of whether they are used for Text, Image, Audio or Video.

1.4.1. Public & Private Watermarking:

In public watermarking, users of the content are authorized to detect the watermark while in private watermarking the users are not authorized to detect the watermark.

1.4.2. Asymmetric & Symmetric Watermarking:

Asymmetric watermarking (also called asymmetric key watermarking) is a technique where different keys are used for embedding and detecting the watermark. In symmetric watermarking (or symmetric key watermarking) the same keys are used for embedding and detecting watermarks.

1.4.3. Steganographic & Non-Steganographic watermarking:

Steganographic watermarking is the technique where content users are unaware of the presence of a watermark. In non- steganographic watermarking, the users are aware of the presence of a watermark. Steganographic watermarking is used in fingerprinting applications while non - steganographic watermarking techniques can be used to deter piracy.

1.4.4. Robust & Fragile Watermarking:

Robust watermarking is a technique in which modification to the watermarked content will not affect the watermark. As opposed to this, fragile watermarking is a technique in which watermark gets destroyed when watermarked content is modified or tampered with.

1.4.5. Visible & Transparent watermarking:

Visible watermarks are ones, which are embedded in visual content in such a way that they are visible when the content is viewed. Transparent watermarks are imperceptible and they cannot be detected by just viewing the digital content.

Inserting Watermark Type: watermark can be inserted in the form of noise Tagged information, or Image.

Processing Method: The watermark can classified by the technique on the basis of whether it is used in spatial domain, frequency domain, compression domain or hybrid for the insertion of watermark. Necessary Data for Extraction: on the basis of necessary data for extraction watermarks can be divided into two categories:

- Blind
- Informed

In blind watermarking original document or image is not required during watermark detection process. But in informed original document or image is required.

1.5. Soft Computing Techniques

The soft computing techniques like fuzzy logic, ANN and special case of ANN in the form of ELM have been used for making the model intelligent while imparting logic nearer to the human perception. It was also required to make the system fast in learning process and applying the needful learning while imparting the watermarking.

1.5.1. Fuzzy Logic

The term fuzzy logic was introduced with the 1965 proposal of fuzzy set theory by Lotfi Zadeh [6]. In current research work Fuzzy logic has been applied to many fields of human perception towards images, it is used from control theory to the hybridization with artificial intelligence built upon various parameters judged by the inference engine.

1.5.2. Artificial Neural Network

Artificial neural networks are generally presented as systems of interconnected "neurons" which exchange messages between each other. The connections have numeric weights that can be tuned based on experience, making neural nets adaptive to inputs and capable of learning.

Like other machine learning methods – systems that learn from data – neural networks have been used to solve a wide variety of tasks that are hard to solve using ordinary rule-based programming, including computer vision and speech recognition.

1.5.3. Extreme Learning Machine

Extreme Learning Machine (ELM) for single hidden layer feedforward neural networks (SLFNs) which randomly chooses the input weights of the neurons accepting input data from the input layer and analytically determines the output weights of SLFNs. In theory, this algorithm tends to provide the best generalization performance at extremely fast learning speed as mentioned by Huang [7]. The experimental results based on real world benchmarking function approximation and classification problems including large complex applications show that the new algorithm can produce best generalization performance in some cases and can learn much faster than traditional popular learning algorithms for feedforward neural networks.

1.6. Android Framework

While searching for a mobile platform, which could support this research work, Android framework was found most suitable amongst all other available mobile development frameworks. Being an open source framework, it provided the privilege of using APIs and libraries while undergoing the process of developing the model to be incorporated for mobile devices. [8]

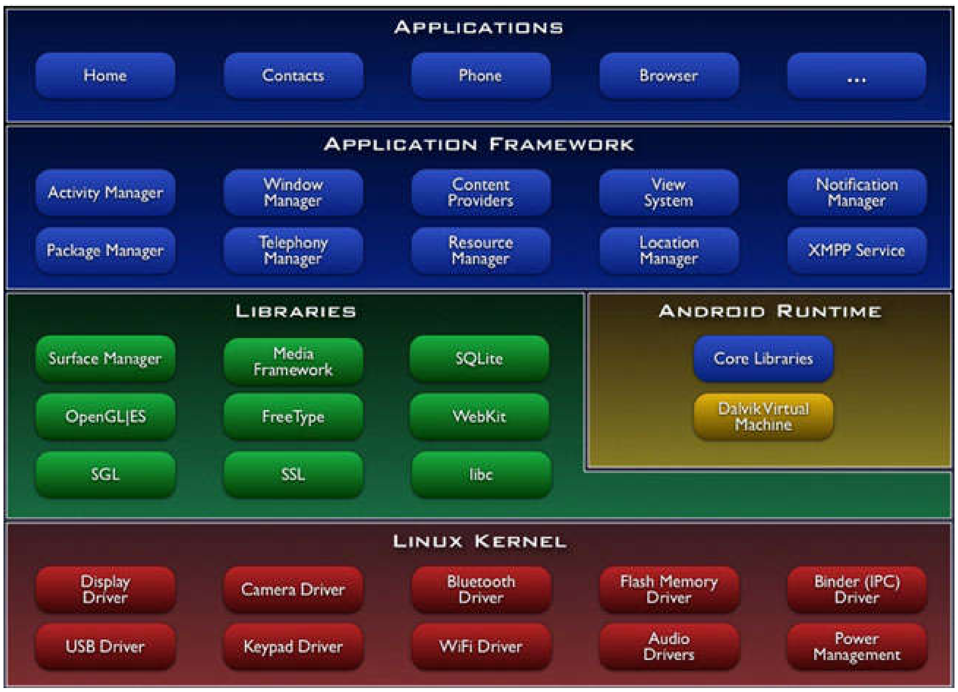


FIGURE 1-2: ANDROID FRAMEWORK

Android is designed to run on many different types of devices, as per the requirement of this research work it suffices the requirements theouth the availability of various mobile phones working on android platform. The range of devices provides a huge potential audience for the model designed as an outcome of research work in the form of a camera app. It tolerated some feature variability and provided a flexible user interface that adapts to different screen configurations and various other versioning of operating system.

To facilitate your effort toward that goal, Android provides a dynamic app framework in which provided configuration-specific app resources in static files (such as different XML layouts for different screen sizes). Android then loads the appropriate resources based on the current device configuration. So that the work can be published as a single application package (APK) that provides an optimized user experience on a variety of devices.

1.7. Motivation/need and overview

Over a past few decades most of data has been transformed, computed, stored and transferred amongst various different computers, and a rapid growth in this activity has been observed through the evolution and implementation of computer networks, especially the protocols and technology applied through World Wide Web. The performance of computer network along with its cloud based storage capacity has increased and facilitated the sharing of images, audio and video amongst users through network and cloud based services, which helped in duplication of multimedia in a short span of time. Multimedia software and tools have provided the enhanced features used in manipulation and modification of the images. Most of the people after modifying the original images have claimed the ownership of that image, whereas the onus lies with someone else as the owner of that image. Digital watermarks have been proposed as a solution to take care of this issue of replication, duplication of the images and their misuse. Digital watermarking is a technology for embedding different type of data as a piece of information in digital image, which can be further used for discriminating it amongst its fake counterparts.

The concept of digital image watermarking is one of the various techniques, which is used to protect the digital image content. Further, the expansion of internet from IPv 4 to IPv 6, will also lead to further complexities pertaining to security of the same, thus securing the digital images is of prime concern. Nowadays, the electronic gadgets are used for capturing the images, with greater accuracy and finishing; and getting the stuff uploaded using the internet almost in real time like Whatsapp, Hangout or Skype.

Now, with the advent of smartphones, everyone has got the power of capturing images using the inbuilt image capturing capability of smartphones. The simplicity of capturing images with a camera, has been upgraded with modifying the available or shared images with the help of various software packages available. So, it is of utmost concern to develop a real time mechanism for image authentication like watermarking, to impart greater protection to the originality of the work and hence guarding the ownership rights. All the existing digital watermarking schemes are enabled to work in offline mode on the existing or stored images either in actual or virtual storage space. There had been a vacuum in transforming the digital watermarking as online tool to work in real time, where our scheme found its space by applying the digital watermarking on images captured in realtime through the same camera as a hardware installed on the mobile devices.

1.8. Objectives

1. To study the existing digital image watermarking techniques and various block transformations to be used in this process.
2. To enhance the functionality of existing techniques with proven soft computing techniques like Fuzzy Logic, ANN which can be further enhanced for the upcoming advanced devices and technologies.
3. To create an integrated digital watermarking scheme which is near to the human vision system, so that it can become more natural while its implementation. It should be robust in its characteristics to resist all the counter attacks on the watermarked images through that scheme.
4. To simulate the developed digital image watermarking scheme using a proven simulation framework Simulink, and to understand the modifications required in the scheme while implementing it in an embedded framework to be used with a camera.
5. To finalize the correct embedded framework to be used in sync with digital camera for enhancing its inbuilt capabilities of capturing, transforming it through our scheme and storing the image in the most energy efficient manner.
6. To understand the mobile framework which can be used as an embedded environment for enabling our scheme to be deployed and integrated with their built-in camera and other hardware components in most energy efficient way.
7. To design energy efficient mobile application which can perform the needful operations required by our digital image watermarking scheme i.e. to capture, transform, embed watermark, store images and extract watermark from stored images with most energy efficient manner.

1.9. Research Methodology

This research work is classified under exploratory research, as this research is conducted for a problem that has not been clearly defined in the form of real time implementation of any image watermarking technique in a mobile phone. It often occurs before known enough to make conceptual distinctions or posit an explanatory relationship. For this research work finally the data collection method is dependent on the model proposed in the form of an app and selection of subjects for capturing image are totally in real time bases.

1.10. Chapter Scheme

This research work has been chaptered in the following phases

Chapter – I: This chapter provides introduction about this research work, it provides the detailed information about the topic of Digital Watermarking (DWM) and its various categories explored under several research work done. It also provides the information in regard of soft computing tools and techniques like fuzzy logic rules and fuzzy inference system, specialized single layer feed forward network (SLFN) in the form of Extreme Learning Machine (ELM) used in the course of this research work. It also provides the information about Android framework and its different versions used in this research work.

Chapter – II: This chapter provides information is about Literature Review carried out for this research work from the domain of Digital Image Watermarking (DIW), usage of various soft computing techniques like Fuzzy Logic, Support Vector Machine (SVM), Artificial Neural Network (ANN) for DIW, Applications of DWM especially DIW in the domain of mobile phones and various other techniques like SLFN which were rarely used in the research work of DIW, but, embraced in this research work.

Chapter – III: This chapter explains the initial framework designed for optimized and robust digital image watermarking while implementing Human Visual System (HVS) using spatial and frequency transformation like DCT and optimization techniques of Fuzzy Logic and fuzzy inference system applied during this research work.

Chapter – IV: This chapter describes the usage of embedded system tools from National Instruments (NI) and Texas Instruments (TI). It also provides the insights regarding the simulation of further enhancement of the research while extracting Blue Channel from RGB image and used it while embedding a visible watermark channelized through the Blue Channel of the host image. The next step towards this research work in the form of a simulation model, for implementing Visible Digital Image Watermarking through Blue Channel **DIWBC**, finally provides the watermarked image in blue channel **WBC** and background parameters along with the results received for the optimization scheme proposed in this chapter.

Chapter – V: This chapter provides the details about the final scheme and framework proposed for Digital Mobile Transcendence **DMT** for real time and resource optimized digital image watermarking for android mobile devices. It also shares the details of its comparative outcomes of time consumed while installing and using the mobile app via different android based mobile devices having variance in their hardware and software configurations.

Chapter – VI: This chapter provides the details about the results and evaluation

2. Chapter-II: Review of Literature

The introduction to this research work is redirecting towards the previous work done in this field to affirm the motivation and need towards this work. It also attracts the nature of research methodology used previously and provides a direction for the methods and dimensions to be used in this research work. In this chapter the main dimensions playing vital role in this research work are being explored as much possible, to provide a correct direction.

2.1. Literature Review

Any research needs a bridge to be created amongst the previous work done in the same domain and the future scope referred from those work accomplished. It intertwines the work done and current scope of the research work. The knowledge gained from reading previous research articles and/or the books mentioned in an order to put forth the stream of thought that has flowed regarding the chosen topic. In fact, the topic of research was derived from the gap in research literature reviewed for various parameters like methods used for digital watermarking of an image, usage of various soft computing techniques in this process, energy consumption and energy efficiency techniques used in mobile phones and smart phones etc.

2.2. Steganography and Cryptography

Watermarking as a field of research and interest has been evolved from Steganography and it also associates its hiding algorithms with cryptography. Katzenbeisser & Petitcola [1] have provided their valuable research outcomes on information hiding techniques for steganography and digital watermarking, these have been used in various image watermarking research works. Diffie & Hellman [6] have provided new directions to the field of cryptography which is a great help in understanding the way of hiding the messages in any media. Badgaiyan and Dewagan [7] have provided their valuable research outcome on data hiding techniques in an image, which can be used in various mobile applications. Whereas, Chattopadhyay and Pal [8] have provided their valuable inputs through a Survey on Video Security with focus on H.264 Steganography, Cryptography and Watermarking techniques. Cox [5] have been the legendary researchers who have enlightened the path of image watermarking through secure spread spectrum watermarking for multimedia. Jawad and Gazali [9] have further enhanced the watermarking technique through a review of color image encryption techniques, which can be used in the current era of imaging. Samanta, Dutta, & Sanyal in [10] have provided the techniques of enhancement of security of RGB image using component wise permutation techniques.

2.3. Watermarking Schemes Adopted:

The watermarking schemes which operated directly on the original image in spatial domain were not providing a scenario of robust watermarking. In their research work using frequency transformation of spatial domain to convert it into frequency domain and then insert the watermark was incorporated by Cox, Kilian, Leighton, & Shamoon in [5], where they not only described the method of creating strong and robust watermarks, but also revealed that there are two parts for building a strong watermark which are needed to be taken care; the watermark structure and the insertion strategy. In order for a watermark to be robust and secure, these two components must be designed correctly.

The above work was refereed by Agarwal & Mishra [16], they introduced A Novel Image Watermarking Technique using Fuzzy-BP Network for improvising the ways of research in this field of robust image watermarking. Agarwal, Mishra, & Sharma [17] have provided their collaborated efforts in the field of Digital image watermarking in DCT domain using fuzzy inference system and made the soft computing approach in this field as well established phenomenon. Furthermore, Agarwal C., Mishra, Sharma, & Chetty [18] elaborated and enhance their research work through the novel scene based robust video watermarking scheme in DWT domain using ELM which was rarely used in this domain of research prior to this work done. They also explained that the high speed of learning capacity showcased by ELM provided a positive variation in their research work.

Whereas, Liu & Tan [11] used the pseudo random noise sequences which were modified by the watermark using direct sequence spread spectrum techniques, Madhesiya & Ahmed in [12] involved both DCT and DWT as a transformation tool and SVD for optimization. Alattar [19] has worked on smart images using DigiMarc watermarking technology and provided an altogether new refined approach in this field of research.

Badgaiyan, Dewagan, Pandey, Yeulkar, & Sinha [7] have provided their valuable research outcome on data hiding techniques in an image, which can be used in various mobile applications. Chattopadhyay & Pal [8] have provided a Novel, Low Complexity Video Watermarking Scheme for H.264 which is being used in video transmission now a days. Chattopadhyay & Pal [2] have provided their valuable inputs through a Survey on Video Security with focus on H.264 Steganography, Cryptography and Watermarking techniques.

Al-Gindy, Al-Ahmad, Qahwaji, & Tawfik [20] Watermarking of colour images in the DCT domain using Y channel which became the baseline for their research and helped in applying the watermarking through Y-channel in this research work. Al-Gindy, Al-Ahmad, Qahwaji, & Tawfik [21] worked on a new watermarking scheme for colour images captured by mobile phone cameras which modernized the field of digital image watermarking.

Digital image watermarking through the usage of Singular Value Decomposition [SVD] was done by Ali, Ahn, & Pant in [13] and Aslantas & Mevlut [14], whereas videos watermarking using SVD have been explored by Rajab, Al-Khatib, & Al-Haj [15] in their research paper. In his research work Liu & Tan [11] explored the SVD based watermarking scheme for protecting rightful ownership, whereas Madhesiya & Ahmed [12] explored advanced technique of digital watermarking based on SVD-DWT-DCT and arnold transform which altogether provided the robust framework for the technique of digital watermarking.

Guo, Chen, Luo, & Chen [22] have worked on a blind watermarking algorithm using DWT and DCT techniques blended together for color image watermarking. Hess-Nielsen & Wickerhauser [23] have analyzed wavelets and related time frequency analysis, which is very helpful in the research work of this domain. Huang & Selin [24] have provided the research outcome as wavelet feature selection for image classification. Huang, Chiang, & Chang in [25] have described the robust spatial watermarking technique for color images via direct saturation adjustment which has opened new thoughts for its implementation in various upcoming applications. IDRISSI and others in [26] have synchronized two most important transformation techniques using their research about a Robust Digital Watermarking Technique using DWT-DCT and Statics blocks. Jawad & Gazali [9] have further enhanced the watermarking technique through a review of color image encryption techniques, which can be used in the current era of imaging. Jayant, Johnson, & Safranek [27] have worked on signal compression techniques through human perceptions which reduces the gap of applications developed from computer towards actual usage in real life. Jeedella & Al-Ahmad [28] have provided an algorithm for watermarking mobile phone colour images using BCH code which was used on static images already captured in the phone or downloaded from any social media. Jeswani & Sarode [29] have researched and provided an improved blind color image watermarking using DCT in RGB Color Space. Katzenbeisser & Petitcola [1] have provided their valuable research outcomes on information hiding techniques for steganography and digital watermarking, these have been used in various image watermarking research works.

Lee & Lu [30] has worked on FUZZY BP: a neural network model with fuzzy inference which incorporates soft computing techniques, this work helped during initial part of current research work. Lin & Lin [31] have devoted Wavelet based copyright protection scheme for digital images based on local features which is equally good research work for further usage in this domain. Lou, Ming-Chang, & Jhiang-Lung, [32] have not only worked for image watermarking but apply the same in Healthcare Image Watermarking Scheme Based on Human Visual Model and Back-Propagation Network. Nikoliadis & Pitas in [34] have worked for Benchmarking of watermarking algorithms which provides a comparative outcome amongst all well-known algorithms in this field. Park, Singhal, Lee, Cho, & Kim [35] have worked on Design and Performance Evaluation of Image processing algorithms on GPUs which will be used in forthcoming technology of designing GPUs for future computing and imaging machines.

Petitcolas [36] have provided Watermarking Schemes Evaluation which are used in all upcoming research work in this domain. Piao, Beack, Woo, & Han in [37] have described their research work through a blind watermarking algorithm based on HVS and RBF neural network for digital image. (Rao & Yip, 1990) have redirected the usage of Discrete Cosine Transform: Algorithms Advantages, Applications in various other research domains. Sewaif, Al-Mualla, & Al-Ahmad [38] has introduced 2 D Walsh Coding for Robust Digital Image Watermarking. Su, Yugang, Zou, & Zhao in [39] have worked on a blind double color image watermarking algorithm based on QR decomposition which opened a new perspective in this domain.

Verma, Jain, Agarwal, & Phadikar [40] have also introduced a new color image watermarking Scheme which could be further used in applications. Wang, Lin, & Yang in [41] defined an intelligent watermarking method based on particle swarm optimization which could be further used in optimization of such applications. Wei, Dai, & Li [42] have used Genetic watermarking based on DCT domain techniques which improvised the intelligence in such techniques. Wolfgang & Delp [43] have researched and provided a Fragile Watermarking using the VW2D watermark technique which is of immense utilization in Security and Watermarking of Multimedia Contents. Yong, Li-Cai, Shen, & Tao [44] provided a blind watermarking algorithm based on block DCT for dual colour images which has its own way of using block based transformations in this domain.

Zhao & Eckhard, [45] proposed and setup a new way of Embedding Robust Labels into Images for Copyright Protection. In their another work Zhao & Eckhard, [46] presented the work Towards robust and hidden image copyright labeling, which has defined the way of labeling text as a watermark in the digital images. Although, the work was still very helpful in understanding the labelling of watermark in the host image. Zhao, Hua, & Hu [47] have provided a blind watermarking algorithm based on DCT which is again of immense help in this research work. Zhou & Liu [48] have worked on Blind watermarking algorithm based on DCT for colour images.

Sharma, Prateek, & Chattopadhyay [3] have worked upon Optimized Robust Image Watermarking using HVS model supported by soft-computing and in the following research work [49] have used mix transformation techniques and soft-computing through DCT Based Fuzzy Image Watermarking. Sharma, Prateek, & Chattopadhyay [4] have simulated the research outcome DCT and Simulink Based Real-time Robust Image Watermarking before going for the final mobile based application of image watermarking.

Gonzales, Woods, & Eddins, [50] Digital Image Processing using MATLAB and Gonzales & Woods, Digital Image Processing [51] have been very helpful text books for the research work in this field.

2.4. Energy Efficiency or Power Consumption in Mobile or Smart Phones

Miao, Yutao, & Jane [33] have applied in developing a mobile application known as hymnmark: Towards Efficient Digital Watermarking on Android Smartphones. There work was of tremendous potential and provided the final guideline for this current research work towards measuring power consumed by the application using various parameters used in Android platform while executing any mobile app.

Watermarking of colour images in the DCT domain using Y channel which became the baseline for their research by Al-Gindy, Al-Ahmad, Qahwaji, & Tawfik [21]. In another paper by same authors [20] worked on a new watermarking scheme for colour images captured by mobile phone cameras which has revolutionized he field of watermarking, in their work have introduced a new watermarking scheme for colour images captured by mobile phone cameras to provide security while being shared through Emails, SNS or MMS at that time. In this work an image authentication technique that embeds a binary watermark into a host color image was proposed, they have shared the process of Watermarking of colour images in the DCT domain using Y channel. An analysis of Power consumption in smartphones Carroll & Heiser [52] have provided a different dimension to the research where the applications running on mobile devices can have their energy usage graph in real time. New upcoming steganographic technique of hiding images in a mobile application was being explored by Badgaiyan, Dewagan, Pandey, Yeulkar, & Sinha, [7] and the energy consumption by various mobile apps were shared as their research work by Balasubramanian, & Venkataramani [53] have opened new ways of understanding the energy attributes of the mobile applications, whereas with the help of augmented smartphone application through the execution of clone cloud was shared by Byung-Gon & Petros [54] which has extended the work done in watermarking to be used in cloud activities as well. Carroll & Heiser [52] work on the Analysis of Power Consumption in a Smartphone and Self-constructive high-rate system energy modeling for battery-powered mobile systems was the outcome of Dong & Lin [55] has been a another milestone achieved in this direction of research.

Other schemes like Kejariwal, Gupta, Nicolau, Dutt, & Gupta [56], Energy Analysis of Multimedia Watermarking on Mobile Handheld Devices. The real time less energy consuming watermarking is exhibited by various researchers in past, Kejariwal, Gupta, Nicolau, Dutt, & Gupta [57] Energy efficient watermarking on mobile devices using proxy-based partitioning, performed the energy efficient watermarking by using the “proxy based partitioning technique” for mobile devices, as digital image watermarking consumes computational resources exhaustively and adds to the drain of the battery power in handheld devices. It involves dual utilization of cyber infrastructure by utilizing the proxy server and the handheld device separately, which in turn leads to duplication of energy consumption. The proposed work exhibited the image authentication by reducing the cyber infrastructure load by utilizing the mobile devices in an energy efficient manner. Kshirsagar & Kulkarni [58] have worked on Real Time Implementation of Secured Multimedia Messaging Service System using Android as a mobile framework. While working with mobile telephony Lee, Yeh, & Chen [59] found the impact of inactivity timer on energy consumption on wcdma and cdma2000 technologies which revolutionized the mobile communication. Liu, Sridharan, Machiraju, Seshadri, & Zang [60] their work on Experiences in a 3g network: interplay between the wireless channel and Applications have also provided a thoughtful information in this context, which can be further used in upcoming wireless channels and there usage in application development. Mark Gordon [61] have provided a wonder app by the name of “PowerTutor” which has made the life easier regarding the application based research work especially on android. Motwani & Harris, Jr [62] have provided Fuzzy Perceptual Watermarking For Ownership Verification which defines a new way of softcomputing for multimedia validation especially images. Nikoliadis & Pitas [34] have worked for Benchmarking of watermarking algorithms which provides a comparative outcome amongst all well-known algorithms in this field. Pathak, Hu, & Zhang [63] have provided the answer to the important question of Where is the energy spent inside my app? Fine Grained Energy Accounting on Smartphones with (Eprof Mobile Enerlytics).

