Secure Solid Waste Bin Status Detection Using Image-Based Processing with Mobile Application: In case of Addis Ababa City, Ethiopia

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***Abstract*— Nowadays, technology is integrating different applications to get fast, secure, reliable and efficient service. People are also adapting this new evolving technology as well. Mobile and web applications are one of this evolving technology and together make us to get and manage information in move. Solid waste management (SWM) is one of this information management which is used to manage and monitor the disposal of solid wastes particularly in the urban area. Because urban area is over populated so that people dispose wastes frequently. This disposal results in great challenge for SWM office. In developing counties like Ethiopia, this problem is categorized under top challenges which needs urgent solution to SWM office. This paper brings solution particularly for respective city municipals to effectively monitor and manage the Solid Waste Bin (SWB) by integrating mobile applications with image processing in secure manner. In the securing part, the recognized citizen has to be authenticated with his/her finger tag and the specified location of the SWB through Global Position System (GPS). In the image processing part, the system receives the bin image, then processes the bin image by following pre-processing, segmentation, feature extraction and classifying/matching steps. The image processing part has been simulated with optimized techniques by using MATLAB.**

***Keywords*—Solid waste management, public key, private key, encryption, decryption, pre-processing, segmentation, feature extraction.**

I. INTRODUCTION

Collecting, dumping and managing a solid waste is big challenge for countries in the world. Such challenge is more manifested in countries where high numbers of people lead to frequent disposal and generation of wastes. This challenge is exaggerated particularly in developing countries like Ethiopia because of people moving from rural to urban like Addis Ababa city [1]. As a current study shows in lower-income countries like Ethiopia an estimated 30-50% solid waste material in urban areas is not collected [2]. When wastes are uncollected, it creates problems not only for city municipals but also for citizens in the city. In addition to this, accumulated wastes cause the ever-present hazard of physically injury to people coming into its close proximity specifically for children in the city as well [3]. Generally, the consequence of this effect results in uncontrollable for the government of the country. To benchmark, clean and healthy living conditions in cities like Addis Ababa will never be achieved without fast, secure, reliable and regular waste collection and effective disposal systems. These problems motivated the authors to come up with a solution for concerned bodies using effective monitoring and management of the solid waste disposals. Image data for our work has been taken from different places in Addis Ababa city where solid wastes are dumped in to the bin. In this paper, researchers have used two technologies; secure mobile application and image processing techniques.

Secure image submission is ensured using finger tag of concerned citizens around the specified area of SWB and then it is sent to authentication server for signature. And the authentic server encrypts the sent bin image and envelope this with the signature by using public key and shared key. Then the authentic server sends this encrypted and enveloped file to SWM server. The SWM server verifies and authenticates that the message is really sent from the authentic server by creating its signature using shared key and decrypting the bin image file separately. Finally, if the result matches, then the SWM server starts the image processing for the verified bin image.

Image processing starts by pre-processing the sent bin image by using median and average filter techniques and then proceeds to the next steps segmentation by using Canny Edge detection techniques and then extracts feature for bin status by using Gabor filter and eventually classifies this extracted feature using Support Vector Machine (SVM). Eventually, the system detects the status of bin as classifying full or not full by considering the bin image and surrounding area as well. The main goal of this paper is to effectively detect the status of solid waste bin and monitor it by using optimized image processing techniques and securing the image submission by using finger tag of the user and geographic location of the bin using smart mobile phones. To do this, users of this system will use Internet and GPS and all details of the bin is also registered in the SWM server.

The paper is divided into the following sections, section II about related works, section III about preliminaries and notation, logical concepts used in this paper, section IV about the contributions of the research work done, with proposed conceptual model, simulation, evaluations and selection of optimized image processing using MATLAB, section V about conclusion.

II. RELATED WORK

There are many research papers which suggest alternative solutions for overcoming the SWM problems: M. Islam et al. [4], designed and modelled that Solid Waste Bin level estimation system by using a webcam as image capturing device integrated with latest image processing techniques. The authors in this work focused for object detection and feature extraction using Dynamic Time Warping (DTW) and Gabor Wavelet (GW) respectively and a Multi-Layer Perceptron (MLP) network for waste level classification. But in order to install webcam in each and every place for bins, it is too cost. Even if their idea is novel, they did not consider the requirements for the webcam such as computation cost, image quality and the life time of the device as well. The solution could not be economically feasible particularly for developing countries. And this paper also didn't consider security issues as well.

John Canny [15] in his work focused on edge-based image segmentation using Canny Edge detection technique defined as a set of goals for an edge detector and showed an optimized way for achieving edges. These goals have three main principles one is Error rate in which the edge detector should respond only to edges and should find all of the them which means no edges should be missed. Second Localization in which the distance between the edge pixels as found by the edge detector and actual edge should be as small as possible. Third Response in which the edge detector should not identify multiple edge pixels where only a single edge exists [15].

A number of authors focused on embedded systems and methods have introduced to overcome this problem in SWM. Some of them have intended to develop an ideal SWM system, including approaches involving Geographic Information Systems (GIS), sensor intelligent bins [5]. Image-based processing solutions for the Solid Waste (SW) collection have also been developed; however, during capturing the bin image, it is challenging to position the camera for getting a bin area centralized image.

III. PRELIMINARIES

A. Common gap for the above related works

- Economic infeasibility to install sensor camera in each of the waste dumping area.
- Impractical to regularly maintain the installed sensor camera in respective bin for making camera sustainable.
- Lack of advanced image processing techniques which accurately process the bin image.
- Lack of considering the surrounding area of the waste bin.
- Lack of taking care for security and authentication of users.