Nurminen & Noyranen [64] has provided a research outcome on Energy-consumption in mobile peer-to-peer quantitative results from file sharing after an immense research work on this topic, which has been a very useful work for this research work. Rahmati & Zhong [65] have worked to find the answer in Context-for-wireless: context-sensitive energy-efficient wireless data transfer which is very important in current scenario. Xiao, Kalayanaraman, & Yla-Jaaski [66] have provided Energy consumption of mobile YouTube: Qualitative measurement and analysis which is again important in the context of energy measurement regarding mobile apps used. Yeh, Chen, & Lee [67] have provided the Comparative analysis of energy-saving techniques in 3gpp and 3gp2 systems which are directly associated in terms of image processing and executing as a compressed video.

2.5. Real Time/ Embedded Systems/ Computer Simulation and Mobile Application

Applications are built through coding techniques, and this research work used java as a language for application development, Dmitriev [68] work for Profiling Java applications using code hotswapping and dynamic call graph revelation has helped in understanding the technique for using dynamic perspective of java. But few of the techniques are executed in real time scenario using proxy based systems or Kim & Jung [69] embedded solutions like DSP based or FPGA based; but none of them has proposed an energy efficient, software based real time digital image watermarking, which is the prime requisite for digital image authentication to a greater extent.

Chattopadhyay & Pal [8] A Novel, Low Complexity Video Watermarking Scheme for H.264 emphasized that in the field of computer vision there is a wide requirement of real-time digital image authentication, through some digital watermarking scheme. Based on the need analysis of Chattopadhyay & Pal [2] A Survey on Video Security with focus on H.264 Steganography, Cryptography and Watermarking techniques, the proposed work is planned to implement the robust digital watermarking in real time domain.

Mursalin, Fajrana, & Ridwanul [70] have implemented the real time digital image capturing and processing through microcontrollers for industrial purpose like fabric defect inspection system, using Microcontroller and Aritificial Neural Network; this paper helped in understanding the real time implementation of capturing an image and applying some image processing technique over it. The work performed was restricted to the microcontrollers specifically for the detection of fabric. Our research work has implemented the real time robust digital watermarking through highly portable handheld mobile device.

Kim & Jung [69] has done the hardware implementation of the neural network controller using Micro Controller Unit (MCU) and Field Programmable Gate Array (FPGA) for nonlinear systems, which could help in understanding the way to implement neural network in a hardware configuration using MCU and FPGA. The limitation of the work performed was usage of two separate components MCU and FPGA for hardware implementation of the neural networks, whereas our research work has utilized the microprocessors of the handheld mobile device itself.

Chattopadhyay & Pal [2] has done a survey and comparative analysis on various video watermarking techniques with reference to H.264/ AVC and reciprocated that any image watermarking technique can be extended to video watermarking, but in reality video watermarking techniques face various other challenges than that in image watermarking schemes such as large volume of inherently redundant data between frames, real-time requirements in the video broadcasting etc. This paper presents the need for real-time image watermarking in the industry. In support of the work performed by T. Chattopadhyay the research work has implemented the semi-robust digital watermarking in real-time domain in energy efficient manner which is resource optimized.

The research work provides Universal approximation using incremental networks with random hidden computation nodes Huang, Chen, & Siew, [71] [72] [73] which has provided the information about randomization amongst hidden nodes that was applied in algorithm of this research work. They have provided their research outcome on Real-time learning capability of neural networks, which has enhanced the softcomputing part of the research. Mohanty & Elias [74] in their research outcome have worked on real-time perceptual watermarking architectures for video broadcasting, which is an advanced work towards real-time image processing and watermarking. Motwani & Harris, Jr. [62] have provided Fuzzy Perceptual Watermarking for Ownership Verification which defines a new way of softcomputing for multimedia validation especially images. Nikoliadis & Pitas [34] have worked for Benchmarking of watermarking algorithms which provides a comparative outcome amongst all well-known algorithms in this field. Samanta, Dutta, & Sanyal [10] have provided the techniques of enhancement of security of RGB image using component wise permutation techniques. Satyanarayanan, et al., [75] have worked on Pervasive personal computing in an internet suspend/resume system which has provided the architecture for using pervasive personal computing in application of research work in mobile apps.

2.6. Usage of Soft computing (Fuzzy Logic/ Genetic Algorithm/ ANN) in the field of image watermarking

Agarwal & Mishra, [16] have proposed an image watermarking technique which has used the combination of Fuzzy logic and back propagation methods used in neural networks, it helped in understanding and using these techniques in my research work. Agarwal, Mishra, & Sharma [17] have proposed the techniques of using DCT as frequency transformation along with the fuzzy inference system as soft computing techniques for image watermarking. Agarwal C. , Mishra, Sharma, & Chetty [18] in their research have proposed a novel scene based robust video watermarking scheme in DWT domain of frequency transformation using extreme learning machine as the fastest pattern learning mechanism. Chen & Huang, [76] in their research work have used co-evolutionary genetic watermarking technique for owner identification, which was quite good and workable in static images. Cormen, Leiserson, Rivest, & Stein, [77] in their book have emphasized upon various algorithm in different fields of computer science. They were very helpful in implementation of the research work done so far. Digital image watermarking through the usage of Singular Value Decomposition [SVD] was done by Aslantas & Mevlut, [14], Freeman & Skapura, [78] Neural Networks Algorithms, Applications and Programming Techniques. Gupta, Jin, & Homma [79] have enlightened on Static and Dynamic Neural Networks and their usage in various applications. Huang, Zhu, & Siew [72] have provided their research outcome on Real-time learning capability of neural networks, which has enhanced the softcomputing part of the research.

Huang, Zhu, & Siew [73] Extreme learning machine: a new learning scheme of feedforward neural networks. Isac & Santhi [80] have done a study on digital image and video watermarking schemes using neural networks. Jang & Gulley [81] Fuzzy Logic Toolbox for Use With MATLAB has been an immense help in this research work. The real time less energy consuming watermarking is exhibited by various researchers in past, Kejariwal, Gupta, Nicolau, Dutt, & Gupta, [57] Energy efficient watermarking on mobile devices using proxy-based partitioning, performed the energy efficient watermarking by using the "proxy based partitioning technique" for mobile devices, as digital image watermarking consumes computational resources exhaustively and adds to the drain of the battery power in handheld devices. Other schemes like Kejariwal, Gupta, Nicolau, Dutt, & Gupta, [56], Energy Analysis of Multimedia Watermarking on Mobile Handheld Devices. Kim & Jung [69] has done the hardware implementation of the neural network controller using Micro Controller Unit (MCU) and Field Programmable Gate Array (FPGA) for nonlinear systems, which could help in understanding the way to implement neural network in a hardware configuration using MCU and FPGA. Lee & Lu, [30] has worked on FUZZY BP: a neural network model with fuzzy inference which incorporates soft computing techniques. Lou & Yin [82] Adaptive Digital Watermarking using Fuzzy Logic Techniques which has been an important input for this research work. Madhesiya & Ahmed, [12] involved both DCT and DWT as a transformation tool and SVD for optimization. Mamdani & Assilian, [83] An experiment in linguistic synthesis with a fuzzy logic controller was the work gave a different dimension of using fuzzy logic controller in various other applications. Mehta, Rajpal, & Vishwakarma, [84] Adaptive Image Watermarking Scheme Using Fuzzy Entropy and GA-ELM Hybridization in DCT Domain for Copyright Protection, this research work was synthesized version of Fuzzy, ELM with transformation in DCT domain.

Mitra & Pal, [85] Fuzzy self organization, inferencing and rule have defined a path of making inference rules using fuzzy logic and enable in different problem solving. Mitra & Hayashi, [86] Neuro-fuzzy rule generation: Survey in softcomputing framework and the work done by Mishra A. , Goel, Singh, Chetty, & Singh, [87] A novel image watermarking scheme using extreme learning machine, Mishra & Goel, [88] A novel Image Watermarking Scheme using Hybrid DWT-DCT-ELM Technique, Mishra & Goel, [89] A Novel HVS Based Gray Scale Image Watermarking Scheme Using Fast Fuzzy-ELM Hybrid Architecture, in their research have provided directions of using ELM with different softcomputing techniques in other research domains.

Mursalin, Fajrana, & Ridwanul, [70] have implemented the real time digital image capturing and processing through microcontrollers for industrial purpose like fabric defect inspection system, using Microcontroller and Artificial Neural Network; this paper helped in understanding the real time implementation of capturing an image and applying some image processing technique over it. The work performed was restricted to the microcontrollers specifically for the detection of fabric. Our research work has implemented the real time robust digital watermarking through highly portable handheld mobile device. Motwani & Harris, Jr. [62] have provided Fuzzy Perceptual Watermarking for Ownership Verification which defines a new way of softcomputing for multimedia validation especially images.

Nakamura, Katayama, Kitahara, & Nakazawa, [90] A fast and robust digital watermark detection scheme for cellular phones has been a help in understanding and implementing watermarking scheme in cellular phone. Nikoliadis & Pitas, [34] have worked for Benchmarking of watermarking algorithms which provides a comparative outcome amongst all well-known algorithms in this field. Park, Singhal, Lee, Cho, & Kim, [35] have worked on Design and Performance Evaluation of Image processing algorithms on GPUs which will be used in forthcoming technology of designing GPUs for future computing and imaging machines. Piao, Beack, Woo, & Han, [37] have described their research work through a blind watermarking algorithm based on HVS and RBF neural network for digital image. Ramamurthy & Varadarajn, [91] have provided their research outcome in the field of Robust Digital Image Watermarking Scheme with Neural Network and Fuzzy Logic Approach, which has also provided the way of mapping two different soft computing techniques to achieve a problem.

Sharma, Prateek, & Chattopadhyay, [3] have worked upon Optimized Robust Image Watermarking and in the following research work Sharma, Prateek, & Chattopadhyay, GJEIS, [49] have used mix transformation techniques and soft computing through DCT Based Fuzzy Image Watermarking. Sharma, Prateek, & Chattopadhyay, IJIP [4] have simulated the research outcome DCT and Simulink Based Realtime Robust Image Watermarking before going for the final mobile based application of image watermarking. Sharma, Prateek, & Chattopadhyay, [92] in the work of Realtime Energy Efficient Digital Image Watermarking on Mobile Devices using Android which has provided an experimental outcome of DCT, DWT transformations mapped with ELM and executed as an app in android mobile framework. Shieh, Huang, Wang, & Pan, [93] in their research work Genetic watermarking based on transform-domain techniques has been a great help in understanding the usage of softcomputing in watermarking. Sun, Au, & Choi [94] proposed a neuro-fuzzy inference system through integration of fuzzy logic and extreme learning machines has been a great help in understanding the linking process of fuzzy logic and extreme learning machine frameworks. Szmidt & Kacprzyk, [95] have incorporated in their research work in finding Distances between intuitionistic fuzzy sets, which has been a help for this research to move ahead in the shape of an application. Tzafestas & Zikidis, [96] have worked on the topic of NeuroFAST: On-line neuro-fuzzy ART-based structure and parameter learning TSK model, which has been a help in understanding neuro-fuzzy structure in learning process. Wang, Lin, & Yang, [41] have worked on an intelligent watermarking method based on particle swarm optimization, which is yet another technique in the field of designing optimal solutions. Wei, Dai, & Li, [42] have used the soft computing techniques with DCT transformation in the research work in Genetic watermarking based on DCT domain techniques. Zhang, Walter, Miao, & Lee, [97] in their research work of Wavelet Neural Networks for Function Learning has been a help for understanding the integration of wavelets with neural networks for any type of function learning.

Zadeh, [98] was a great inspiration while going through his work on Fuzzy sets, which actually transformed the way of implementing human perspectives in computer programming. Rajasekran & Vijaylakshmi Pai, [99] have written a book on Neural Networks, Fuzzy Logic, and Genetic Algorithms Synthesis and Applications, which has been a great source of learning in this field and its further usages in various research activities. Sivanandam, Sumathi, & Deepa, [100] written a book on Introduction to Neural Networks using MATLAB 6.0 which has been an immense help in applying neural networks in MATLAB environment and further used in a simulation environment of SIMULINK to understand the working in almost realtime framework. Tyagi, [101] written a book on Matlab and Simulink for Engineers which has opened up the doors of using MATLAB and SIMULINK for their usage in this research work.

2.7. ELM and its Applications

Huang, Zhu, & Siew, [73] in their research work have provided a powerful tool Extreme learning machine: a new learning scheme of feedforward neural networks, which has opened up plethora of opportunities in research and applications. Huang, Zhu, & Siew, [72] Extreme Learning Machine: Theory and Applications, has been a bunch of applications with a theory at the background for a better outcome in research. Sun, Au, & Choi, [94] A neuro-fuzzy inference system through integration of fuzzy logic and extreme learning machines. Huang G. B., [102] Extreme Learning Machines, website, has provided immense help to anyone who'd like to use this tool in research work.

Mishra A. , Goel, Singh, Chetty, & Singh, [87] A novel image watermarking scheme using extreme learning machine, has been a research work of applying ELM in image watermarking for the first time. It changes the perception of using SLFN based ELM for the transformation of digital image watermarking in real time because of its least time consumption during the learning process. Agarwal C. , Mishra, Sharma, & Chetty, [18] in their research have proposed a novel scene based robust video watermarking scheme in DWT domain of frequency transformation using extreme learning machine as the fastest pattern learning mechanism. Mishra & Goel, [88] A novel Image Watermarking Scheme using Hybrid DWT-DCT-ELM Technique, which integrated various tranformation techniques along with ELM and provided a hybrid scheme for faster computation. Mishra & Goel [89] A Novel HVS Based Gray Scale Image Watermarking Scheme Using Fast Fuzzy-ELM Hybrid Architecture.

Gao, Zhou, & Cui, [103] Reversible Watermarking Using Prediction-Error Expansion and Extreme Learning Machine, and Mehta, Rajpal, & Vishwakarma [84] Adaptive Image Watermarking Scheme Using Fuzzy Entropy and GA-ELM Hybridization in DCT Domain for Copyright Protection, this research work was synthesized version of Fuzzy, ELM with transformation in DCT domain. These research work have provided immense help in current research activity and design of scheme.

Sharma, Prateek, & Chattopadhyay [92] Realtime Energy Efficient Digital Image Watermarking on Mobile Devices using Android which has provided an experimental outcome of DCT, DWT transformations mapped with ELM and executed as an app in android mobile framework.

Cormen, Leiserson, Rivest & Stein [77] Introduction to Algorithms and Freeman & Skapura [78] Neural Networks Algorithms, Applications and Programming Techniques are some of the books published which are providing a well knotted theoretical approach to be used in application design or research work.

2.8. Applications of watermarking

Concept of Smart images using the technology of Digimarc was explored by Alattar [19] where he tried to bridge the gap of traditional and modern way of using images in electronic commerce and authenticate the same using digital watermark in physical or digital images. Al-Gindy, Al-Ahmad, Qahwaji, & Tawfik [21] worked on a new watermarking scheme for colour images captured by mobile phone cameras which has revolutionized he field of watermarking. Al-Gindy, Al-Ahmad, Qahwaji, & Tawfik [20] in their work have introduced a new watermarking scheme for colour images captured by mobile phone cameras to provide security while being shared through Emails, SNS or MMS at that time. Digital image watermarking through the usage of Singular Value Decomposition [SVD] was done by Ali, Ahn & Pant [13]. Most of the help in developing this research work under execution phase has been provided by Android Open Source Project [104]. Badgaiyan, Dewagan, Pandey, Yeulkar & Sinha [7] have provided their valuable research outcome on data hiding techniques in an image, which can be used in various mobile applications. the energy consumption by various mobile apps were shared as their research work by Balasubramanian, Balasubramanian, & Venkataramani [53] have opened new ways of understanding the energy attributes of the mobile applications, whereas with the help of augmented smartphone application through the execution of clone cloud was shared by Byung-Gon & Petros [54] which has extended the work done in watermarking to be used in cloud activities as well. An analysis of Power consumption in smartphones Carroll & Heiser [52] have provided a different dimension to the research where the applications running on mobile devices can have their energy usage graph in real time. Chattopadhyay & Pal [8] A Novel, Low Complexity Video Watermarking Scheme for H.264 emphasized that in the field of computer vision there is a wide requirement of real-time digital image authentication, through some digital watermarking scheme. Elias, Mohanty & Pradhan [105] have provided their useful research outcomes on Simulink Based Architecture Prototyping of Compressed Domain MPEG-4 Watermarking. Ibrahim & Kee [106] have provided an important research outcome in terms of MoBiSiS: An Android-based Application for Sending Stego Image through MMS, which has provided a logical framework of using android as a framework for the research work. Jeedella & Al-Ahmad [28] have provided an algorithm for watermarking mobile phone colour images using BCH code which was used on static images already captured in the phone or downloaded from any social media. The real time less energy consuming watermarking is exhibited by various researchers in past, Kejariwal, Gupta, Nicolau, Dutt, & Gupta [57] Energy efficient watermarking on mobile devices using proxy-based partitioning, performed the energy efficient watermarking by using the "proxy based partitioning technique" for mobile devices, as digital image watermarking consumes computational resources exhaustively and adds to the drain of the battery power in handheld devices. Other schemes like Kejariwal, Gupta, Nicolau, Dutt, & Gupta [56] Energy Analysis of Multimedia Watermarking on Mobile Handheld Devices. Kshirsagar & Kulkarni, March [58] have worked on Real Time Implementation of Secured Multimedia Messaging Service System using Android as a mobile framework. Lou, Ming-Chang, & Jhiang-Lung [32] have not only worked for image watermarking but apply the same in Healthcare Image Watermarking Scheme Based on Human Visual Model and Back-Propagation Network. Miao, Yutao, & Jane [33] have applied in developing an application known as hymnmark: Towards Efficient Digital Watermarking on Android Smartphones. Mark Gordon, [61] have provided a wonder app by the name of powertutor which has made the life easier regarding the application based research work especially on android. Nakamura, Katayama, Kitahara, & Nakazawa [90] a fast and robust digital watermark detection scheme for cellular phones has been a help in understanding and implementing watermarking scheme in cellular phone. Nurminen & Noyranen [64] has provided a research outcome on Energy-consumption in mobile peer-to-peer - quantitative results from file sharing after an immense research work on this topic, which has been a very useful work for this research work. Park, Singhal, Lee, Cho, & Kim [35] have worked on Design and Performance Evaluation of Image processing algorithms on GPUs which will be used in forthcoming technology of designing GPUs for future computing and imaging machines. Rahmati & Zhong [65] have worked to find the answer in Context-for-wireless: context-sensitive energy-efficient wireless data transfer which is very important in current scenario. Satyanarayanan, et al. [75] have worked on Pervasive personal computing in an internet suspend/resume system which has provided the architecture for using pervasive personal computing in application of research work in mobile apps. Sharma, Prateek, & Chattopadhyay, [92] Realtime Energy Efficient Digital Image Watermarking on Mobile Devices using Android which has provided an experimental outcome of DCT, DWT transformations mapped with ELM and executed as an app in android mobile framework.

3. Chapter-III: DMT Scheme (Phase-I): Optimized Framework for Digital Image Watermarking

3.1. DMT Scheme

The algorithm or DMT scheme developed in the research work is to provide energy efficient resource optimized digital watermarking for mobile devices has undergone three phases as mentioned below:

The experimental mode was used for the execution of this research work, which initially includes the process designed for image watermarking using DCT and Fuzzy logic to relate with the Human Visual System (HVS), this research design was further extended for the simulation using Matlab-Simulink and execute the same under controlled environment to fetch the results of time complexity.

Finally, to the design was incorporated with the required input, process and output parameters in an android app, and energy consumption was measured in real-time while its execution. During entire research process the results are compared with existing research work in the same domain. Techniques Used during this entire process were further explained in phased manner

3.2. Overview of Phase-I

First phase of this research work proposed to explore the optimized robust image watermarking technique to model the Human Visual System (HVS), as already proven digital watermarking embeds an imperceptible signature as a watermark in any digital file categorized as text, image, audio, video etc. It could be used for the authentication of the data file for tamper detection. Implementing HVS using a soft computing technique of Fuzzy Logic needed in-depth understanding of step wise application of fuzzy logic as well as digital image watermarking. Now, it was finalized to work on three parameters of HVS on images namely luminance, edge detection and texture recognition after exploring the literature in detail.

The Fuzzy Inference System was trained by logical inference rules considering HVS features namely luminance sensitivity, edge sensitivity and texture or contrast sensitivity. The Fuzzy network computed the image, block wise for producing a single output weighting factor which is used to embed unique identification numbers as watermark for authorization and verification of the original image. The robustness of the embedded watermark was checked by Stirmark image processing attacks. Computed value of SIM(X, X*) parameter for the image concluded it as good watermark recovery process.

3.3. Phase-I (HVS Modeling using Gray Scale Image)

As identified from the literature review, the research work moved in the direction of calculating the three parameters for any gray scale image. Initially the gray scale host image of size 256 x 256 pixel was identified to be used that of Lena, then image was needed to be divided into 1024 blocks of 8 x 8 pixel, in the Spatial Domain.

Spatial Transformation: While using this transformation technique, two Cartesian coordinate systems were used "Input Space" and "Output Space". There could be two different types of transformations used like forward transformation or inverse transformation. Let us, consider (a, b) for input space and (c, d) for output space.

- Forward transformation considered as T{ }, maps a location in input space to a location in output space: $(c_0, d_0) = T\{(a_0, b_0)\}$.
- Inverse transformation considered as T^{-1}\{ \}, maps a location in output space to a location in input space: $(a_1, b_1) = T^{-1}\{(c_1, d_1)\}$.

Finally, computed 1024 block of 8x8 pixels from the host image of 256x256 pixels were transformed from spatial domain into frequency domain using Discrete Cosine Transformation (DCT), needed to be implemented during transformation of an image from its spatial domain to frequency domain so, that the image watermarking could be robust and can with stand the tampering with the original image, by attacks applied for its removal as reviewed from [5] [14].

A discrete cosine transform (DCT) expresses a finite sequence of data points in terms of a sum of cosine functions oscillating at different frequencies. whereas for differential equations the cosines express a particular choice of boundary conditions.

EQUATION 3-1: DISCRETE COSINE TRANSFORMATION

$$y(k,l) = w(k)\sum_{m=1}^{M} u(m,l)cos\frac{\pi(2m \quad 1)(k \quad 1)}{2M}, k = 1, \dots, M$$

Where

$$w(k) = \begin{cases} \frac{1}{\sqrt{M}}, \; k = 1 \\ \sqrt{\frac{2}{M}}, 2 \le k \le M \end{cases}$$

DCT is a Fourier-related transform similar to the discrete Fourier transform (DFT), but using only real numbers. DCTs are equivalent to DFTs of roughly twice the length, operating on real data with even symmetry (since the Fourier transform of a real and even function is real and even), where in some variants the input and/or output data are shifted by half a sample. There are eight standard DCT variants, of which four are common.

The mentioned techniques are frequently used in the field of steganography, cryptography, watermarking etc; which are frequently used for data authentication. The proposed work relates to the field of image authentication through digital watermarking technique which is planned to be implemented in the real time domain. The data fuzzification and neural networks are the techniques which are readily used for such purpose. Now, for the matter of applying fuzzy logic for inferencing the HVS following three parts of a gray scale image were extracted on the basis of their sensitivity analysis.

i) Luminance Sensitivity
ii) Edge Sensitivity
iii) Texture or Contrast Sensitivity

3.4. Components of HVS

The research work needs to compute three HVS characteristics

1. luminance sensitivity
2. edge sensitivity and
3. contrast sensitivity

Luminance Sensitivity is computed using the DC coefficients of the DCT blocks of the host image are used as luminance sensitivity according to following formula:

EQUATION 3-2: LUMSEN COMPUTATION

$$LUMSEN = \frac{X_{DC,i}}{X_{DCM}}$$

Where, LUMSEN is the luminance sensitivity, X_{DC}, i denotes the DC coefficient of the i^{th} block and X_{DCM} is the mean value of the DC coefficients of all the blocks put together.

Fuzzy Input Variables for Luminance sensitivity of the eye where, the brightness can be categorized as dark, medium or bright. The figure below plots the fuzzy input variable with less, moderate and high brightness values.

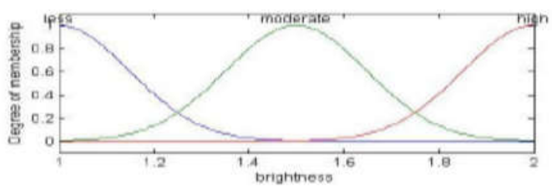


FIGURE 3-1: FUZZY VALUES FOR LUMINANCE SENSITIVITY

The Edge Sensitivity: As the edge is detected with in the image using threshold operation, edge sensitivity can be quantified as a natural corollary to the computation of the block threshold T. It has been implemented as follows:

EQUATION 3-3: EDGSEN - THRESHOLD USING GREYTHRESH()

T = graythresh(f)

Where, f is the host sub-image (block) in question and T is the computed threshold value. Matlab image processing toolbox implements graythresh( ) routine which computes the block threshold using histogram.

The Edge Sensitivity can be small, medium, or large as shown in the plots below in figure below.

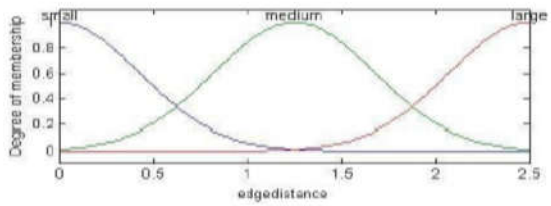


FIGURE 3-2: FUZZY VALUES FOR EDGE SENSITIVITY

Thresholding for Edge Sensitivity

Due to its intuitive properties of segmenting shades in an image, thresholding is used for identifying local and global distinctions of intensity in an image. Any image is composed of foreground and background with difference in an edge, and to extract the image of any object with distinct features it is needed to differentiate using threshold of difference in their edge.

Let, the image is showcased using following function f (x, y) composed of a light shaded object in front of dark shaded background, in such a way that object and background pixels have intensity levels grouped into two dominant modes. This method is using threshold T which differentiates these modes. Then any point (x, y) for which f(x, y) >= T is called an object point, otherwise the point is called a background point. Thus, threshold image g(x, y) is defined as follows:

EQUATION 3-4: IMAGE THRESHOLD

$$g(x,y) = \begin{cases} 0, if\ f(x,y) < T \\ 1, if\ f(x,y) \geq T \end{cases}$$

Whereas, in this research work Otsu's approach of thresholding has been adopted, the formulation of this histogram based method, by treating normalized histogram as a discrete probability density function, as mentioned below:

EQUATION 3-5: DISCRETE PROBABILITY DENSITY FUNCTION

$$p_r(r_q) = \frac{n_q}{n}\ ; \qquad q = 0,1,2,\dots,L \quad 1$$

Where,

n = Total number of pixels in the image
n_q = Number of pixels that have intensity level r_q
L = Total number of possible intensity levels in the image

Suppose, *k* is chosen as a midpoint of threshold which divides two sets of intensity level say C_0, C_1

Where,

C_0 = [0, 1, …… , k-1]

C_1 = [k, k+1, ….. , L-1]

Otsu's method chooses the threshold value k that maximizes the between-class variance

Equation 3-6: Computation of Class Variance

$$\sigma_B^2 = \omega_0 (\mu_0 \quad \mu_r)^2 + \omega_1 (\mu_1 \quad \mu_r)^2$$

Where,

$$\omega_0 = \sum_{q=0}^{k-1} p_q (r_q)$$

$$\omega_1 = \sum_{q=k}^{L-1} p_q (r_q)$$

$$\mu_0 = \sum_{q=0}^{k-1} q p_q (r_q) / \omega_0$$

$$\mu_1 = \sum_{q=k}^{L-1} q p_q (r_q) / \omega_1$$

$$\mu_T = \sum_{q=0}^{L-1} q p_q (r_q)$$

Function graythresh() takes an image, computes its histogram, and then finds the threshold value that maximizes σ_B^2. The threshold is returned as a normalized value between (0.0 to 1.0), the returned value of T is multiplied by 255 before using it further in the algorithm.

Contrast Senstivity: An important way to describe a region is to quantify its texture content or contrast sensitivity. The computed variance value of an image block is the direct metric to quantify this parameter. A Matlab routine proposed by Gonzalez et al. [51] to compute the block variance is used for this purpose. The implementation of this routine is as follows:

Equation 3-7: Calculation CONSEN

t = statxture(f, scale)

Where f is the input image or the sub-image (block) and t is the output in the form of a 7-element row vector, one of which is the variance of the block in question.

Contrast or Texture sensitivity of the eye is human eye's response to texture which is classified into 3 categories - low, medium, and high. Plots below illustrate smooth, medium and rough texture values for this fuzzy input variable.

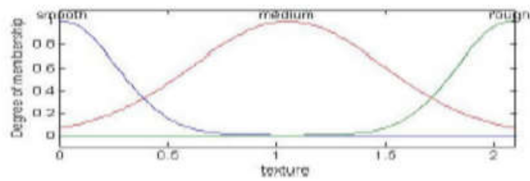


FIGURE 3-3: FUZZY VALUES FOR CONTRAST SENSITIVITY

An important approach for describing a region is to quantify its texture content, which can be computed using statistical and spectral measures. A frequency used approach for texture analysis is based on statistical properties of the intensity histogram of the image. One class of such measures is based on statistical moments, the expression for the n^{th} moment about the mean is given by

EQUATION 3-8: EXPRESSION FOR THE NTH MOMENT

$$\mu_n = \sum_{i=0}^{L-1} (z_i \quad m)^n \, p(z_i)$$

Where,

z_i = Random variable indicating intensity.

p(z) = Histogram of the intensity levels in a region.

L = number of possible intensity levels

m = mean or average intensity.

Mean: A measure of average intensity is expressed using

EQUATION 3-9: MEAN OF AVERAGE INTENSITY

$$m = \sum_{i=0}^{L-1} z_i p(z_i)$$

Standard deviation: A measure of average contrast is expressed using

EQUATION 3-10: STANDARD DEVIATION OF AVERAGE CONTRAST

$$\sigma = \sqrt{\mu_2(z)} = \sqrt{\sigma^2}$$

Variance: A measure of average contrast is expressed using

EQUATION 3-11: VARIANCE OF AVERAGE CONTRAST

$$\mu_2(z) = \sigma^2$$

Third moment: It measures the skewness of a histogram, it is 0 for symmetric histograms, positive by histograms skewed to right (about the mean) and negative for histograms skewed to the left. Values of this measure are brought into a range of values comparable to the other five measures by dividing μ_3 by $(L\text{-}1)^2$ also, which is the same divisor used to normalize the variance.

EQUATION 3-12: THIRD MOMENT

$$\mu_3 = \sum_{i=0}^{L-1} (z_i \quad m)^3 \, p(z_i)$$

Smoothness: Measure the relative smoothness of the intensity in a region. R is 0 for a region of constant intensity and approaches 1 for regions with large excursions in the value of its intensity levels. The variance used in this measure is normalized to the range [0,1] by dividing it by $(L\text{-}1)^2$.

EQUATION 3-13: SMOOTHNESS

$$R = 1 \quad 1/(1 + \sigma^2)$$

Uniformity: This measure of uniformity is maximum when all gray levels are equal (maximally uniform) and start decreasing from there on.

EQUATION 3-14: UNIFORMITY

$$U = \sum_{i=0}^{L-1} p^2 \, (z_i)$$

Entropy: It provided the measure of randomness.

EQUATION 3-15: ENTROPY - THE MEASURE OF RANDOMNESS

$$e = \quad \sum_{i=0}^{L-1} p(z_i) \; log_2 \, p(z_i)$$

4. Mamdani **-** Fuzzy Inference System whose Engine is working on Fuzzy rule based system (F_{HVS}) where 27 rules were bent upon three dimensions of human visual systems i.e.
   i. LUMSEN
   ii. EDGSEN
   iii. CONSEN

These dimensions are generating a weighting factor (W) which is acting as another input variable to the Fuzzy Inference System to derive an inference upon input variables.

EQUATION 3-16: FUNCTION FOR HVS

$$F_{HVS} = f\,(LUMSEN, CONSEN, EDGSEN, WEIFAC)$$

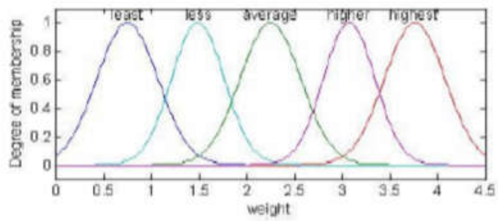


FIGURE 3-4: FUZZY VALUES FOR WEIGHTING FACTOR (W)

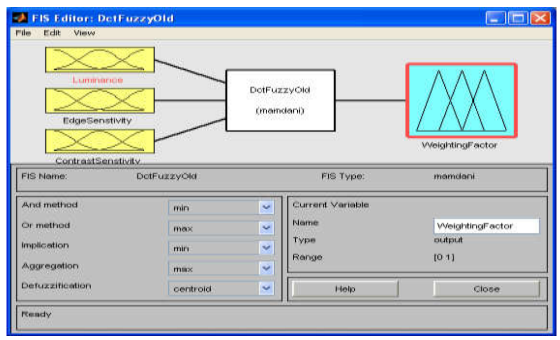


FIGURE 3-5: FUZZY MODEL FOR HVS

A total of 27 such rules are developed and are listed in table 1 below:

TABLE 3-1: HVS BASED 27 RULES FOR FUZZY INFERENCE SYSTEM

Rule No.	Luminance Sensitivity	Contrast Sensitivity	Edge Sensitivity	Weighting Factor
1	DARK	LOW	SMALL	LEAST
2	DARK	MEDIUM	SMALL	LEAST
3	DARK	HIGH	SMALL	LEAST
4	MEDIUM	LOW	SMALL	LEAST
5	MEDIUM	MEDIUM	SMALL	LEAST
6	MEDIUM	HIGH	SMALL	LEAST
7	BRIGHT	LOW	SMALL	LEAST
8	BRIGHT	MEDIUM	SMALL	LEAST
9	BRIGHT	HIGH	SMALL	LEAST
10	DARK	LOW	MEDIUM	LESS
11	DARK	MEDIUM	MEDIUM	HIGHER
12	DARK	HIGH	MEDIUM	HIGHER
13	MEDIUM	LOW	MEDIUM	LESS
14	MEDIUM	MEDIUM	MEDIUM	AVERAGE
15	MEDIUM	HIGH	MEDIUM	AVERAGE
16	BRIGHT	LOW	MEDIUM	LESS
17	BRIGHT	MEDIUM	MEDIUM	AVERAGE
18	BRIGHT	HIGH	MEDIUM	HIGHER
19	DARK	LOW	LARGE	LESS

20	DARK	MEDIUM	LARGE	HIGHER
21	DARK	HIGH	LARGE	HIGHEST
22	MEDIUM	LOW	LARGE	LESS
23	MEDIUM	MEDIUM	LARGE	AVERAGE
24	MEDIUM	HIGH	LARGE	HIGHER
25	BRIGHT	LOW	LARGE	LESS
26	BRIGHT	MEDIUM	LARGE	HIGHER
27	BRIGHT	HIGH	LARGE	HIGHEST

A total of 27 such rules are developed and are listed below:

[Rule 1] If [Luminance Sensitivity] is DARK and [Contrast Sensitivity] is LOW and [Edge Sensitivity] is SMALL then [Weighting factor] is LEAST

LUMSEN (DARK) CONSEN (LOW) EDGSEN (SMALL) → WEIFAC (LEAST)

[Rule 2] If [Luminance Sensitivity] is DARK and [Contrast Sensitivity] is MEDIUM and [Edge Sensitivity] is SMALL then [Weighting factor] is LEAST

LUMSEN (DARK) CONSEN (MEDIUM) EDGSEN (SMALL) → WEIFAC (LEAST)

[Rule 3] If [Luminance Sensitivity] is DARK and [Contrast Sensitivity] is HIGH and [Edge Sensitivity] is SMALL then [Weighting factor] is LEAST

LUMSEN (DARK) CONSEN (HIGH) EDGSEN (SMALL) → WEIFAC (LEAST)

[Rule 4] If [Luminance Sensitivity] is MEDIUM and [Contrast Sensitivity] is LOW and [Edge Sensitivity] is SMALL then [Weighting factor] is LEAST

LUMSEN (MEDIUM) CONSEN (LOW) EDGSEN (SMALL) → WEIFAC (LEAST)

[Rule 5] If [Luminance Sensitivity] is MEDIUM and [Contrast Sensitivity] is MEDIUM and [Edge Sensitivity] is SMALL then [Weighting factor] is LEAST

LUMSEN (MEDIUM) CONSEN (MEDIUM) EDGSEN (SMALL) → WEIFAC (LEAST)

[Rule 6] If [Luminance Sensitivity] is MEDIUM and [Contrast Sensitivity] is HIGH and [Edge Sensitivity] is SMALL then [Weighting factor] is LEAST

LUMSEN (MEDIUM) CONSEN (HIGH) EDGSEN (SMALL) → WEIFAC (LEAST)

[Rule 7] If [Luminance Sensitivity] is BRIGHT and [Contrast Sensitivity] is LOW and [Edge Sensitivity] is SMALL then [Weighting factor] is LEAST

LUMSEN (BRIGHT) CONSEN (LOW) EDGSEN (SMALL) → WEIFAC (LEAST)

[Rule 8] If [Luminance Sensitivity] is BRIGHT and [Contrast Sensitivity] is MEDIUM and [Edge Sensitivity] is SMALL then [Weighting factor] is LEAST

LUMSEN (BRIGHT) CONSEN (MEDIUM) EDGSEN (SMALL) → WEIFAC (LEAST)

[Rule 9] If [Luminance Sensitivity] is BRIGHT and [Contrast Sensitivity] is HIGH and [Edge Sensitivity] is SMALL then [Weighting factor] is LEAST

LUMSEN (BRIGHT) CONSEN (HIGH) EDGSEN (SMALL) → WEIFAC (LEAST)

[Rule 10] If [Luminance Sensitivity] is DARK and [Contrast Sensitivity] is LOW and [Edge Sensitivity] is MEDIUM then [Weighting factor] is LESS

LUMSEN (DARK) CONSEN (LOW) EDGSEN (MEDIUM) → WEIFAC (LESS)

[Rule 11] If [Luminance Sensitivity] is DARK and [Contrast Sensitivity] is MEDIUM and [Edge Sensitivity] is MEDIUM then [Weighting factor] is HIGHER

LUMSEN (DARK) CONSEN (MEDIUM) EDGSEN (MEDIUM) → WEIFAC (HIGHER)

[Rule 12] If [Luminance Sensitivity] is DARK and [Contrast Sensitivity] is HIGH and [Edge Sensitivity] is MEDIUM then [Weighting factor] is HIGHER

LUMSEN (DARK) CONSEN (HIGH) EDGSEN (MEDIUM) → WEIFAC (HIGHER)

[Rule 13] If [Luminance Sensitivity] is MEDIUM and [Contrast Sensitivity] is LOW and [Edge Sensitivity] is MEDIUM then [Weighting factor] is LESS

LUMSEN (MEDIUM) CONSEN (LOW) EDGSEN (MEDIUM) → WEIFAC (LESS)

[Rule 14] If [Luminance Sensitivity] is MEDIUM and [Contrast Sensitivity] is MEDIUM and [Edge Sensitivity] is MEDIUM then [Weighting factor] is AVERAGE

LUMSEN (MEDIUM) CONSEN (MEDIUM) EDGSEN (MEDIUM) → WEIFAC (AVERAGE)

[Rule 15] If [Luminance Sensitivity] is MEDIUM and [Contrast Sensitivity] is HIGH and [Edge Sensitivity] is MEDIUM then [Weighting factor] is AVERAGE

LUMSEN (MEDIUM) CONSEN (HIGH) EDGSEN (MEDIUM) → WEIFAC (AVERAGE)

[Rule 16] If [Luminance Sensitivity] is BRIGHT and [Contrast Sensitivity] is LOW and [Edge Sensitivity] is MEDIUM then [Weighting factor] is LESS

LUMSEN (BRIGHT)   CONSEN (LOW)   EDGSEN (MEDIUM) → WEIFAC (LESS)

[Rule 17] If [Luminance Sensitivity] is BRIGHT and [Contrast Sensitivity] is MEDIUM and [Edge Sensitivity] is MEDIUM then [Weighting factor] is AVERAGE

LUMSEN (BRIGHT)   CONSEN (MEDIUM)   EDGSEN (MEDIUM) → WEIFAC (AVERAGE)

[Rule 18] If [Luminance Sensitivity] is BRIGHT and [Contrast Sensitivity] is HIGH and [Edge Sensitivity] is MEDIUM then [Weighting factor] is HIGHER

LUMSEN (BRIGHT)   CONSEN (HIGH)   EDGSEN (MEDIUM) → WEIFAC (HIGHER)

[Rule 19] If [Luminance Sensitivity] is DARK and [Contrast Sensitivity] is LOW and [Edge Sensitivity] is LARGE then [Weighting factor] is LESS

LUMSEN (DARK)   CONSEN (LOW)   EDGSEN (LARGE) → WEIFAC (LESS)

[Rule 20] If [Luminance Sensitivity] is DARK and [Contrast Sensitivity] is MEDIUM and [Edge Sensitivity] is LARGE then [Weighting factor] is HIGHER

LUMSEN (DARK)   CONSEN (MEDIUM)   EDGSEN (LARGE) → WEIFAC (HIGHER)

[Rule 21] If [Luminance Sensitivity] is DARK and [Contrast Sensitivity] is HIGH and [Edge Sensitivity] is LARGE then [Weighting factor] is HIGHEST

LUMSEN (DARK)   CONSEN (HIGH)   EDGSEN (LARGE) → WEIFAC (HIGHEST)

[Rule 22] If [Luminance Sensitivity] is MEDIUM and [Contrast Sensitivity] is LOW and LARGE then [Weighting factor] is LESS

LUMSEN (MEDIUM)   CONSEN (LOW)   EDGSEN (LARGE) → WEIFAC (LESS)

[Rule 23] If [Luminance Sensitivity] is MEDIUM and [Contrast Sensitivity] is MEDIUM and [Edge Sensitivity] is LARGE then [Weighting factor] is AVERAGE

LUMSEN (MEDIUM)   CONSEN (MEDIUM)   EDGSEN (LARGE) → WEIFAC (AVERAGE)

[Rule 24] If [Luminance Sensitivity] is MEDIUM and [Contrast Sensitivity] is HIGH and [Edge Sensitivity] is LARGE then [Weighting factor] is HIGHER

LUMSEN (MEDIUM)   CONSEN (HIGH)   EDGSEN (LARGE) → WEIFAC (HIGHER)

[Rule 25] If [Luminance Sensitivity] is BRIGHT and [Contrast Sensitivity] is LOW and [Edge Sensitivity] is LARGE then [Weighting factor] is LESS

LUMSEN (BRIGHT) CONSEN (LOW) EDGSEN (LARGE) → WEIFAC (LESS)

[Rule 26] If [Luminance Sensitivity] is BRIGHT and [Contrast Sensitivity] is MEDIUM and [Edge Sensitivity] is LARGE then [Weighting factor] is HIGHER

LUMSEN (BRIGHT) CONSEN (MEDIUM) EDGSEN (LARGE) → WEIFAC (HIGHER)

[Rule 27] If [Luminance Sensitivity] is BRIGHT and [Contrast Sensitivity] is HIGH and [Edge Sensitivity] is LARGE then [Weighting factor] is HIGHEST

LUMSEN (BRIGHT) CONSEN (HIGH) EDGSEN (LARGE) → WEIFAC (HIGHEST)

3.5. Algorithm: Watermark Embedding in Phase-I

1. Divide the host image into 8x8 size blocks in spatial domain and compute DCT of all blocks

2. Compute luminance sensitivity, threshold (edge sensitivity) and variance (contrast sensitivity) of all blocks of the host image

3. Supply these parameters as input to the Fuzzy Inference System (FIS)

4. Apply 27 fuzzy inference rules to the FIS and obtain the weighting factor

5. Perform Watermark Embedding in low frequency DCT coefficient of host image

6. Compute Inverse DCT (IDCT) to obtain watermarked (signed) image

The formula for embedding the watermark used in the present work is given in eq. below

EQUATION 3-17: PHASE-1 WATERMARK EMBEDDING

$$X' = X + k*w*p$$

where X is the low frequency DCT coefficient of the host image, w is the output of FIS, p is the watermark, k is the watermark scaling coefficient or watermark embedding strength and X' is the DCT coefficient of the signed image, k is optimized to be 0.05 for this experiment.

A set of Most Frequently Fired Rules in the Fuzzy Rule Engine are shown in the figure 3-6 below:

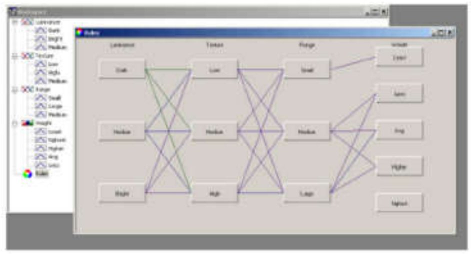


FIGURE 3-6: MOST FREQUENTLY FIRED RULES IN THE FUZZY RULE ENGINE

Any computational device has certain identification numbers like MAC address for a computer, IMEI no. of a mobile phone.

Once the FIS is trained with given set of 27 inference rules. This work proposes the following process for embedding unique identification numbers as watermark for authorization and verification of the original image

Zhao, Jian et. al. [45] suggested the following algorithm which could be further extended for the usage in current computational devices. The first step generates a pseudo random position sequence using the outcome of FIS for selecting the 8x8 sub-blocks, where the code is embedded. This step is denoted as a function Ts(y, U_K) where y is the image data to be labelled, and U_K is the user-supplied secret key. The second step simply embeds or retrieves the code into or from the blocks specified in the position sequence.

The function Ts(y, U_K) initially extracts the required features from the image data, for its further usage with the unique identification numbers provided by user as secret key to be used as seeds for position sequence generation .The featured must be robust against simple image processing that does not affect the visual quality of the image, and they must be image-dependent, i.e. the image can be recognized, distinctively in an ideal case, by these features extracted from the data provided by image under consideration.

Let D be the embedded code generated from the unique secret key, represented by binary bit stream $\{d_0,d_1,..,d_n\}$. Let, i be the index of current bit in this stream. Let B be the block set in which each block can be randomly selected. Initialize i to 0 and B to {}. The framework for writing and reading robust labels is described below:

In figures below following legends are used for label embedding and extraction.

Image Data as (y), User defined Key (U_K), Label Code and Embedded Code as (D), Position Sequence as (PS), Labeled image as (y'), Position Sequence Generator as [$T_s(y, U_k)$], Label Embedding System as (LES), Label Retrieval System (LRS).

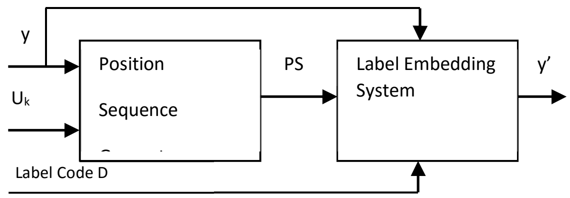


FIGURE 3-7: WRITE LABEL

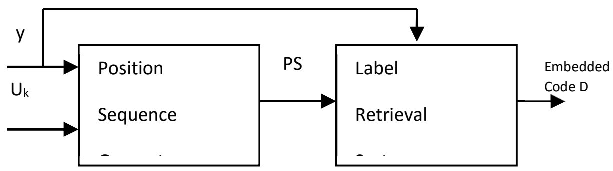


FIGURE 3-8: READ LABEL

Algorithm 1(a): Framework (write)

(1) If $i \geq n$, return.

(2) Randomly select a block *b*, using the position sequence generation function $Ts(U_K, y)$ in Figure 3-7.

(3) If *b* exists already in B, go to (2), otherwise add *b* to B.

(4) Call ***check_write(b, d_i)*** to check whether *b* is a valid block: if this function returns False (i.e. the block

*b*is an invalid block), go to (2).

(5) Call ***write(b,d_i)*** to embed a bit d_i to the block *b*.

(6) Increment i, go to (1).

Algorithm 1(b): Framework (read)

(1) If $i \geq n$, return.

(2) Randomly select a distributed or a contiguous 8x8 block b, using the position sequence generation function $Ts(U_K, y)$ in Figure 3-8.

(3) If b exists already in B, then go to (2), otherwise add b to B.

(4) Call check_read(b,di) to check whether b is a valid block: if this function returns False (i.e. the blockb is an invalid block), go to (2).

(5) Call read(b) to retrieve a bit from the block b.

(6) Increment i, and go to (1).

Once the label is embedded then Quality assessment of the signed image is done by computing Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR).

Executing StirMark Attacks: The watermarked image is further subjected to seven image processing attacks as prescribed by StirMark standard proposed by Petitcolas [38].

(1) Counterclockwise rotation of 90^0.

(2) Dithering of color levels from 256 to 16-color

(3) Gaussian Blur (Radius = 1.0 units)

(4) Brightness and Contrast operation (each 15%)

(5) Median Filtering (Filtering aperture = 3 units)

(6) 10% Gaussian Noise addition

(7) Jpeg compression (QF=90).

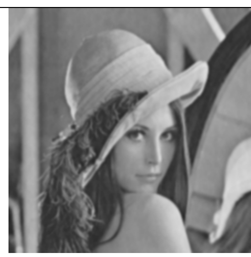
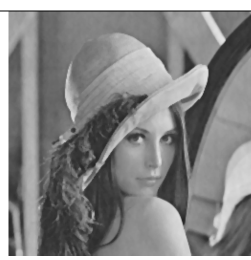
Quality assessment is done using Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR) before and after execution of attacks on the signed image.

Extracting Watermark from Signed Image and Computing SIM(X, X^*) Parameter: Firstly, the DCT of both host and signed images are computed block wise. Thereafter, the computed coefficients are subtracted from each other and the watermark is recovered. Let the original and recovered watermarks be denoted as X and X^* respectively. A comparison check is performed between X and X^* using the similarity correlation parameter given by equation for calculating similarity mentioned below:

EQUATION 3-18: IMAGE SIMILARITY CHECK

$$SIM(X,X\ ) = \frac{\sum_{i=1}^{n}(X,X\ )}{\sum_{i=1}^{n}\sqrt{(X,X\ )}}$$

Figure 3-9 depicts both the host and signed images. The detectable quality of the signed image is very good as indicated by the computed MSE and PSNR values mentioned above it.

 Original Image	 Signed Image MSE: 4.0224dB; PSNR: 42.0860dB
 Attack (a): Rotated CCW-900 MSE: 4.0224dB; PSNR: 42.0860dB	 Attack (b): Brightness & Contrast (10%) MSE: 304.3149dB; PSNR: 23.2976dB
 Attack (c): Blur 3% MSE: 78.3239dB; PSNR: 29.1919dB	 Attack (d): Gassian Noise 10% MSE: 58.0232dB; PSNR: 30.4948dB
 Attack (e): Median Filter(Aperture 3) MSE: 51.9919dB; PSNR: 30.9715dB	 Attack (f): Dithering MSE: 15764.8618dB; PSNR: 6.1539dB

Attack (g): JPEG Compression (Quality 90%) MSE: 7.3549dB; PSNR: 39.4650dB

FIGURE 3-9: MSE AND PSNR CALCULATION OF ATTACKED IMAGES

Figure 3-9(a-g) represent attacked images obtained after executing StirMark prescribed image processing attacks over the image shown Signed image. The respective MSE and PSNR values are mentioned above these images. These computed values are within the expected range for these attacks.

3.6. Conclusion of Optimized Image Watermarking

Computed value of SIM(X, X^*) parameter for the image depicted in Figure 3-9 (Signed Image) is 18.6215 which indicates a good watermark recovery process.

4. Chapter-IV: DMT Scheme (Phase-II): Hardware Implementation and Simulation of image watermarking model.

4.1. Overview of Phase-II

In the previous chapter it has been shared that initial phase of DMT scheme was focused upon the HVS modeling using DCT and Fuzzy Inference system. To integrate all the three sensitive areas identified and extracted from a gray scale image and its implementation using MATLAB coding. But, further the research work to achieve objective of this research work need to identify the hardware implementation of the DMT scheme.

4.2. Phase-II (Simulation of Image Watermarking Model)

Furthermore, the research work was redirected towards the simulation of image watermarking model. It required the steps for implementation which were already taken care from previous implementations. Now, the Block Transforming Techniques used in this research work used following block transformation techniques Discrete Cosine Transformation (DCT), Discrete Wavelet Transformation (DWT), needed to be implemented during transformation of an image from its spatial domain to frequency domain so, that the image watermarking could be robust and can with stand the tampering with the original image, by attacks applied for its removal.

i) Discrete Cosine Transform (DCT): A discrete cosine transform (DCT) expresses a finite sequence of data points in terms of a sum of cosine functions oscillating at different frequencies. DCTs are important to numerous applications in science and engineering, from lossy compression of audio (e.g. MP3) and images (e.g. JPEG) (where small high-frequency components can be discarded), to spectral methods for the numerical solution of partial differential equations. The use of cosine rather than sine functions is critical in these applications: for compression, it turns out that cosine functions are much more efficient (fewer functions are needed to approximate a typical signal), whereas for differential equations the cosines express a particular choice of boundary conditions.

EQUATION 4-1: DCT FOR DIFFERENTIAL EQUATIONS

$$y(k,l) = w(k) \sum_{m=1}^{M} u(m,l) cos \frac{\pi(2m \quad 1)(k \quad 1)}{2M}, k = 1, \dots, M$$

Where

$$w(k) = \begin{cases} \frac{1}{\sqrt{M}}, \; k = 1 \\ \sqrt{\frac{2}{M}}, 2 \leq k \leq M \end{cases}$$

DCT is a Fourier-related transform similar to the discrete Fourier transform (DFT), but using only real numbers. DCTs are equivalent to DFTs of roughly twice the length, operating on real data with even symmetry (since the Fourier transform of a real and even function is real and even), where in some variants the input and/or output data are shifted by half a sample. There are eight standard DCT variants, of which four are common.

ii) Discrete Wavelets Transform (DWT): In numerical analysis and functional analysis, a discrete wavelet transform (DWT) is any wavelet transform for which the wavelets are discretely sampled. As with other wavelet transforms, a key advantage it has over Fourier transforms is temporal resolution: it captures both frequency and location information (location in time).

The DWT of a signal x is calculated by passing it through a series of filters. First the samples are passed through a low pass filter with impulse response ‘g’ resulting in a convolution of the two:

EQUATION 4-2: DWT EQUATION

$$y[n] = (x \quad g)[n] = \sum_{k=-\infty}^{\infty} x[k] g[n \quad k]$$

The mentioned techniques are frequently used in the field of steganography, cryptography, watermarking etc; which are frequently used for data authentication. The proposed work relates to the field of image authentication through digital watermarking technique which is planned to be implemented in the real time domain. The data fuzzification and neural networks are the techniques which are readily used for such purpose. The research work has demonstrated the implementation of real-time robust digital watermarking, by using these techniques.

4.3. BlueThresh() Thresholding Method

This method in the research work propose a technique to embed imperceptible watermark in an image in real-time. The model constitutes of webcam needed to acquire an image in realtime, Matlab version 8.0 with Simulink running on a computer. The acquired image constitutes of RGB colour frames; the work propose to extract the Blue frame for embedding the watermark in it and merge it with other two Red and Green colour frames to reconstitute the image. This process makes the image watermarking robust and optimized.

Blue Channel selected from the RGB Image and applying the formulation to find the threshold that minimizes the weighted within-class variance.

This turns out to be the same as maximizing the between-class variance.

Operates directly on the gray level histogram [e.g. 256 numbers, P(i)], so it's fast (once the histogram is computed).

Histogram (and the image) are bimodal.

No use of spatial coherence, nor any other notion of object structure.

Assumes stationary statistics, but can be modified to be locally adaptive. (exercises)

Assumes uniform illumination (implicitly), so the bimodal brightness behavior arises from object appearance differences only.

The weighted within class variance is:

Equation 4-3: Class Variance

$$\sigma_w^2(t) = q_1(t)\sigma_1^2(t) + q_2(t)\sigma_2^2(t)$$

Where, the class probabilities are estimated as:

Equation 4-4: Class Probability

$$q_1(t) = \sum_{i=1}^{t} P(i)$$

$$q_2(t) = \sum_{i=t+1}^{I} P(i)$$

And the class means are

Equation 4-5: Class Means

$$\mu_1(t) = \sum_{i=1}^{t} \frac{iP(i)}{q_1(t)}$$

$$\mu_2(t) = \sum_{i=t+1}^{I} \frac{iP(i)}{q_2(t)}$$

Finally, the individual class variances are:

Equation 4-6: Individual Class Variance

$$\sigma_1^2(t) = \sum_{i=1}^{t} [i \quad \mu_1(t)]^2 \frac{P(i)}{q_1(t)}$$

$$\sigma_2^2(t) = \sum_{i=t+1}^{I} [i \quad \mu_2(t)]^2 \frac{P(i)}{q_2(t)}$$

This process run through the full range of t values [1,256] and pick the value that minimizes the value of $\sigma_w^2(t)$.

But the relationship between the within-class and between class variances can be exploited to generate a recursion relation that permits a much faster calculation.

For any given threshold, the total variance is the sum of the within-class variances (weighted) and the between class variance, which is the sum of weighted squared distances between the class means and the grand mean, the total variance can be expressed as:

EQUATION 4-7: TOTAL VARIANCE

$$\sigma^2 = \sigma_w^2(t) + q_1(t)[1 \quad q_1(t)][\mu_1(t) \quad \mu_2(t)]^2$$

With-in class from before $\sigma_w^2(t)$

Between class, $\sigma_B^2(t)$ is $q_1(t)[1 \quad q_1(t)][\mu_1(t) \quad \mu_2(t)]^2$

Since the total is constant and independent of t, the effect of changing the threshold is merely to move the contributions of the two terms back and forth.

So, minimizing the within-class variance is the same as maximizing the between-class variance.

The nice thing about this is that it can compute the quantities in $\sigma_B^2(t)$ recursively as it run through the range of t values.

Finally,

$$q_1(1) = P(1)\ ; \mu_1(0) = 0$$

$$q_1(t+1) = q_1(t) + P(t+1)$$

EQUATION 4-8: RECURSION FOR COMPUTATION OF FINAL VALUE

$$\mu_1(t+1) = \frac{q_1(t)\mu_1(t) + (t+1)P(t+1)}{q_1(t+1)}$$

$$\mu_2(t+1) = \frac{\mu \quad q_1(t+1)\,\mu_1(t+1)}{1 \quad q_1(t+1)}$$

The model depicted below is used in the research work for simulating the real-time watermark embedding in the blue channel of an image captured through webcam.

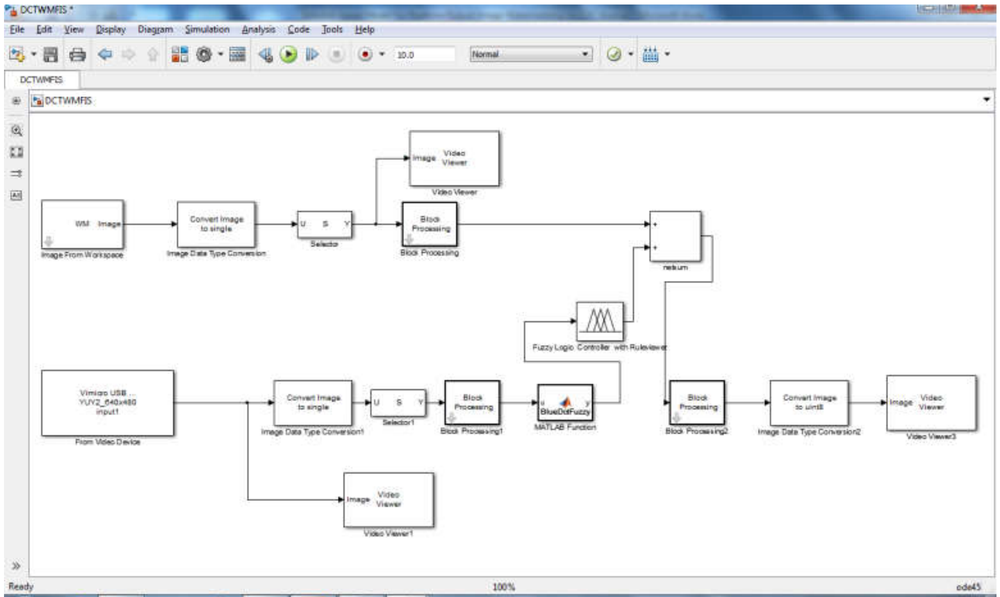
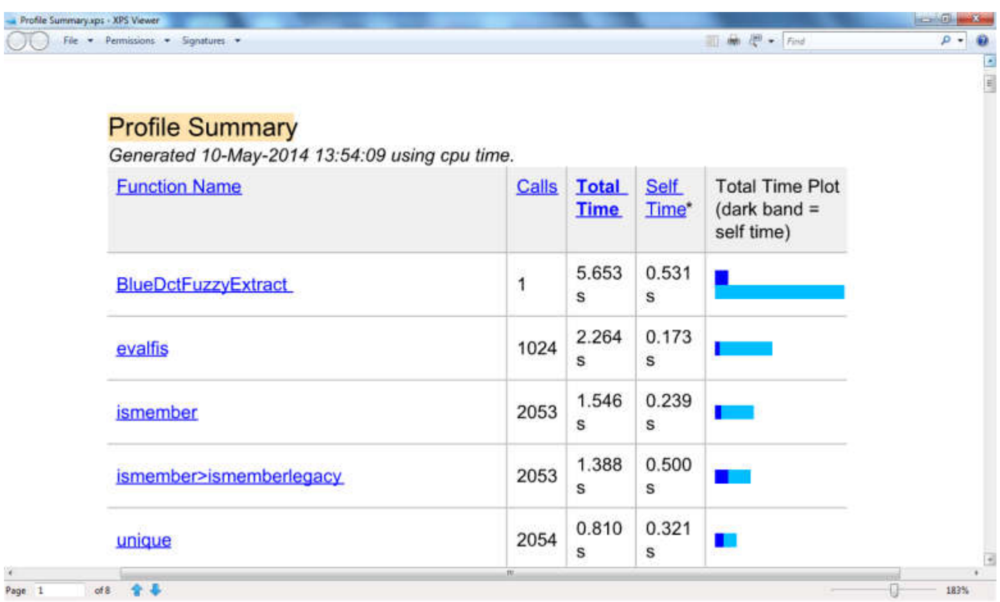


FIGURE 4-1: SIMULINK MODEL FOR REAL-TIME WBC

The profile summary shows the time consumed in the entire process of real-time image watermarking using the proposed method.



Profile Summary

Generated 10-May-2014 13:54:09 using cpu time.

Function Name	Calls	Total Time	Self Time*	Total Time Plot (dark band = self time)
BlueDctFuzzyExtract	1	5.653 s	0.531 s	
evalfis	1024	2.264 s	0.173 s	
ismember	2053	1.546 s	0.239 s	
ismember>ismemberlegacy	2053	1.388 s	0.500 s	
unique	2054	0.810 s	0.321 s	

FIGURE 4-2: PROFILE SUMMARY OF SIMULINK BASED REAL-TIME WBC

Following are the result of watermark embedding process adopted in this paper using SIMULINK

FIGURE 4-3: ORIGINAL IMAGE CAPTURED IN REALTIME

FIGURE 4-4: WATERMARKED IMAGE IN BLUE CHANNEL

MSE: 4.2053dB; PSNR: 41.957dB

4.4. Conclusion of Simulink based real-time watermark embedding

Computed value of SIM(X, X*) parameter for the image depicted in Figure 4-4 (Singed Image) is 18.5987 which indicates a good watermark recovery process. The time consumed in image watermarking is computed as approx. 12 seconds, this model could be extended for the realtime digital image watermarking in camera enabled mobile devices for improving the authenticity of images captured and shared using Smartphone.

5. Chapter-V: DMT Scheme (Phase-III): Realtime implementation image watermarking using Android Mobile phone

As discussed in the previous Phase-I and Phase-II in the chapter 3 and 4 have laid foundation for the implementation of final Phase i.e. Realtime Digital Image Watermarking on Mobile Devices using Android with Energy Efficiency.

5.1. Overview of this chapter

This watermarking scheme used DCT – DWT hybrid transformation through the proposed method, which is using a 2 – level of quantization on the Y component of true color image captured in real time and low frequency band coefficients are selected for the dataset prepared of size 256 * 10 using these coefficients, which is supplied to Extreme Learning Machine (ELM) a single layer feed forward network. A normalized column vector of size 256 * 1 is generated by ELM for its usage as key sequence for embedding the watermark. This hybrid transforms provide a better imperceptibility and reduction in the time taken by entire watermarking process i.e. within a second, makes it energy efficient and suitable for the proposed smart phone android app for a real time image watermarking.

5.2. Phase-II (Hardware Implementation)

As the research work redirected towards hardware implementation of the same, it required a lot of expertise for designing after selecting the right components to be used in this case as suggested in [4]. Various development kits with DSP or Microcontroller and camera from Texas Instruments (TI) with Leopard Imaging which provided the Time-to-Market camera development kit with seamless interface to a TI DM6446 and DM355 DaVinci digital media processor EVM through DM355 Adapter Board (LI-355A). LI-5M01 is a high-resolution digital camera board and it incorporates an Aptina 1/2.5-inch CMOS digital image sensor MT9P031, with an active imaging pixel array of 2592H x 1944V having a capacity of (5038848 pixels) i.e. 5.0 Megapixel.

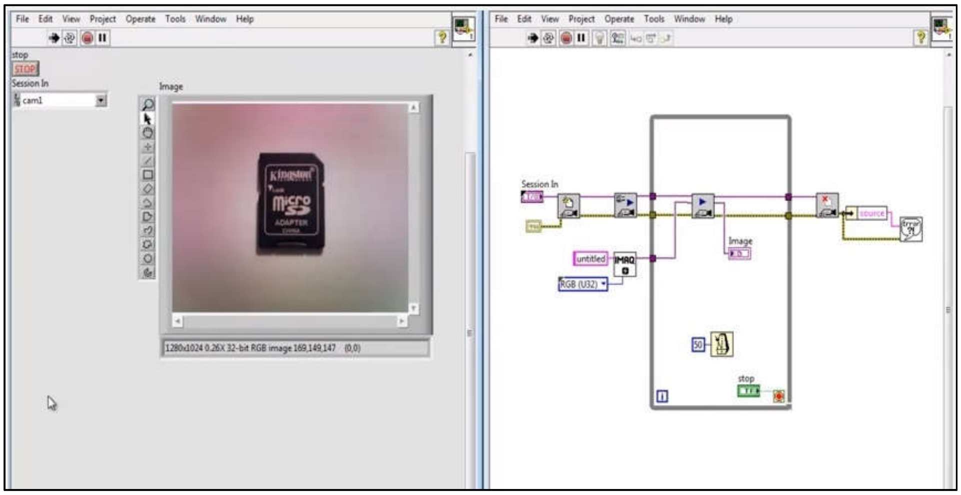


FIGURE 5-1: HARDWARE IMPLEMNTATION OF DMT SCHEME

The LI-5M01 Camera Board produces extraordinarily clear, sharp digital pictures, and it is capable of capturing both continuous video and single frame, which makes it the perfect choice for digital video cameras and surveillance camera, using its software development IDE. Furthermore, National Instruments (NI) development kit with LabVIEW 7.1 VISION and a webcam were explored, but both of the embedded options didn't serve the purpose for this research work of getting implemented in a mobile device, it had only one option to be used a separate gadget, thus the research direction was reframed to be used with built-in capacity of a mobile phone with camera.

5.3. Introduction of Modelling and Analysis

In continuation to the work done by author, the next step comes out to be incorporation and implementation of the proposed model [4] [3]. Initially, android based mobile "LG Optimus P970" was narrowed down to be used as the hardware component because of its good camera handling capabilities. The camera App namely CameraPHD labeled as "Next Gen Cam!" was initially designed for the purpose of real time image watermarking for Android Froyo (2.2) available in the hardware device, then upgraded to Android Gingerbread (2.3) and finally to Ice Cream Sandwich (4.0). Further the updated model was implemented in various other updated Android OS i.e. Jelly Bean, Kitkat, Lollypop and Marshmallow

The image captured by the camera aperture of any android mobile phone through the “Next Gen Cam!” will be processed through the algorithm designed for real time energy efficient image watermarking. In this work Koch’s algorithm [47] is used as a base for the workflow design due to low power consumption and small execution time which further supports in real time performance of the proposed work.

Embedding process comprises of the Host image captured in real time, information needed to embed as watermark and key for the positioning of watermark. The captured host image is loaded for color space transformation into YUV instead of RGB, as Y component is used for the embedding digital watermark. The proposed method is using DWT for 2 – level of quantization on the Y component of true color image converted from the RGB image captured in real time.

EQUATION 5-1: RGB TO YUV CONVERSION

$$\begin{bmatrix} Y' \\ U \\ V \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ 0.14713 & 0.28886 & 0.436 \\ 0.615 & 0.51499 & 0.10001 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

Its low frequency band coefficients are selected for the dataset prepared by DCT of 8x8 blocks integrating to the size 256 * 10 using these coefficients, which is supplied to Extreme Learning Machine (ELM) a single layer feed forward network. The ELM produces a normalized column vector of size 256 * 1 to be used as key sequence for embedding the watermark consisting of attributes like time of capturing the image, IMEI No. of mobile device, SIM No. of the first carrier captured in real time using the camera app installed in any android mobile device. Further, once the watermarked image is created after embedding process, it leads towards de-quantization and inverse DCT (IDCT) of every block. It is needed to multiplex the embedded blocks to create the Y-component layer and loaded for color space transformation from YUV to RGB to get watermarked image.

EQUATION 5-2: YUV TO RGB CONVERSION

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1 & 0 & 1.13983 \\ 1 & 0.39465 & 0.58060 \\ 1 & 2.03211 & 0 \end{bmatrix} \begin{bmatrix} Y' \\ U \\ V \end{bmatrix}$$

5.3.1. ELM Model

Given a series of training samples $(x_i, y_i)_{i=1,2,\ldots,n}$ and $\widehat{N}$ are the number of hidden neurons, where, $x_i = (x_{i1}, x_{i2},\ldots,x_{in}) \in {}^n$ and $y_i = (y_{i1}, y_{i2},\ldots,y_{im}) \in {}^m$,the actual outputs of the single-hidden-layer feed forward neural network (SLFN) with activation function g(x) for these N training data is mathematically modeled as follows:

EQUATION 5-3: SLFN ACTIVATION FUNCTION FOR N TRAINING DATA

$$\sum_{k=1}^{\widehat{N}} \beta_k g(\ w_k, x_i\ +\ b_k) =\ o_i, \forall\ i = 1, \ldots, N \qquad \text{Eq. (A)}$$

Where, $w_k = (w_{k1}, \ldots, w_{kn})$ is a weighting vector connecting the k[th] hidden neuron, $\beta_k = (\beta_{k1}, \ldots, \beta_{km})$ is a weighting vector connecting the k[th] hidden neuron and output neuron and b_k is the threshold bias of the k[th] hidden neuron. The weight vectors w_k are randomly chosen. The term w_k, x_i denotes the inner product of the vectors w_k and x_i, g is the activation function. The above N equations can be written as

$H\beta = O$ Eq. (B) and in practical applications $\widehat{N}$ is usually much less than the number N of training samples and $\beta \neq Y$, where

EQUATION 5-4: REWRITTEN FOR ALL N EQUATIONS

$$H = \begin{bmatrix} g(\ w_1, x_1\ +\ b_1) & g(\ w_N, x_1\ +\ b_{\widehat{N}}) \\ g(\ w_1, x_N\ +\ b_1) & g(\ w_N, x_N\ +\ b_{\widehat{N}}) \end{bmatrix}_{N\times\widehat{N}}$$

EQUATION 5-5: MATRIX VARIABLES FOR N TRAINING SAMPLE

$$\beta = \begin{bmatrix} \beta_1 \\ \beta_{\widehat{N}} \end{bmatrix}_{\widehat{N}\times m} , \; O = \begin{bmatrix} O_1 \\ O_N \end{bmatrix}_{N\times m} \text{ and } \; Y = \begin{bmatrix} Y_1 \\ Y_N \end{bmatrix}_{N\times m} \qquad \text{Eq. (C)}$$

The matrix H is called the hidden layer output matrix. For fixed input weights, $w_k = (w_{k1},\ldots, w_{kn})$ and hidden layer biases b_k , we get the least-squares solution $\hat{\beta}$ of the linear system of equation $H\hat{\beta} = Y$ with minimum norm of output weights β, which gives a good generalization performance. The resulting $\hat{\beta}$ is given by $\hat{\beta} = H^{+}Y$, where H^{+} is the Moore-Penrose generalized inverse of matrix H[9]. The above mathematical expressions of ELM may be generalized as the following form of algorithm.

5.3.2. ELM Algorithm

Given a training set

EQUATION 5-6: TRAINING SET

$$S = \{(x_i, y_i) \in {}^{m+n}, \; y_i \in {}^{m}\} \textstyle\sum_{i=1}^{N}$$

for activation function g(x) and the number of hidden neurons $\widehat{N}$;

Step 1: For k = 1, … $\widehat{N}$ randomly assign the input weight vector $w_k \in {}^{n}$and bias $b_k \in$.

Step 2: Determine the hidden layer output matrix H.

Step 3: Calculate H^{+}

Step 4: Calculate the output weights matrix $\hat{\beta}$ by using $\hat{\beta} = H^{+}T$

Many activation functions can be used for ELM computation. We are using sigmoid activation function to train the ELM.

5.4. Final DMT Model

Analysis of Time complexity and Energy Efficiency and steps used in image watermarking using Camera App designed by the author are mentioned as following steps:

Initialization: Landing Interface or Layout of Camera App (Fig. 3)
Step 1: Screen after clicking Retrieve Information (Fig. 4)
Step 2: This Screen is shown after clicking File Explorer to showcase the path of image saved. (Fig. 5)
Step 3: If you click Original Image for Retrieval, you won't find any watermark and above information screen will be showcased. (Fig. 6)
Step 4: If encrypted image is clicked for retrieving watermark, you find above information screen showcasing the watermark embedded in the image. (Fig. 7)
Step 5: Once you click "View" you will be able to see the watermarked image. (Fig. 8)
"Original Image" (Fig. 9), Watermarked Image (Fig. 10) for the following energy consumption results by the camera app. Storage path for saving captured and watermarked images. 4th Col, 2nd Row indicates the name of folder "durgansh camera" (Fig. 11).

Results for Energy Consumption calculated by Android App for Real-time system and application power monitor "PowerTutor" referred from [16].

- Overall Energy Consumption by CameraPHD is **34.4 J** (Fig. 12)
- Energy Consumption by CameraPHD for for LCD usage is **31.5 J** (Fig. 13)
- Energy Consumption by CameraPHD for CPU usage is **2.9 J** (Fig. 14)

5.4.1. Phase 3 (DMT Scheme)

Finally the phase-1 and phase-2 have provided the inputs required for development of the DMT scheme, which could enable embedding of logic for the usage of mobile phone in image watermarking in real-time. This phase is divided into sub phases or stages of the DMT scheme.

1. Camera as input device – The initial stage is to design the software for using built in camera of phone as an input device to capture the images of size 640 x 480 pixels.
2. Kernel for Digital Watermarking – The kernel was designed to induct the digital watermark consisting of device ID and time of capturing in the image captured by our camera only.
3. User Interface – The interface designed was simple to capture the image as well to see the images captured and watermarked.

Details of Kernel

1. Kernel (Stage-1) Watermark created with device ID and time of image captured, DWT of the captured image
2. Kernel (Stage-2) Division of transformed Image in the block of 8x8 segments and DCT of each block
3. Kernel (Stage-3) Random Position sequence using SLFN based ELM
4. Kernel (Stage-4) Algorithm for the Process of Watermark Embedding
5. Kernel (Stage-5) Watermarked Image saved after Spatial Transformation using IDCT/ IDWT of each block.
6. Kernel (Stage-6) Algorithm for Watermark Extraction

5.4.2. Time Complexity of DMT Scheme (Stage wise and Overall):

1. DWM Kernel with DWT, DCT and ELM
   a. DWT is O(N)
   b. But the Time complexity for 2D Haar DWT matrix method is O(4N^2log2 N)
   c. Fast DCT is O(N log N)

d. ELM Time complexity is C^2 * N.
   Where C is number of features and N is number of entities assuming (N>C).

2. Overall Time complexity of DMT Scheme comes out to be

EQUATION 5-7: OVERALL TIME COMPLEXITY OF DMT SCHEME

a. O(4N^2log2 N) + O(N log N) + C^2 * N

5.4.3. Final Workflow for Mobile App

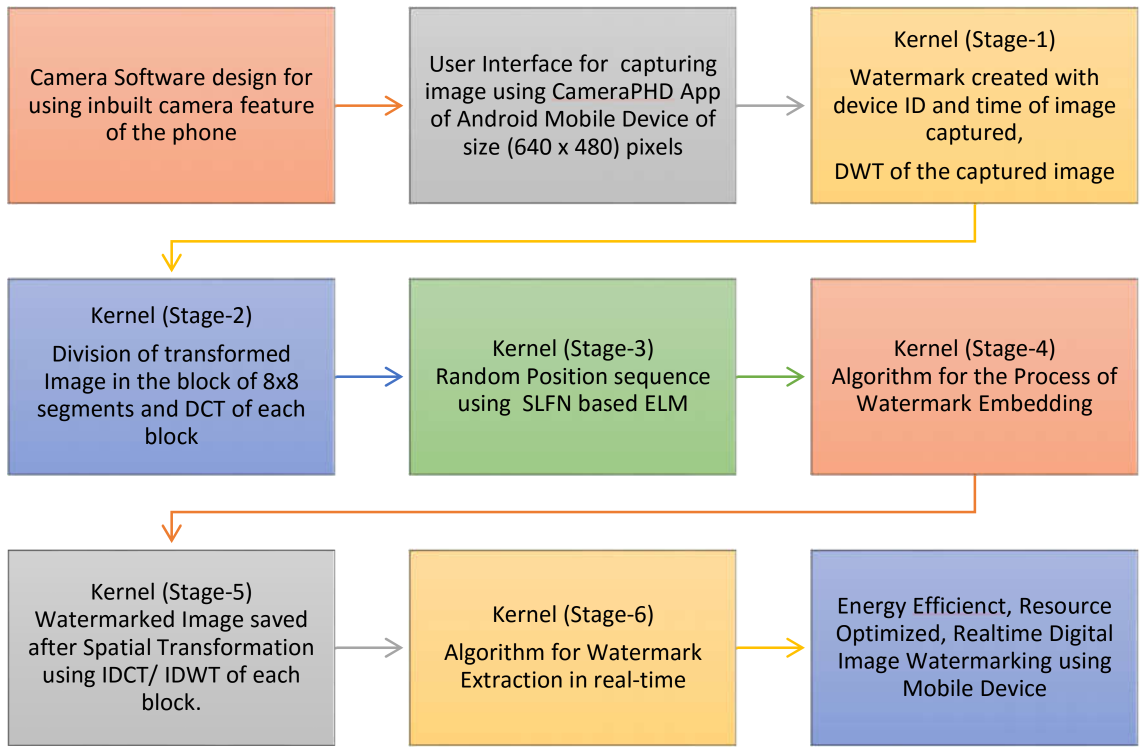


FIGURE 5-2: FINAL WORKFLOW

In continuation to the work done the next step comes out to be incorporation and implementation of the proposed model. Initially, android based mobile "LG Optimus P970" was narrowed down to be used as the hardware component because of its good camera handling capabilities. The camera App namely CameraPHD labeled as "Next Gen Cam!" was initially designed for the purpose of real time image watermarking for Android Froyo (2.2) available in the hardware device, then upgraded to Android Gingerbread (2.3) and finally to Ice Cream Sandwich (4.0).

The image captured by the camera aperture of any android mobile phone through the "Next Gen Cam!" will be processed through the algorithm designed by author for real time energy efficient image watermarking. In this work (Zhao & Eckhard, Embedding Robust Labels into Images for Copyright Protection,

1995) is used as a base for the workflow design due to low power consumption and small execution time which further supports in real time performance of the proposed work.

Embedding process comprises of the Host image captured in real time, information needed to embed as watermark and key for the positioning of watermark. The captured host image is loaded for color space transformation into YUV instead of RGB, as Y component is used for the embedding digital watermark. The proposed method is using DWT for 2 – level of quantization on the Y component of true color image converted from the RGB image captured in real time.

EQUATION 5-8: RGB TO YUV CONVERSION

$$\begin{bmatrix} Y' \\ U \\ V \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ 0.14713 & 0.28886 & 0.436 \\ 0.615 & 0.51499 & 0.10001 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

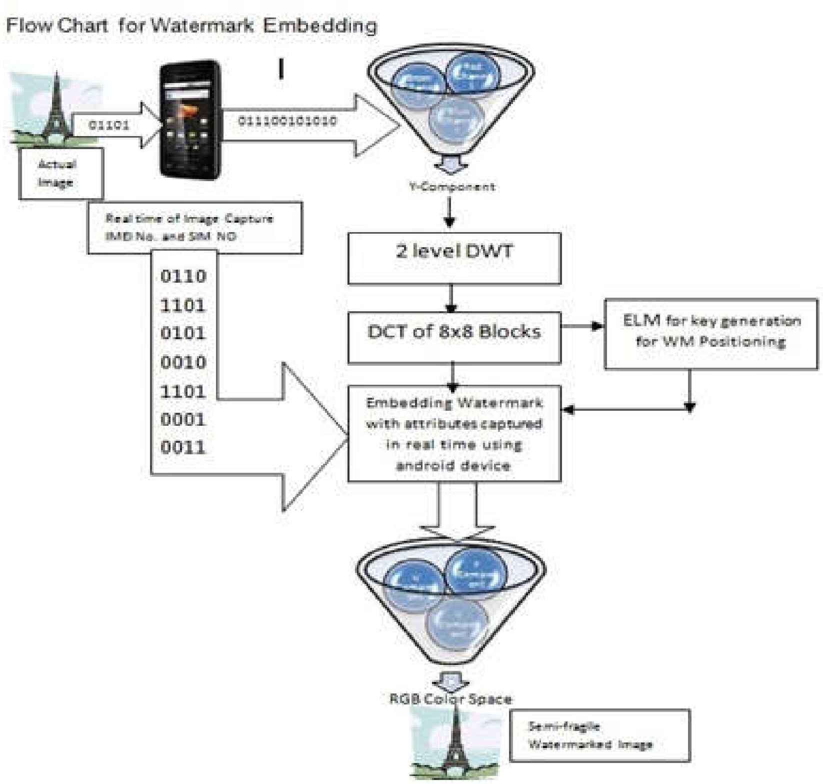


FIGURE 5-3: FLOWCHART FOR WATERMARK EMBEDDING

Its low frequency band coefficients are selected for the dataset prepared by DCT of 8x8 blocks integrating to the size 256 * 10 using these coefficients, which is supplied to Extreme Learning Machine (ELM) a single layer feed forward network. The ELM produces a normalized column vector of size 256 * 1 to be used as key sequence for embedding the watermark consisting of attributes like time of capturing the image, IMEI No. of mobile device, SIM No. of the first carrier captured in real time using the camera app installed in any android mobile device. Further, once the watermarked image is created after embedding process, it leads towards de-quantization and inverse DCT (IDCT) of every block. It is needed to multiplex the embedded blocks to create the Y-component layer and loaded for color space transformation from YUV to RGB to get watermarked image.

EQUATION 5-9: YUV TO RGB CONVERSION

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1 & 0 & 1.13983 \\ 1 & 0.39465 & 0.58060 \\ 1 & 2.03211 & 0 \end{bmatrix} \begin{bmatrix} Y' \\ U \\ V \end{bmatrix}$$

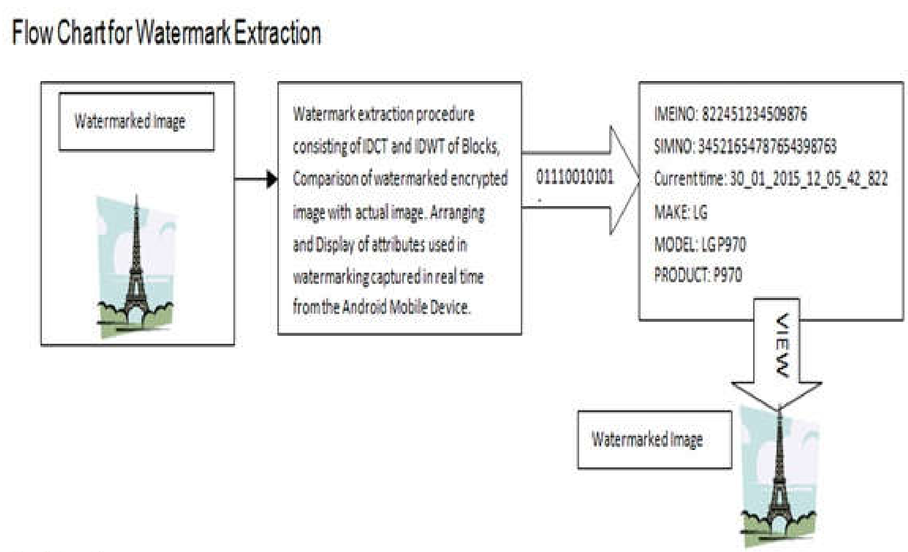


FIGURE 5-4: FLOWCHART FOR WATERMARK EXTRACTION

Computing Moore-Penrose Generalized Inverse of a matrix

A matrix G of order N x N is the Moore-Penrose Generalized Inverse of a real matrix A of order of N x N; AGA = A, GAG = G and AG, GA are symmetric matrices.

Several methods like orthogonal projection, orthogonalization method, iterative methods and singular value decomposition (SVD) methods exists to calculate the Moore-Penrose Generalized Inverse of a real matrix. In ELM algorithm, the SVD method is used to calculate the Moore Penrose generalization inverse of H. Unlike other learning methods, ELM is very well suited for both differential and non-differential activation functions. In the present work computation are done using “Sigmoid” activation function.

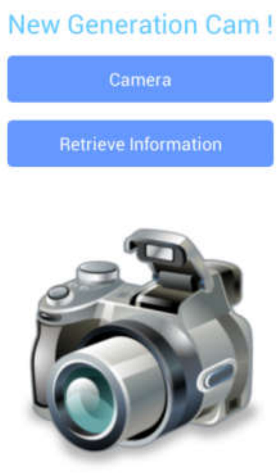


FIGURE 5-5: LANDING LAYOUT

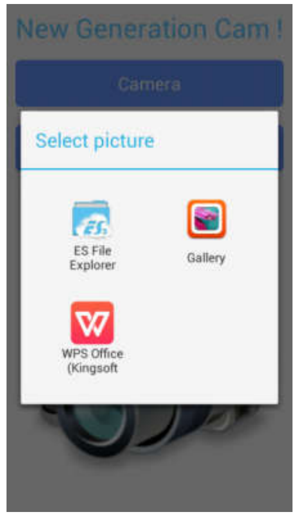


FIGURE 5-6: STEP 1

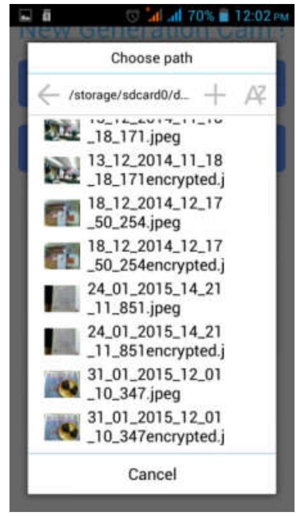


FIGURE 5-7: STEP 2

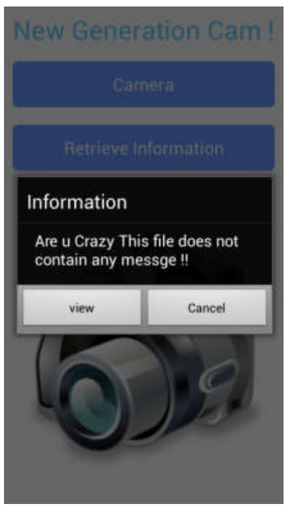


FIGURE 5-8: STEP 3

FIGURE 5-9: STEP 4

FIGURE 5-10: STEP 5

FIGURE 5-11: ORIGINAL IMAGE

FIGURE 5-12: WATERMARKED IMAGE

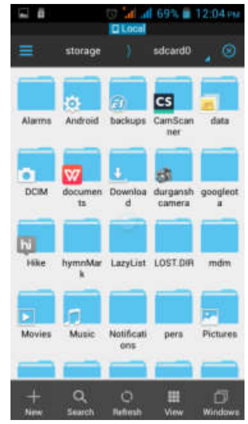


FIGURE 5-13: STORAGE PATH

FIGURE 5-14: OVERALL ENERGY CONSUMPTION BY CAMERA APP

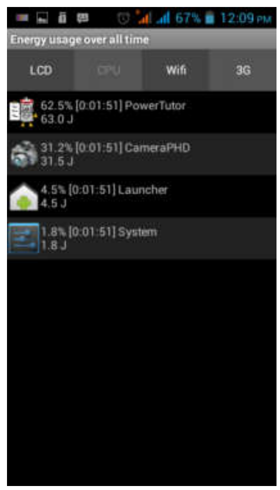


FIGURE 5-15: ENERGY CONSUMPTION BY LCD FOR CAMERA APP

FIGURE 5-16: ENERGY CONSUMPTION BY CPU FOR CAMERA APP

1. Conclusion

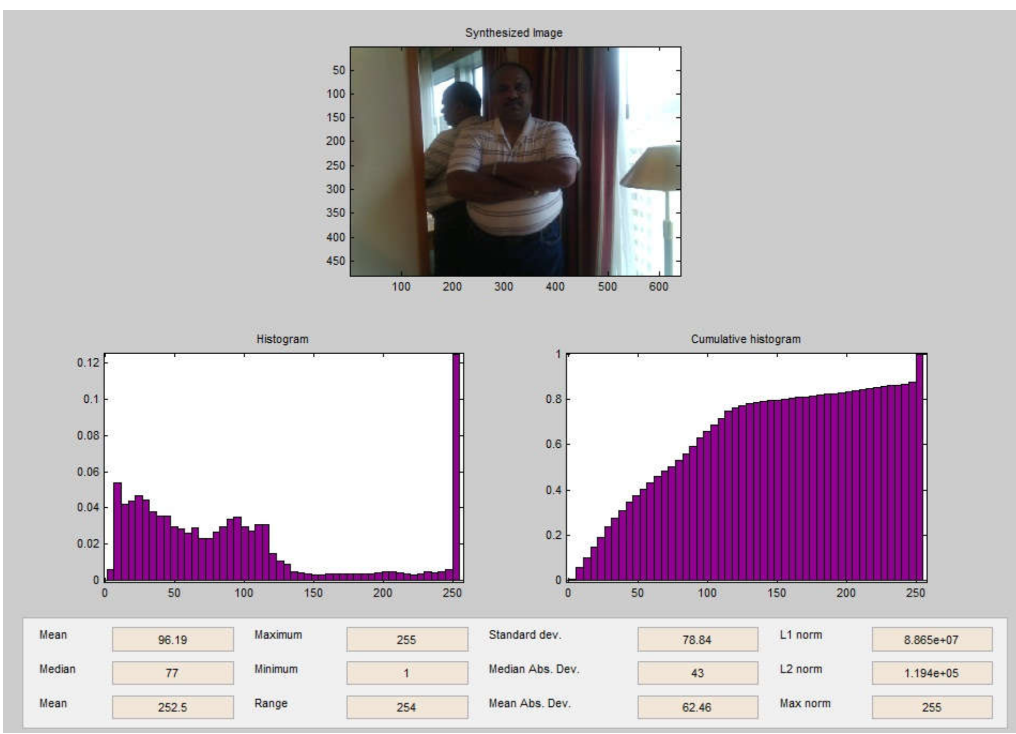
   The camera App is successfully tested and working in Android Jelly Bean 4.2.2 providing energy efficient and realtime image watermarking of the ownership credentials which can be extracted using the application installed.

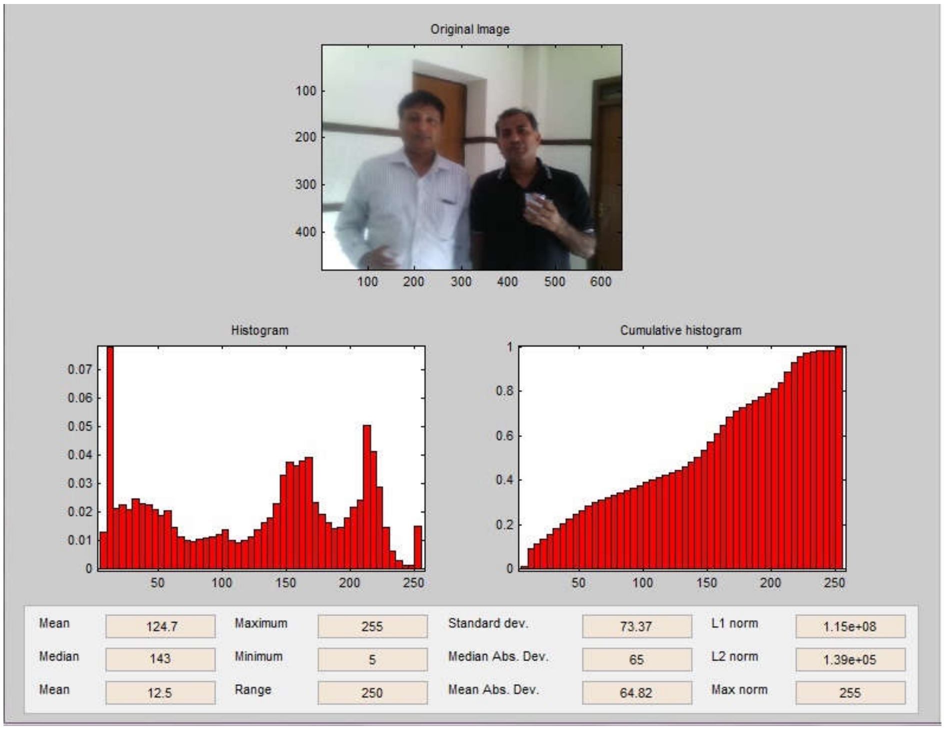
2. Future Scope

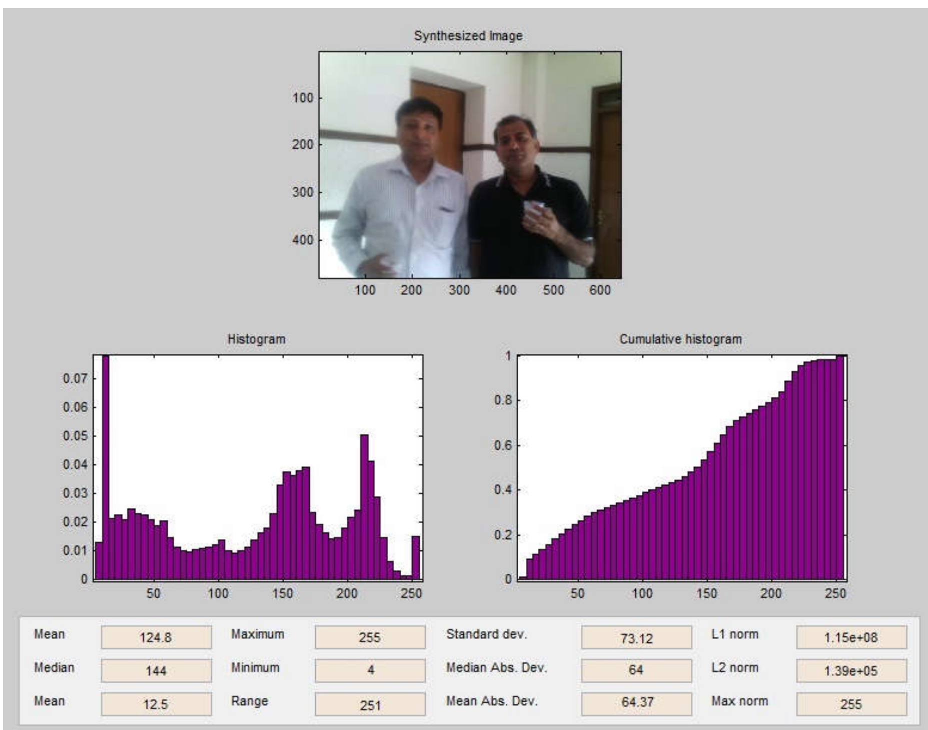
   This research work of energy efficient and real time image watermarking in mobile devices could be further enhanced for various upcoming versions of Android and Models of next generation camera enabled android devices. Extraction of the image watermark could be made generic where essential credentials once provided through cloud services can extract the necessary information from the encrypted image for proving the ownership of the image. This research work could be used in various other camera oriented applications.

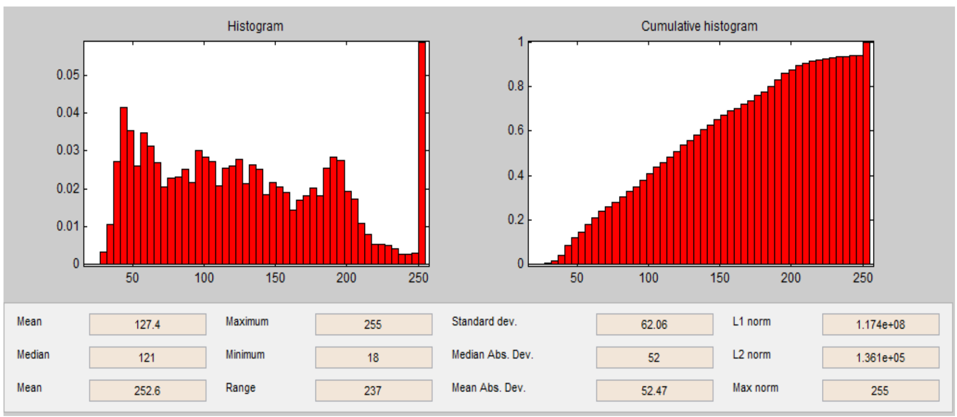
6. Chapter-VI: Results and Evaluation

The results of DMT Scheme are mentioned below




Original Image
Histogram
Cumulative histogram
Mean 124.7
Median 143
Mean 12.5
Maximum 255
Minimum 5
Range 250
Standard dev. 73.37
Median Abs. Dev. 65
Mean Abs. Dev. 64.82
L1 norm 1.15e+08
L2 norm 1.39e+05
Max norm 255


Synthesized Image
Histogram
Cumulative histogram
Mean 124.8
Median 144
Mean 12.5
Maximum 255
Minimum 4
Range 251
Standard dev. 73.12
Median Abs. Dev. 64
Mean Abs. Dev. 64.37
L1 norm 1.15e+08
L2 norm 1.39e+05
Max norm 255


Histogram
0.05
0.04
0.03
0.02
0.01
0
50
100
150
200
250
Cumulative histogram
1
0.8
0.6
0.4
0.2
0
50
100
150
200
250
Mean 127.4
Median 121
Mean 252.6
Maximum 255
Minimum 18
Range 237
Standard dev. 62.06
Median Abs. Dev. 52
Mean Abs. Dev. 52.47
L1 norm 1.174e+08
L2 norm 1.361e+05
Max norm 255

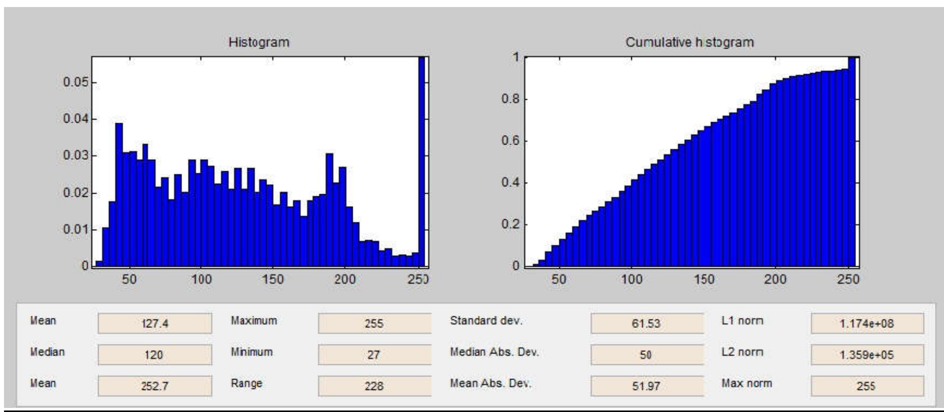

Histogram
Cumulative histogram
Mean 127.4
Median 120
Mean 252.7
Maximum 255
Minimum 27
Range 228
Standard dev. 61.53
Median Abs. Dev. 50
Mean Abs. Dev. 51.97
L1 norm 1.174e+08
L2 norm 1.359e+05
Max norm 255

Table 6-1: Data table for various images captured

Sno	Image	WMTime (ms)	Android-OS	Camera-MegaPixel	CPU-Speed (GHz)	CPU Core	RAM (MB)	Internal Memory (GB)	Internal Memory User (GB)	SD Card (GB)	Battery (mAh)
1	Img1	45	1	5	1	2	512	2	1	2	1500
2	Img2	46	1	5	1	2	512	2	1	2	1500
3	Img3	45	1	5	1	2	512	2	1	2	1500
4	Img4	44	1	5	1	2	512	2	1	2	1500
5	Img5	45	1	5	1	2	512	2	1	2	1500
6	Img6	45	1	5	1	2	512	2	1	2	1500
7	Img7	45	1	5	1	2	512	2	1	2	1500
8	Img8	46	1	5	1	2	512	2	1	2	1500
9	Img9	47	1	5	1	2	512	2	1	2	1500
10	Img10	52	1	5	1	2	512	2	1	2	1500
11	Img11	46	2	5	1	2	512	2	1	2	1500
12	Img12	45	2	5	1	2	512	2	1	2	1500
13	Img13	44	2	5	1	2	512	2	1	2	1500
14	Img14	45	2	5	1	2	512	2	1	2	1500
15	Img15	45	2	5	1	2	512	2	1	2	1500
16	Img16	44	2	5	1	2	512	2	1	2	1500
17	Img17	45	2	5	1	2	512	2	1	2	1500
18	Img18	44	2	5	1	2	512	2	1	2	1500
19	Img19	44	2	5	1	2	512	2	1	2	1500
20	Img20	44	3	5	1	2	512	2	1	2	1500
21	Img21	43	3	5	1	2	512	2	1	2	1500
22	Img22	44	3	5	1	2	512	2	1	2	1500
23	Img23	45	3	5	1	2	512	2	1	2	1500
24	Img24	44	3	5	1	2	512	2	1	2	1500

Sno	Image	WMTime (ms)	Android-OS	Camera-MegaPixel	CPU-Speed (GHz)	CPU Core	RAM (MB)	Internal Memory (GB)	Internal Memory User (GB)	SD Card (GB)	Battery (mAh)
25	Img25	43	3	5	1	2	512	2	1	2	1500
26	Img26	44	3	5	1	2	512	2	1	2	1500
27	Img27	44	3	5	1	2	512	2	1	2	1500
28	Img28	43	3	5	1	2	512	2	1	2	1500
29	Img29	44	3	5	1	2	512	2	1	2	1500
30	Img30	45	3	5	1	2	512	2	1	2	1500
31	Img31	43	3	5	1	2	512	2	1	2	1500
32	Img32	44	3	5	1	2	512	2	1	2	1500
33	Img33	44	3	5	1	2	512	2	1	2	1500
34	Img34	44	3	5	1	2	512	2	1	2	1500
35	Img35	43	3	5	1	2	512	2	1	2	1500
36	Img36	44	3	5	1	2	512	2	1	2	1500
37	Img37	44	3	5	1	2	512	2	1	2	1500
38	Img38	44	3	5	1	2	512	2	1	2	1500
39	Img39	45	3	5	1	2	512	2	1	2	1500
40	Img40	45	3	5	1	2	512	2	1	2	1500
41	Img41	45	3	5	1	2	512	4	2	4	2000
42	Img42	46	3	5	1	2	512	4	2	4	2000
43	Img43	44	3	5	1	2	512	4	2	4	2000
44	Img44	44	3	5	1	2	512	4	2	4	2000
45	Img45	45	3	5	1	2	512	4	2	4	2000
46	Img46	44	3	5	1	2	512	4	2	4	2000
47	Img47	44	3	5	1	2	512	4	2	4	2000
48	Img48	43	3	5	1	2	512	4	2	4	2000

Sno	Image	WMTime (ms)	Android-OS	Camera-MegaPixel	CPU-Speed (GHz)	CPU Core	RAM (MB)	Internal Memory (GB)	Internal Memory User (GB)	SD Card (GB)	Battery (mAh)
49	Img49	44	3	5	1	2	512	4	2	4	2000
50	Img50	44	3	5	1	2	512	4	2	4	2000
51	Img51	43	4	5	1	2	512	4	2	4	2000
52	Img52	43	4	5	1	2	512	4	2	4	2000
53	Img53	43	4	5	1	2	512	4	2	4	2000
54	Img54	44	4	5	1	2	512	4	2	4	2000
55	Img55	43	4	5	1	2	512	4	2	4	2000
56	Img56	43	4	5	1	2	512	4	2	4	2000
57	Img57	43	4	5	1	2	512	4	2	4	2000
58	Img58	43	4	5	1	2	512	4	2	4	2000
59	Img59	43	4	5	1	2	512	4	2	4	2000
60	Img60	43	4	5	1	2	512	4	2	4	2000
61	Img61	38	4	5	1.3	2	1024	4	2	8	3000
62	Img62	37	4	5	1.3	2	1024	4	2	8	3000
63	Img63	38	4	5	1.3	2	1024	4	2	8	3000
64	Img64	38	4	5	1.3	2	1024	4	2	8	3000
65	Img65	38	4	5	1.3	2	1024	4	2	8	3000
66	Img66	37	4	5	1.3	2	1024	4	2	8	3000
67	Img67	38	4	5	1.3	2	1024	4	2	8	3000
68	Img68	38	4	5	1.3	2	1024	4	2	8	3000
69	Img69	37	4	5	1.3	2	1024	4	2	8	3000
70	Img70	37	4	5	1.3	2	1024	4	2	8	3000
71	Img71	37	4	5	1.3	2	1024	4	2	8	3000
72	Img72	38	4	5	1.3	2	1024	4	2	8	3000

Sno	Image	WMTime (ms)	Android-OS	Camera-MegaPixel	CPU-Speed (GHz)	CPU Core	RAM (MB)	Internal Memory (GB)	Internal Memory User (GB)	SD Card (GB)	Battery (mAh)
73	Img73	37	4	5	1.3	2	1024	4	2	8	3000
74	Img74	38	4	5	1.3	2	1024	4	2	8	3000
75	Img75	38	4	5	1.3	2	1024	4	2	8	3000
76	Img76	37	4	5	1.3	2	1024	4	2	8	3000
77	Img77	37	4	5	1.3	2	1024	4	2	8	3000
78	Img78	37	4	5	1.3	2	1024	4	2	8	3000
79	Img79	37	4	5	1.3	2	1024	4	2	8	3000
80	Img80	38	4	5	1.3	2	1024	4	2	8	3000
81	Img81	38	5	8	1.2	4	1024	8	6	8	2200
82	Img82	38	5	8	1.2	4	1024	8	6	8	2200
83	Img83	38	5	8	1.2	4	1024	8	6	8	2200
84	Img84	39	5	8	1.2	4	1024	8	6	8	2200
85	Img85	37	5	8	1.2	4	1024	8	6	8	2200
86	Img86	38	5	8	1.2	4	1024	8	6	8	2200
87	Img87	38	5	8	1.2	4	1024	8	6	8	2200
88	Img88	38	5	8	1.2	4	1024	8	6	8	2200
89	Img89	38	5	8	1.2	4	1024	8	6	8	2200
90	Img90	38	5	8	1.2	4	1024	8	6	8	2200
91	Img91	36	7	5	1.3	4	1024	8	6	8	1700
92	Img92	37	7	5	1.3	4	1024	8	6	8	1700
93	Img93	36	7	5	1.3	4	1024	8	6	8	1700
94	Img94	37	7	5	1.3	4	1024	8	6	8	1700
95	Img95	37	7	5	1.3	4	1024	8	6	8	1700
96	Img96	37	7	5	1.3	4	1024	8	6	8	1700

Sno	Image	WMTime (ms)	Android-OS	Camera-MegaPixel	CPU-Speed (GHz)	CPU Core	RAM (MB)	Internal Memory (GB)	Internal Memory User (GB)	SD Card (GB)	Battery (mAh)
97	Img97	37	7	5	1.3	4	1024	8	6	8	1700
98	Img98	36	7	5	1.3	4	1024	8	6	8	1700
99	Img99	37	7	5	1.3	4	1024	8	6	8	1700
100	Img100	37	7	5	1.3	4	1024	8	6	8	1700
101	Img101	36	6	13	1.7	8	2048	16	12	32	3000
102	Img102	35	6	13	1.7	8	2048	16	12	32	3000
103	Img103	35	6	13	1.7	8	2048	16	12	32	3000
104	Img104	36	6	13	1.7	8	2048	16	12	32	3000
105	Img105	34	6	13	1.7	8	2048	16	12	32	3000
106	Img106	34	6	13	1.7	8	2048	16	12	32	3000
107	Img107	35	6	13	1.7	8	2048	16	12	32	3000
108	Img108	34	6	13	1.7	8	2048	16	12	32	3000
109	Img109	35	6	13	1.7	8	2048	16	12	32	3000
110	Img110	34	6	13	1.7	8	2048	16	12	32	3000
111	Img111	34	7	13	1.7	8	2048	16	12	32	3000
112	Img112	34	7	13	1.7	8	2048	16	12	32	3000
113	Img113	33	7	13	1.7	8	2048	16	12	32	3000
114	Img114	33	7	13	1.7	8	2048	16	12	32	3000
115	Img115	34	7	13	1.7	8	2048	16	12	32	3000
116	Img116	33	7	13	1.7	8	2048	16	12	32	3000
117	Img117	34	7	13	1.7	8	2048	16	12	32	3000
118	Img118	34	7	13	1.7	8	2048	16	12	32	3000
119	Img119	33	7	13	1.7	8	2048	16	12	32	3000
120	Img120	34	7	13	1.7	8	2048	16	12	32	3000

In this analysis all independent variable (features) are highly associated with each other. Therefor stepwise regression analysis conducted to avoid multicollinearity. Based on this analysis five models are suggested. CPU-speed is identified as most influencing feature as suggested by model 1. If we are capable of providing variation in product based on more than one features, the immediate next model suggests SD card as next influencing feature which can be considered. Similarly model 3, model 4 and model 5 suggests Android-OS, RAM and CPU Core respectively to be considered for variation in the product to get best time to perform watermarking on captured image. Models summary, models significance and model wise all feature's significance provided below:

TABLE 6-2: MODEL SUMMARY FOR THE IMAGES CAPTURED

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics		
					R Square Change	F Change	df1
1	.913[a]	.833	.832	1.759	.833	589.422	1
2	.950[b]	.902	.900	1.355	.069	81.908	1
3	.970[c]	.941	.940	1.053	.039	77.644	1
4	.973[d]	.947	.946	1.000	.006	13.603	1
5	.980[e]	.961	.960	.862	.014	40.938	1

TABLE 6-3: MODEL SUMMARY FOR THE IMAGES CAPTURED FOR DF2 AND SIGNIFICANCE

Model Summary

Model	Change Statistics	
	df2	Sig. F Change
1	118[a]	.000
2	117[b]	.000
3	116[c]	.000
4	115[d]	.000
5	114[e]	.000

a. Predictors: (Constant), CPU-Speed (GHz)

b. Predictors: (Constant), CPU-Speed (GHz), SD Card (GB)

c. Predictors: (Constant), CPU-Speed (GHz), SD Card (GB), Android-OS

d. Predictors: (Constant), CPU-Speed (GHz), SD Card (GB), Android-OS, RAM (MB)

e. Predictors: (Constant), CPU-Speed (GHz), SD Card (GB), Android-OS, RAM (MB), CPU Core

TABLE 6-4: ANOVA CALCULATED FOR THE IMAGES CAPTURED

ANOVA[a]

Model		Sum of Squares	Df	Mean Square	F	Sig.
	Regression	1823.591	1	1823.591	589.422	.000[b]
1	Residual	365.076	118	3.094		
	Total	2188.667	119			
	Regression	1973.925	2	986.963	537.738	.000[c]
2	Residual	214.742	117	1.835		
	Total	2188.667	119			
	Regression	2060.028	3	686.676	619.212	.000[d]
3	Residual	128.638	116	1.109		
	Total	2188.667	119			
	Regression	2073.635	4	518.409	518.265	.000[e]
4	Residual	115.032	115	1.000		
	Total	2188.667	119			
	Regression	2104.029	5	420.806	566.788	.000[f]
5	Residual	84.638	114	.742		
	Total	2188.667	119			

a. Dependent Variable: WMTime (ms)

b. Predictors: (Constant), CPU-Speed (GHz)

c. Predictors: (Constant), CPU-Speed (GHz), SD Card (GB)

d. Predictors: (Constant), CPU-Speed (GHz), SD Card (GB), Android-OS

e. Predictors: (Constant), CPU-Speed (GHz), SD Card (GB), Android-OS, RAM (MB)

f. Predictors: (Constant), CPU-Speed (GHz), SD Card (GB), Android-OS, RAM (MB), CPU Core

TABLE 6-5SIGNIFICANCE OF COEFFICIENTS AGAINST ALL THE FACTORS USED FOR IMAGES CAPTURED

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	58.939	.783		75.274	.000
	CPU-Speed (GHz)	-15.398	.634	-.913	-24.278	.000
2	(Constant)	72.715	1.637		44.411	.000
	CPU-Speed (GHz)	-29.583	1.642	-1.754	-18.019	.000
	SD Card (GB)	.361	.040	.881	9.050	.000
3	(Constant)	68.324	1.367		49.989	.000
	CPU-Speed (GHz)	-22.780	1.492	-1.350	-15.272	.000
	SD Card (GB)	.304	.032	.743	9.623	.000
	Android-OS	-.808	.092	-.339	-8.812	.000
4	(Constant)	60.204	2.556		23.556	.000
	CPU-Speed (GHz)	-10.662	3.578	-.632	-2.980	.004
	SD Card (GB)	.463	.053	1.132	8.820	.000
	Android-OS	-.778	.087	-.327	-8.894	.000
	RAM (MB)	-.009	.002	-1.108	-3.688	.000
5	(Constant)	44.095	3.345		13.184	.000
	CPU-Speed (GHz)	9.629	4.423	.571	2.177	.032
	SD Card (GB)	.307	.051	.749	5.962	.000
	Android-OS	-1.145	.095	-.481	-12.089	.000
	RAM (MB)	-.019	.003	-2.455	-7.359	.000
	CPU Core	1.331	.208	.689	6.398	.000

a. Dependent Variable: WMTime (ms)

7. Chapter-VII: Conclusion and Future Scope of Work

The research work done has provided the insights of results taken during realtime image watermarking process using Android 4.2.2 (Jelly bean), it was further extended to the latest android OS i.e. Android 6.0 (Marshmallow). It can be extended further for various industrial and commercial applications which could generate a better image authentication and ownership criteria at realtime using most pervasive devices like Android based Smart Phones. For industrial application the algorithm could be embedded in the cameras for better futuristic communications using images and videos.

Conclusion:

The research work done was fast and energy efficient and image watermarking was implemented in real time for mobile devices.

Future Scope:

Realtime Image Watermarking Scheme developed could be extended for high resolution images and made free from space complexities and spatial transformations. The work can be extended for its implementation in microcontrollers and DSP to make better and secure imaging solutions with inbuilt real time watermarking scheme.

8. References

[1] S. Katzenbeisser and F. Petitcola, "Information Hiding Techniques for Steganography and Digital Watermarking," *London: Artech House,* 2000.

[2] T. Chattopadhyay and A. Pal, "A Survey on Video Security with focus on H.264 Steganography, Cryptography and Watermarking techniques," in *2nd National Conference on Recent Trends in Information System (ReTIS)*, Kolkata, India, 2008.

[3] D. Sharma, M. Prateek and T. Chattopadhyay, "Optimized Robust Image Watermarking," in *International Conference on Emerging Trends in Engineering & Technology (IETET)*, Kurukshetra, 2013.

[4] D. Sharma, M. Prateek and T. Chattopadhyay, "DCT and Simulink Based Realtime Robust Image Watermarking," *International Journal of Image Processing,* vol. 8, no. 4, pp. 214-219, 2014.

[5] I. J. Cox, J. Kilian, F. T. Leighton and T. Shamoon, "Secure Spread Spectrum Watermarking for Multimedia," *Image Processing, IEEE Transactions,* vol. 6, no. 12, pp. 1673-1687, December 1997.

[6] W. Diffie and M. Hellman, "New Directions in cryptography," *IEEE Transactions on Information Theory,* Vols. IT-22, pp. 644-654, 1976.

[7] C. Badgaiyan, A. K. Dewagan, B. K. Pandey, K. Yeulkar and K. K. Sinha, "A New Steganographic Technique: Image Hiding in Mobile Application," *International Journal of Advanced Computer and Mathematical Sciences,* pp. 556-562, 2012.

[8] T. Chattopadhyay and A. Pal, "A Novel, Low Complexity Video Watermarking Scheme for H.264," in *TI Developer Conference*, Dallas, Texas, 2007.

[9] M. L. Jawad and B. S. Gazali, "A Review of Color Image Encryption Techniques," *International Journal of Computer Science Issues (IJCSI),* vol. 10, no. 6, 2013.

[10] S. Samanta, S. Dutta and G. Sanyal, "An enhancement of security of image using permutation of RGB-components," in *3rd International Conference on Electronics Computer Technology (ICECT)*, 2011.

[11] R. Liu and T. Tan, "An SVD based watermarking scheme for protecting rightful ownership," *IEEE Trnsactions on Multimedia,* vol. 4, no. 1, pp. 121-128, 2002.

[12] S. Madhesiya and S. Ahmed, "Advanced Technique of Digital Watermarking based on SVD-DWT-DCT and Arnold Transform," *Journal of Advanced Research in Computer Engineering & Technology (IJARCET),* vol. 2, no. 5, p. 1918, 2013.

[13] M. Ali, C. W. Ahn and M. Pant, "A robust image watermarking technique using SVD and differential evolution in DCT domain," *Optik-International Journal for Light and Electron Optics, Elsevier,* vol. 125, no. 1, pp. 428-434, 2014.

[14] V. Aslantas and D. Mevlut, "A new SVD based fragile image watermarking by using genetic algorithm," in *Sixth International Conference on Graphic and Image Processing (ICGIP 2014)*, 2014.

[15] L. Rajab, T. Al-Khatib and A. Al-Haj, "Video watermarking algorithm using the SVD transform," *European Journal of Scientifi Research,* vol. 30, no. 3, pp. 389-401, 2009.

[16] C. Agarwal and A. Mishra, "A Novel Image Watermarking Technique using Fuzzy-BP Network," in *6th International Conference on Intelligent Information Hiding and Multimedia Signal Processing (IIH-MSP)*, 2010.

[17] C. Agarwal, A. Mishra and A. Sharma, "Digital image watermarking in DCT domain using fuzzy inference system," in *24th Canadian Conference in Electrical and Computer Engineering (CCECE)*, 2011.

[18] C. Agarwal, A. Mishra, A. Sharma and G. Chetty, "A novel scene based robust video watermarking scheme in DWT domain using extreme learning machine," in *Extreme Learning Machines 2013: Algorithms and Applications*, 2014.

[19] A. M. Alattar, "Smart images using Digimarc's watermarking technology," in *SPIE Electronic Imaging '00, Security and watermarking of Multimedia content II*, San Jose, CA, 2000.

[20] A. Al-Gindy, H. Al-Ahmad, R. Qahwaji and A. Tawfik, "Watermarking of colour images in the DCT domain using Y channel," in *IEEE/ACS International Conference on Computer Systems and Applications, AICCSA 2009.*, 2009.

[21] A. Al-Gindy, H. Al-Ahmad, R. Qahwaji and A. Tawfik, "A new watermarking scheme for colour images captured by mobile phone cameras," *International Journal of Computer Science and Information Security,* pp. 248-254, 2009.

[22] Q. Guo, G. X. Chen, J. Luo and Q. F. Chen, "A Blind Watermarking Algorithm Using DWT and DCT Techniques for Color Image," *Applied Mechanics and Materials,* vol. 731, pp. 179-82, April 2015.

[23] N. Hess-Nielsen and M. V. Wickerhauser, "Wavelets and Time-Frequency Analysis," in *Proceedings of the IEEE, 84(4)*, 1996.

[24] K. Huang and A. Selin, "Wavelet Feature Selection for Image Classification," in *Image Processing, IEEE Transactions on, 17(9)*, 2008.

[25] P. S. Huang, C. S. Chiang and C. P. Chang, "Robust Spatial Watermatking technique for color images via direct saturation adjustement," in *IEE Proceedings on Vision, Image and Signal Processing*, 2005.

[26] N. IDRISSI and et al., "A Robust Digital Watermarking Technique using DWT-DCT and Statics blocks," *International Journal of Computer Science Issues,* vol. 10, no. 2, 2013.

[27] N. S. Jayant, J. D. Johnson and R. Safranek, "Signal compression based on models of human perception," in *Proceedings of IEEE*, 1993.

[28] J. Jeedella and H. Al-Ahmad, "An algorithm for watermarking mobile phone colour images using BCH code," in *In GCC Conference and Exhibition (GCC)*, 2011.

[29] J. Jeswani and T. Sarode, "An Improved Blind Color Image Watermarking using DCT in RGB Color Space," *International Journal of Computer Applications,* vol. 92, no. 14, 2014.

[30] H.-M. Lee and B.-H. Lu, "FUZZY BP: a neural network model with fuzzy inference," in *IEEE World Congress on Computational Intelligence*, 1994.

[31] T. C. Lin and C. M. Lin, "Wavelet based copyright protection scheme for digital images based on local features," *Information Sciences,* vol. 179, no. 19, pp. 3349-3358, 2009.

[32] D.-C. Lou, H. Ming-Chang and L. Jhiang-Lung, "Healthcare Image Watermarking Scheme Based on Human Visual Model abd Back-Propagation Network," *Journal of CCIT,* vol. 37, no. 1, pp. 151-162, 2008.

[33] N. Miao, H. Yutao and D. Jane, "hymnmark: Towards Efficient Digital Watermarking on Android Smartphones," in *The 2012 International Conference on Wireless Networks (ICWN'12)*, 2012.

[34] N. Nikoliadis and I. Pitas, "Benchmarking of watermarking algorithms," in *Intelligent Watermarking Techniques*, New Jersey, World Scientific, 2004, pp. 315-347.

[35] I. K. Park, N. Singhal, M. H. Lee, S. Cho and C. W. Kim, "Design and Performance Evaluation of Image processing algorithms on GPUs," in *Parallel and Distributed Systems, IEEE Transactions on, 22(1)*, 2011.

[36] F. Petitcolas, *Watermarking Schemes Evaluation,* 2000, pp. 58-64.

[37] C. R. Piao, S. Beack, D. M. Woo and S. S. Han, "A blind watermarking algorithm based on HVS and RBF neural network for digital image," *Advances in Natural Computation, Springer Berlin Heidelberg,* pp. 493-496, 2006.

[38] A. B. Sewaif, M. Al-Mualla and H. Al-Ahmad, "2 D Walsh Coding for Robust Digital Image Watermarking," in *4th IEEE International Symposium on Signal Processing and Information Technology, (ISSPIT2004)*, Rome, Italy, 2004.

[39] Q. Su, N. Yugang, H. Zou and Y. Zhao, "A blind double color image watermarking algorithm based on QR decomposition," *Multimedia tools and applications, Springer,* vol. 72, no. 1, pp. 987-1009, 2014.

[40] B. Verma, S. Jain, D. P. Agarwal and A. Phadikar, "A new color image watermarking Scheme," *Infocomp, Journal of Computer Science,* vol. 5, pp. 37-42, 2006.

[41] Y. R. Wang, W. H. Lin and L. Yang, "An intelligent watermarking method based on particle swarm optimization," *Expert Systems with Applications, Elsevier,* vol. 38, no. 7, pp. 8024-8029, 2011.

[42] Z. Wei, J. Dai and J. Li, "Genetic watermarking based on DCT domain techniques," in *Canadian Conference on Electrical and Computer Engineering, CCECE'06*, 2006.

[43] R. B. Wolfgang and E. J. Delp, "Fragile Watermarking using the VW2D watermark," in *Security and Watermarking of Multimedia Contents*, San Jose, CA, 1999.

[44] Z. Yong, L. Li-Cai, L. Q. Shen and J. Z. Tao, "A blind watermarking algorithm based on block DCT for dual colour images," in *Second International Symposium on Electronic Commerce and Security, ISECS*, 2009.

[45] J. Zhao and K. Eckhard, "Embedding Robust Labels into Images for Copyright Protection," *KnowRight,* pp. 242-251, 1995.

[46] J. Zhao and K. Eckhard, *Towards robust and hidden image copyright labeling,* Neos, Marmaras: IEEE, 1995.

[47] R. M. Zhao, L. Hua and B. N. Hu, "A blind watermarking algorithm based on DCT," in *Second International Symposium on Intelligent Information Technology Application, IITA'08*, 2008.

[48] Y. Zhou and J. Liu, "Blind watermarking algorithm based on DCT for colour images," in *2nd International Congress on Image and Signal Processing, CISP'09*, 2009.

[49] D. Sharma, M. Prateek and T. Chattopadhyay, "DCT Based Fuzzy Image Watermarking," *Global Journal of Enterprise Information System,* vol. 6, no. 2, pp. 90-95, 2014.

[50] R. C. Gonzales, R. E. Woods and S. L. Eddins, Digital Image Processing using MATLAB, New Delhi: Pearson Education, 2008.

[51] R. C. Gonzales and R. E. Woods, Digital Image Processing, 3rd ed., Pearson Education, 2009.

[52] A. Carroll and G. Heiser, "An Analysis of Power Consumption in a Smartphone," in *2010 USENIX Annual Technical Conference*, 2010.

[53] N. Balasubramanian, A. Balasubramanian and A. Venkataramani, "Energy consumption in mobile phones: a measurement study and implications for network applications," in *Proceedings of the 9th ACM SIGCOMM conference on Internet measurement conference*, 2009.

[54] C. Byung-Gon and M. Petros, "Augmented Smartphone Applications Through Clone Cloud Execution," *In HotOS,* vol. 9, pp. 8-11, May 2009.

[55] M. Dong and Z. Lin, "Self-constructive high-rate system energy modeling for battery-powered mobile systems," in *In Proceedings of the 9th international conference on Mobile systems, applications, and services*, 2011.

[56] A. Kejariwal, S. Gupta, A. Nicolau, N. Dutt and R. Gupta, "Energy analysis of multimedia watermarking on mobile handheld devices," in *Embedded Systems for Real-Time Multimedia, 2005. 3rd Workshop on*, 2005.

[57] A. Kejariwal, S. Gupta, A. Nicolau, N. Dutt and R. Gupta, "Energy efficient watermarking on mobile devices using proxy-based partitioning," *IEEE Transactions on Very Large Scale Integration (VLSI) Systems,* vol. 14, no. 6, pp. 625-636, June 2006.

[58] G. R. Kshirsagar and S. Kulkarni, "Real Time Implementation of Secured Multimedia Messaging Service System using Android," *International Journal of Scientific and Research Publications,* pp. 271-274, March, 2013.

[59] C. C. Lee, J. H. Yeh and J. C. Chen, "Impact of inactivity timer on energy consumption on wcdma and cdma2000," in *Proceedings of Third Annual Wireless Telecommunication Symposium (WTS)*, 2004.

[60] X. Liu, A. Sridharan, S. Machiraju, M. Seshadri and H. Zang, "Experiences in a 3g network: interplay between the wireless channel and Applications," in *14th International conference on Mobile computing and networking*, NY, New York, USA, 2008.

[61] L. Z. B. T. Mark Gordon, "PowerTutor," 2011. [Online]. Available: http://ziyang.eecs.umich.edu/projects/powertutor/.

[62] M. Motwani and F. C. Harris, Jr, "Fuzzy Perceptual Watermarking For Ownership Verification," in *International Conference on Image Processing, Computer Vision, & Pattern Recognition*, Las Vegas, 2009.

[63] A. Pathak, Y. C. Hu and M. Zhang, "Where is the energy spent inside my app? Fine Grained Energy Accounting on Smartphones with Eprof," in *EuroSys*, Bern, Switzerland, 2012.

[64] J. Nurminen and J. K. Noyranen, "Energy-consumption in mobile peer-to-peer - quantitative results from file sharing," in *Consumer Communication and Networking Conference (CCNC)*, Washington, DC, USA, 2008.

[65] A. Rahmati and L. Zhong, "Context-for-wireless: context-sensitive energy-efficient wireless data transfer," in *In MobiSys '07: Proceedings of the 5th international conference on Mobile systems, applications and services*, New York, NY, USA, 2007.

[66] Y. Xiao, R. S. Kalayanaraman and A. Yla-Jaaski, "Energy consumption of mobile youtube: Qualitative measurement and analysis," in *NGMAST '08, The Second International Conference on Next Generation Mobile Applications*, Washington, DC, USA, 2008.

[67] J. H. Yeh, J. C. Chen and C. C. Lee, "Comparative analysis of energy-saving techniques in 3gpp and 3gp2 systems," *Transactions on Vehicular Technology, IEEE,* vol. 58, pp. 432-448, 2009.

[68] M. Dmitriev, "Profiling Java applications using code hotswapping and dynamic call graph revelation," *ACM SIGSOFT Software Engineering Notes,* pp. 139-150, 2004.

[69] S.-S. Kim and S. Jung, "Hardware Implementation of a Neural Network Controller with an MCU and an FPGA for Nonlinear Systems," *International Journal of Control, Automation, and Systems,* vol. 4, no. 5, pp. 567-574, October 2006.

[70] T. E. Mursalin, Z. E. Fajrana and I. Ridwanul, *Fabric defect inspection system using neural network and microcontroller,* 2005, p. 100.

[71] G. B. Huang, Q. Y. Zhu and C. K. Siew, "Extreme Learning Machine: Theory and Applications," *Neurocomputing,* vol. 70, no. 1, pp. 489-501, 2006.

[72] G. B. Huang, Q. Y. Zhu and C. K. Siew, "Real-time learning capability of neural networks," *IEEE Transactions on Neural Networks,* vol. 17, no. 4, pp. 863-878, 2006.

[73] G. B. Huang, Q. Y. Zhu and C. K. Siew, "Extreme learning machine: a new learning scheme of feedforward neural networks," in *IEEE International Joint Conference on Neural Networks*, Budapest, Hungary, July, 2004.

[74] S. P. Mohanty and K. Elias, "Real-time perceptual watermarking architectures for video broadcasting," *Journal of Systems and Software,* pp. 724-738, 2011.

[75] M. Satyanarayanan, G. Benjamin, T. Matt, N. Tolia, D. R. Hallaron, A. Surie and A. Wolbach, "Pervasive personal computing in an internet suspend/resume system," *IEEE Internet Computing,* vol. 11, no. 2, pp. 16-25, 2007.

[76] Y. H. Chen and H. C. Huang, "Coevolutionary genetic watermarking for owner identification," *Neural Computing and Applications, Springer,* vol. 26, no. 2, pp. 291-298, 2014.

[77] T. H. Cormen, C. E. Leiserson, R. L. Rivest and C. Stein, Introduction to Algorithms, 2nd ed., New Delhi: Prentice Hall of India, 2007.

[78] J. A. Freeman and D. M. Skapura, Neural Networks Algorithms, Applications and Programming Techniques, Pearson Education, 1991.

[79] M. M. Gupta, L. Jin and N. Homma, Static and Dynamic Neural Networks, New Jersey: IEEE Press & Wiley Interscience, 2002.

[80] B. Isac and V. Santhi, "A study on digital image and video watermarking schemes using neural networks," *International Journal of Computer Applications,* vol. 12, no. 9, pp. 1-6, 2011.

[81] J. Jang and N. Gulley, "Fuzzy Logic Toolbox for Use With MATLAB," The Mathworks, Inc., 2006.

[82] D. C. Lou and T. L. Yin, "Adaptive Digital Watermarking using Fuzzy Logic Techniques," *Optical Engineering,* vol. 41, pp. 2675-2687, 2002.

[83] E. H. Mamdani and S. Assilian, "An experiment in linguistic synthesis with a fuzzy logic controller," *International Journal of Man-Machine Studies,* vol. 7, no. 1, pp. 1-13, 1975.

[84] R. Mehta, N. Rajpal and V. P. Vishwakarma, "Adaptive Image Watermarking Scheme Using Fuzzy Entropy and GA-ELM Hybridization in DCT Domain for Copyright Protection," *Journal of Signal Processing Systems,* pp. 1-17, 2015.

[85] S. Mitra and S. K. Pal, "Fuzzy self organization, inferencing and rule," *IEEE Transactions on Systems, Man and Cybernetics, Part A: Systems and Humans,,* vol. 26, no. 5, pp. 608-620, 1996.

[86] S. Mitra and Y. Hayashi, "Neuro-fuzzy rule generation: Survey in softcomputing framework," *IEEE Transactions on Neural Networks,* vol. 11, no. 3, pp. 748-767, May 2000.

[87] A. Mishra, A. Goel, R. Singh, G. Chetty and L. Singh, "A novel image watermarking scheme using extreme learning machine," in *International Joint Conference on Neural Networks*, 2012.

[88] A. Mishra and A. Goel, "A novel Image Watermarking Scheme using Hybrid DWT-DCT-ELM Technique," *International Journal of Computer Applications,* vol. 98, no. 18, pp. 28-33, 2014.

[89] A. Mishra and A. Goel, "A Novel HVS Based Gray Scale Image Watermarking Scheme Using Fast Fuzzy-ELM Hybrid Architecture," in *Proceedings of ELM-2014*, 2015.

[90] T. Nakamura, A. Katayama, R. Kitahara and K. Nakazawa, "A fast and robust digital watermark detection scheme for cellular phones," *NTT Technical Review,* pp. 57-63, 2006.

[91] N. Ramamurthy and D. S. Varadarajn, "Robust Digital Image Watermarking Scheme with Neural Network and Fuzzy Logic Approach," *International Journal of Emerging Technology, Advanced Engineering,* vol. 2, no. 9, 2012.

[92] D. Sharma, M. Prateek and T. Chattopadhyay, "Realtime Energy Efficient Digital Image Watermarking on Mobile Devices using Android," *International Journal of Image Processing,* vol. 9, no. 2, pp. 61-68, 2015.

[93] C.-S. Shieh, H.-C. Huang, F.-H. Wang and J.-S. Pan, "Genetic watermarking based on transform-domain techniques," *Pattern Recognition,* vol. 37, no. 3, pp. 555-565, 2004.

[94] Z.-L. Sun, K.-F. Au and T.-M. Choi, "A neuro-fuzzy inference system through integration of fuzzy logic and extreme learning machines," *IEEE Transactions on Systems, Man and Cybernetics,* vol. 37, no. 5, pp. 1321-1331, October 2007.

[95] E. Szmidt and J. Kacprzyk, "Distances between intuitionistic fuzzy sets," *Fuzzy Sets and Systems, Elsevier,* vol. 114, no. 3, pp. 505-518, 2000.

[96] S. G. Tzafestas and K. C. Zikidis, "NeuroFAST: On-line neuro-fuzzy ART-based structure and parameter learning TSK model," in *IEEE Transactions on Systems, Man and Cybernetics, Part B: Cybernetics*, 2001.

[97] J. Zhang, G. G. Walter, Y. Miao and W. N. W. Lee, "Wavelet Neural Networks for Function Learning," in *Signal Processing, IEEE Transactions on, 43(6)*, 1995.

[98] L. A. Zadeh, "Fuzzy sets," *Information and Control,* vol. 8, no. 3, pp. 338-353, 1965.

[99] S. Rajasekran and G. A. Vijaylakshmi Pai, Neural Networks, Fuzzy Logic, and Genetic Algorithms Synthesis and Applications, New Delhi: PHI Learning Pvt. Ltd., 2008.

[100] S. N. Sivanandam, S. Sumathi and S. N. Deepa, Introduction to Neural Networks using MATLAB 6.0, New Delhi: Tata McGraw-Hill, 2009.

[101] A. K. Tyagi, Matlab and Simulink for Engineers, New Delhi: Oxford University Press, 2012.

[102] G. B. Huang, "Extreme Learning Machines," 2013. [Online]. Available: http://www.extreme-learning-machines.org/.

[103] G. Gao, C. Zhou and Z. Cui, "Reversible Watermarking Using Prediction-Error Expansion and Extreme Learning Machine," *Mathematical Problems in Engineering,* 2015.

[104] "Android Open Source Project," 2010. [Online]. Available: http://source.android.com.

[105] K. Elias, S. P. Mohanty and D. K. Pradhan, "Simulink Based Architecture Prototyping of Compressed Domain MPEG-4 Watermarking," in *12th IEEE International Conference on Information Technology (ICIT). 2009*, 2009.

[106] R. Ibrahim and L. C. Kee, "MoBiSiS: An Android-based Application for Sending Stego Image through MMS," in *The Seventh International Multi-Conference on Computing in the Global Information Technology*, 2012.

[107] A. B. Sewaif, M. Al-Mualla and H. Al-Ahmad, "Walsh-Coded Signatures for Robust Digital Image Watermarking," in *Proceedings of the 2004 IEEE Region 10 Conference - Analog and Digital Techniques in Electrical Engineering (TENCON2004)*, Chiang Mai, Thailand, 2004.

[108] K. R. Rao and P. Yip, Discrete Cosine Transform: Algorithms Advantages, Applications, Academic Press, 1990.

[109] G. B. Huang, L. Chen and C. K. Siew, "Universal approximation using incremental networks with random hidden computation nodes," *IEEE Transactions on Neural Networks,* vol. 17, no. 4, pp. 879-892, 2006.

[110] Michael Zhang, "The importance of camera in the smartphone war," 12 February 2015. [Online]. Available: http://petapixel.com/2015/02/12/importance-cameras-smartphone-war/.

9. Appendix-I: Images Captured using various Android based Mobile Phones

<u>**Images Captured from LG P970**</u>

FIGURE 9-1: DURGANSH359704042100234_02_06_2013_18_10_15_683

FIGURE 9-2: DURGANSH359704042100234_02_06_2013_18_11_09_374

FIGURE 9-3: DURGANSH359704042100234_04_04_2013_23_22_22_495

FIGURE 9-4: DURGANSH359704042100234_05_07_2013_16_31_07_442

FIGURE 9-5: DURGANSH359704042100234_06_09_2013_15_15_59_207

Images Captured from XIAOMI RedMI2

FIGURE 9-6: 07_02_2016_15_21_39_129

FIGURE 9-7: 07_02_2016_15_21_39_129ENCRYPTED

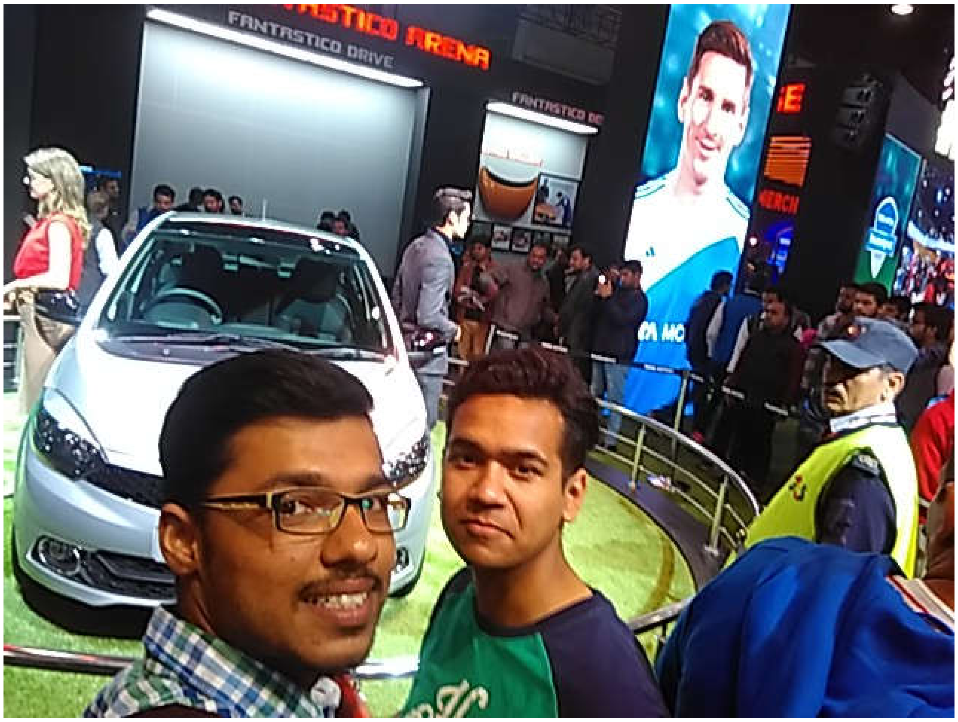


FIGURE 9-8: 07_02_2016_15_26_40_478

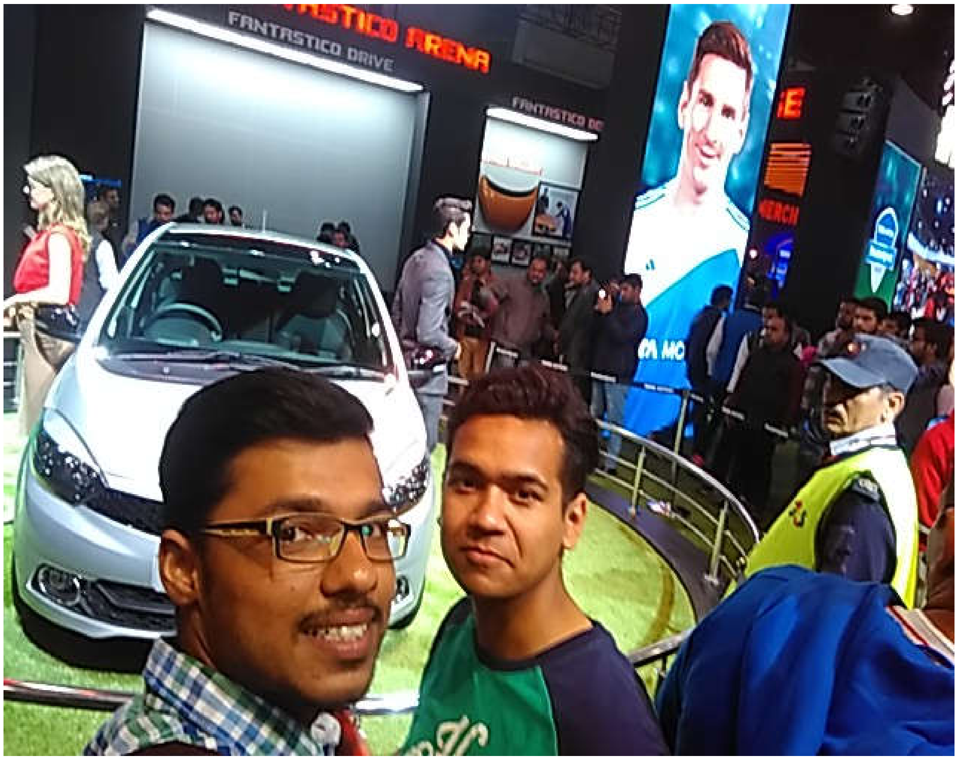


FIGURE 9-9: 07_02_2016_15_26_40_478ENCRYPTED

FIGURE 9-10: 07_02_2016_15_23_34_643

FIGURE 9-11: 07_02_2016_15_23_34_643ENCRYPTED

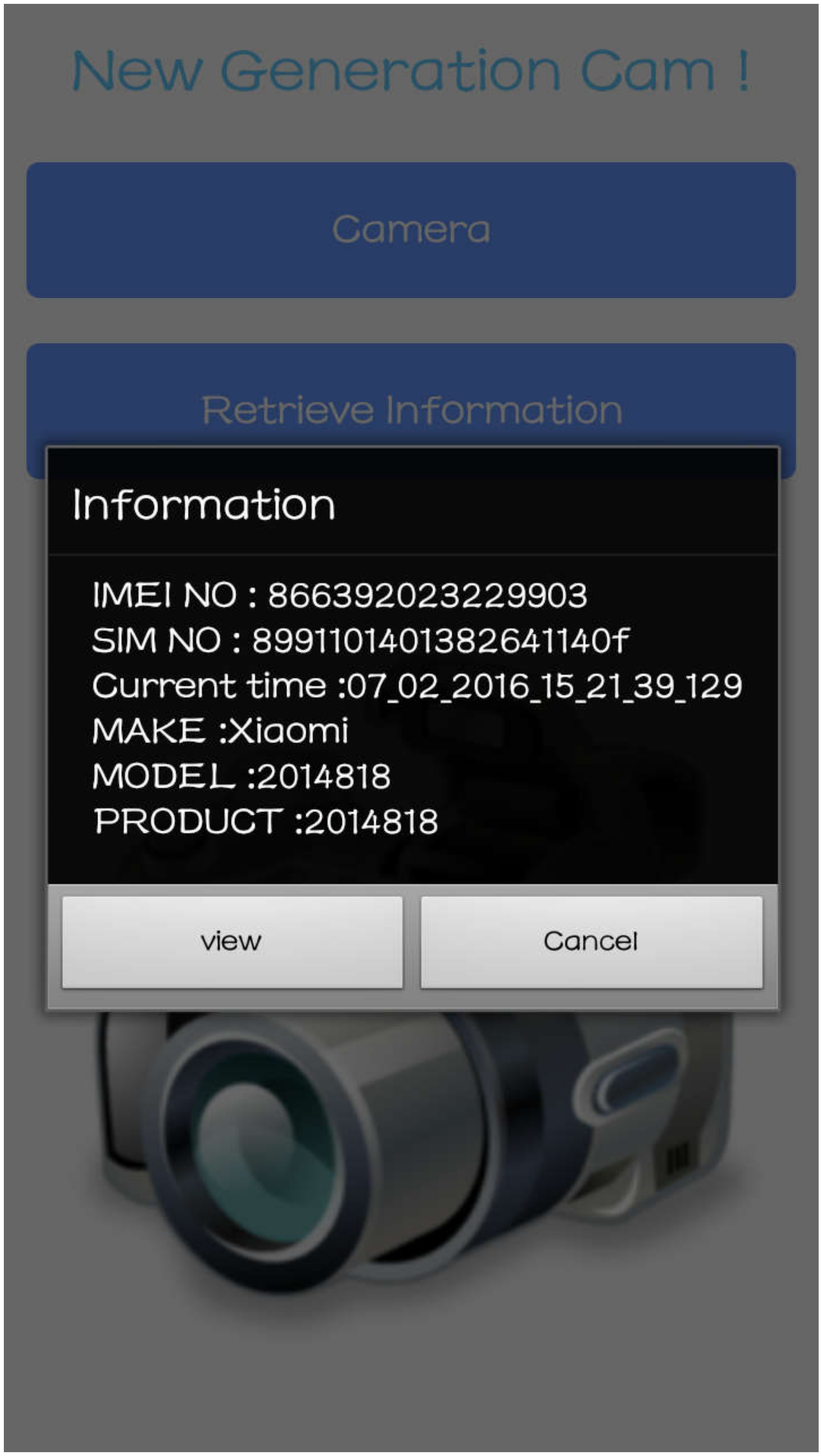


FIGURE 9-12: SCREENSHOT OF ENCRYPTED IMAGE SHOWING THE DETAILS OF XIAOMI

Images Captured from Karbonn Sparkle-V

FIGURE 9-13: 18_02_2016_00_12_24_27

FIGURE 9-14: 18_02_2016_00_12_24_27ENCRYPTED

FIGURE 9-15: 18_02_2016_00_12_43_45

FIGURE 9-16: 18_02_2016_00_12_43_45ENCRYPTED

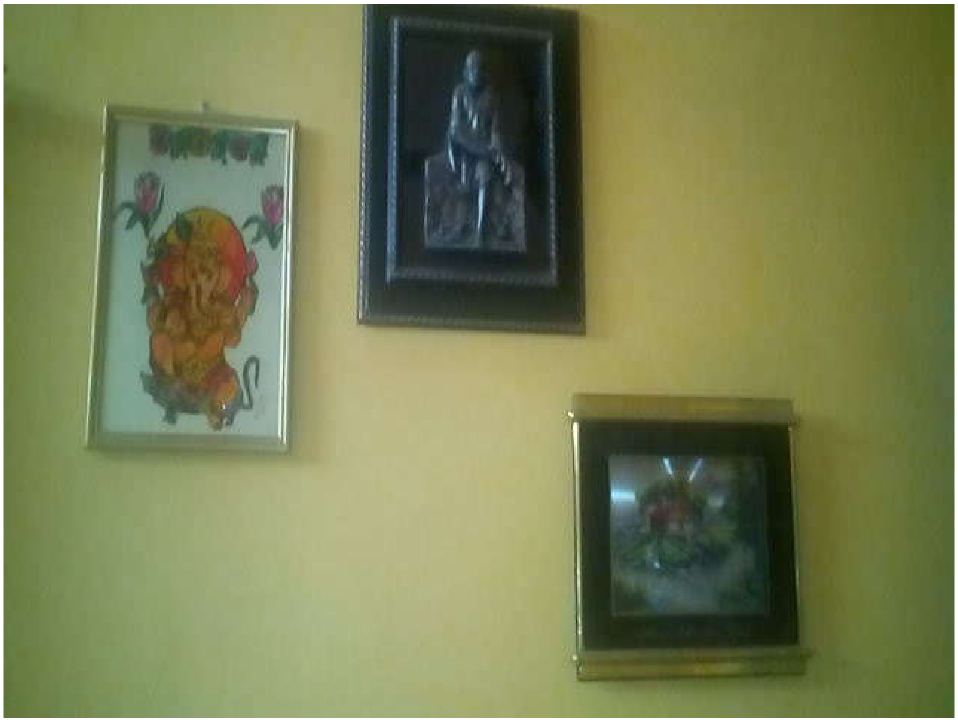


FIGURE 9-17: 18_02_2016_00_13_17_68

FIGURE 9-18: 18_02_2016_00_13_17_68ENCRYPTED

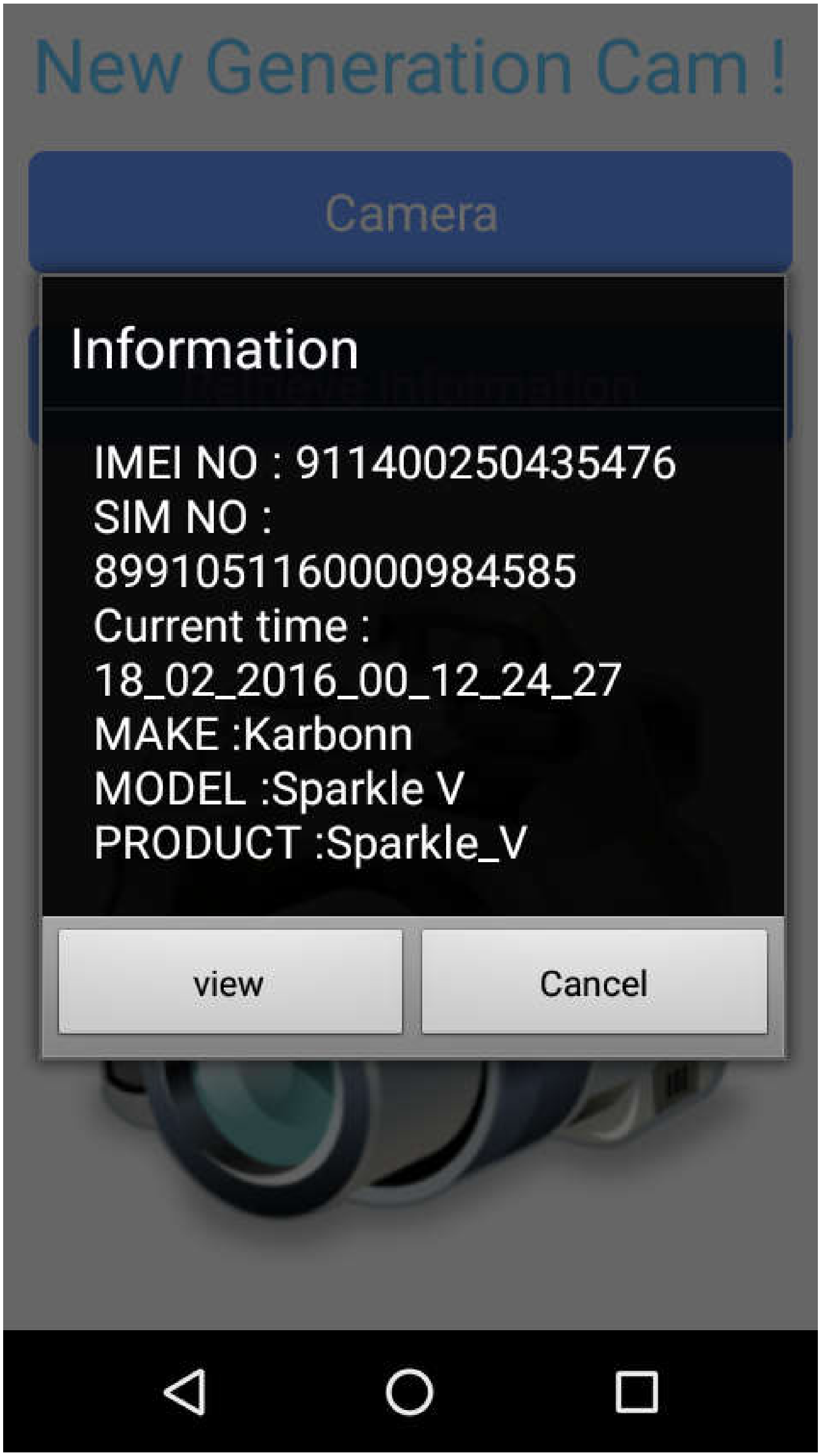


FIGURE 9-19: SCREENSHOT OF ENCRYPTED IMAGE SHOWING THE DETAILS OF KARBONN

Images Captured from Micromax Juice A-77

FIGURE 9-20: 25_06_2015_16_01_19_370

FIGURE 9-21: 25_06_2015_16_01_19_370ENCRYPTED

FIGURE 9-22: 26_08_2015_11_44_05_807

FIGURE 9-23: 26_08_2015_11_44_05_807ENCRYPTED

FIGURE 9-24: 26_08_2015_11_42_23_318

FIGURE 9-25: 26_08_2015_11_42_23_318ENCRYPTED

FIGURE 9-26: 30_11_2015_11_03_53_713

FIGURE 9-27: 30_11_2015_11_03_53_713ENCRYPTED

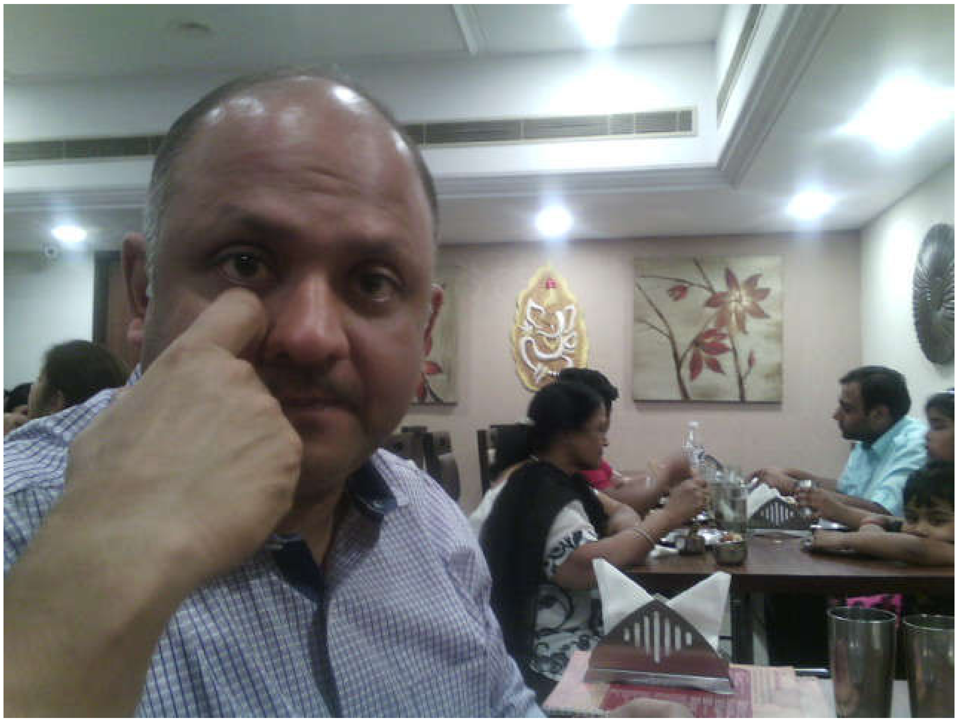


FIGURE 9-28: 24_11_2015_21_09_24_74

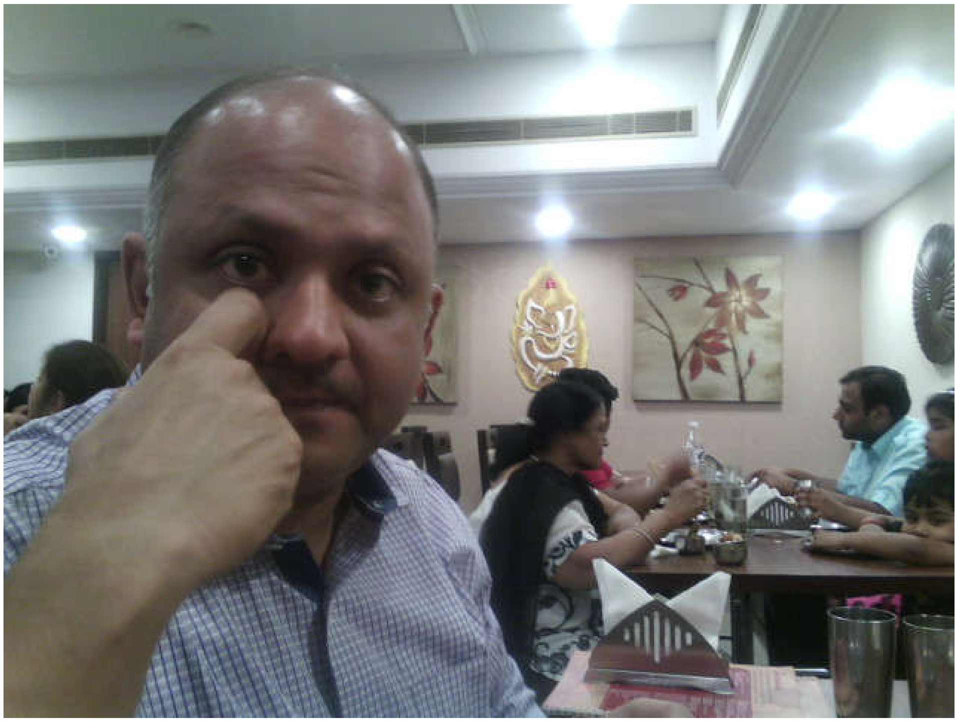


FIGURE 9-29: 24_11_2015_21_09_24_74ENCRYPTED

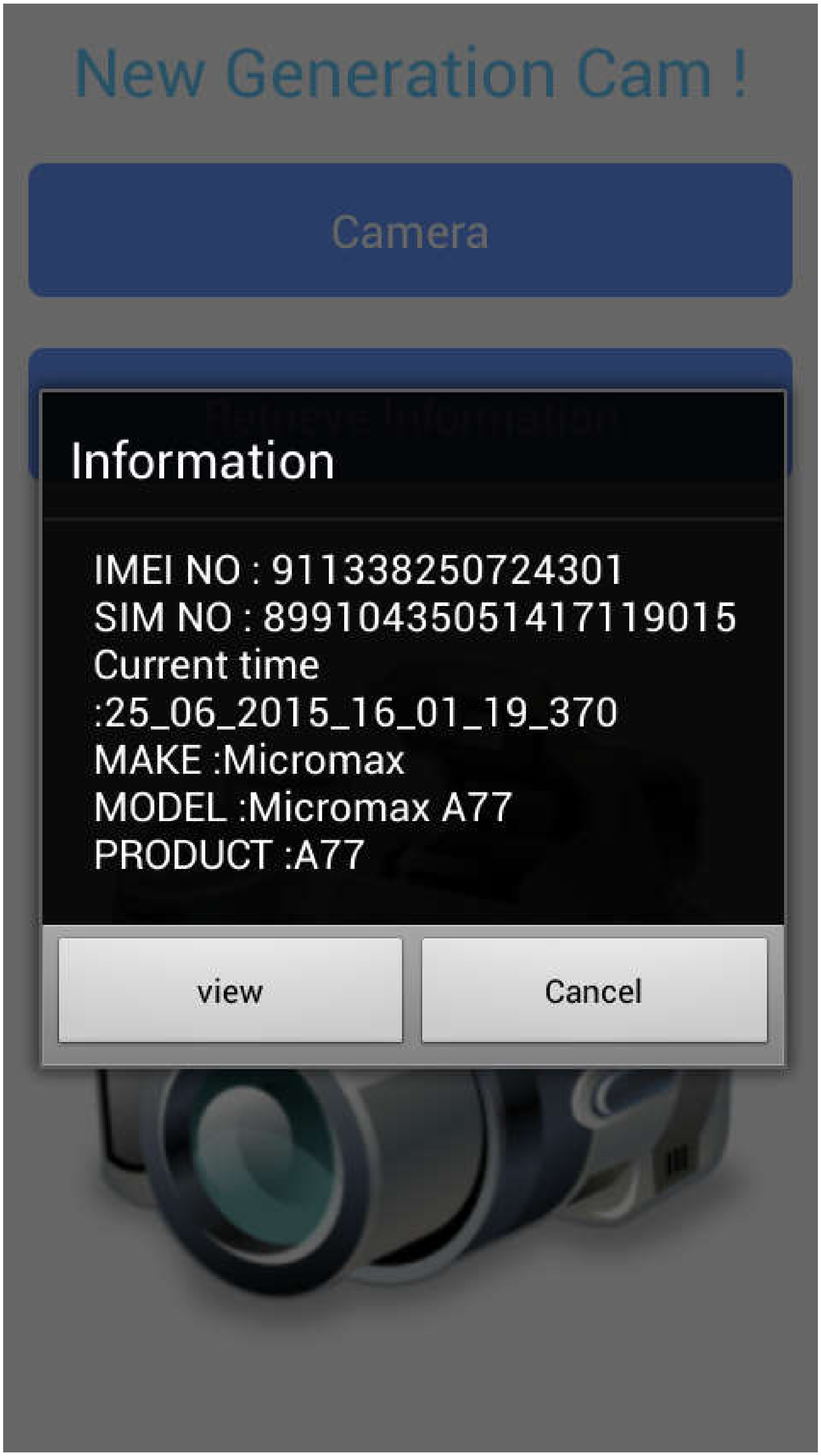


FIGURE 9-30: SCREENSHOT OF ENCRYPTED IMAGE SHOWING THE DETAILS OF MICROMAX JUICE A-77

Images Captured from Lenovo K3 Note K50a40

FIGURE 9-31: 31_01_2016_15_12_58_40

FIGURE 9-32: 31_01_2016_15_12_58_40ENCRYPTED

FIGURE 9-33: 26_01_2016_13_44_51_20

FIGURE 9-34: 26_01_2016_13_44_51_20ENCRYPTED

FIGURE 9-35: SCREENSHOT OF ENCRYPTED IMAGE SHOWING THE DETAILS OF LENOVO K50A40