B. Notations Used

WAP : Wireless Application Protocol Server
E_i: Employee
Geo_{Loc}: Geographic location of the bin
AS: Authentic Server
SWM: Solid Waste Management Server
K_{PUS}: public key of SWM
K_{PUA}: public key of AS
K_{PRS}: Private key of SWM
K_{PRA}: Private key of AS
KS: Shared key
K_S: Session key
f_i: finger tag
Xi: security parameter
Ni: nonce value
k_i: intermediate key
I: Original image
I^1: Encrypted image
h : hashed file
H: hash function

C. Encryption and Decryption

Encryption is a way of converting original message to some unknown part so as to protect our message from unauthorized access. Decryption is way of getting original message without any alter. In this paper, authors have used RSA [7] algorithm for encryption and decryption.

D. Digital signature and hashing

Digital signature is a process of creating a hash value from the message and encrypting it with sender's private key [6]. In our case we have used finger tag for hashing and shared key for encryption of the hashed value. In hashing is the sender pads this hashed and encrypted value with original message to sender [6]. In our case the authentic server creates hash from finger tag and encrypts with shared key and tags it with bin image.

E. Shared key

Shared key (KS) is a key shared between servers. In our case KS is shared between authentic and SWM server for digital signature. This key is shared by using Diffie-Hellman protocol.

IV. OUR CONTRIBUTION

A. Conceptual diagram for proposed work

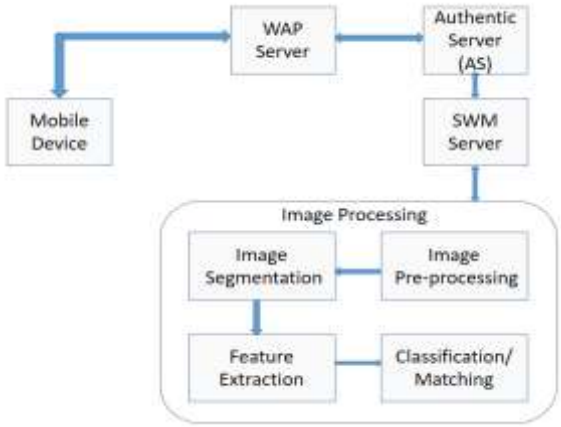

Fig. 1. Conceptual diagram for proposed work

Fig. 1 show the poposed conceptual model for secure solid waste bin status detection using image-based thru mobile application which includes five components mobile device, WAP server, AS server, SWM server and image processing, for secure monitoring the solid waste bin.

B. Registration phase

Employee Ei from city municipal should be connected to Internet. At the first time, the employee sends a geographic location of the specified solid waste bin by connecting with Global Position System. Then WAP [8] server receives it and sends to Authentic Server (AS) by padding the geographic location along with security parameter xi. AS generates public key by using RSA [7] algorithm and sends KPU to SWM server. Then SWM server generates temporary session key Ks and also creates some key by encrypting session key with public key of AS and this new key again is sent back to AS. The AS generates shared key, KS, by encrypting KPU of SWM server and this key will be shared between AS and SWM server until the session is closed. The Fig.2 shows the pictorial flow of the registration process.

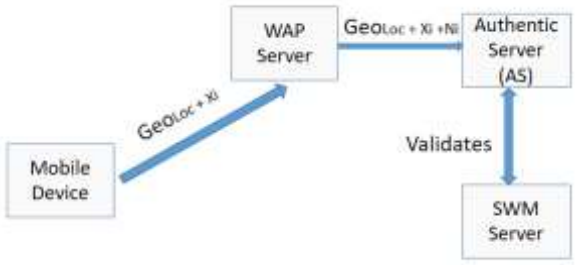

Fig. 2. Registration Phase

C. Image Submission Phase

Ei captures bin image and sends it with its finger tag to WAP server. Then WAP server forwards to AS. Then AS creates digest file, h', from the finger tag, encrypts it with public key of SWM server, KPU, and signs on I by using finger tag, encrypts I and sends I1 to SWM server. The SWM server verifies that sent file by creating a digest file from the finger tag, fi, using shared key and then checks that decrypt finger tag, fi, with the digest created from decrypted finger tag, fi. as show in Fig.3. If the match is true, then the I will be processed by using image processing techniques.

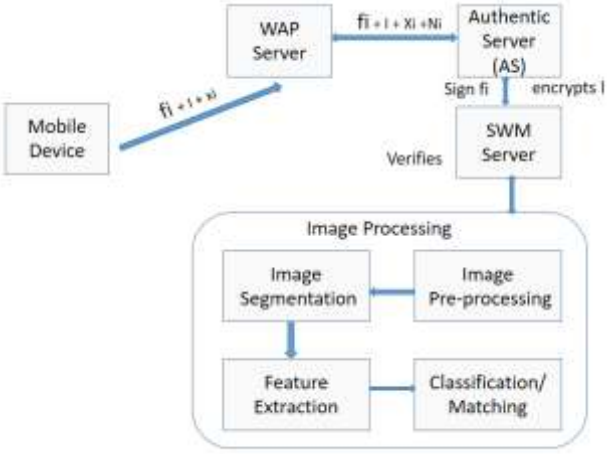

Fig. 3. Image submission Phase

D. Implementation

- Key Generation using RSA for AS:

  Step 1: Select two large prime numbers p and q.
  Step 2: Multiply p and q to get N: N=p*q.
  Step 3: Perform $\phi(n)=(p-1)(q-1)$.
  Step 4: Find e relatively prime, e-1 mod $\phi(n)$.
  Step 5: Ensure that $1 < e < \phi(n)$; GCD $(e, \phi(n)) = 1$
  Step 6: Find d by evaluating; ed=1 mod $\phi(n)$.
  Step 7: Get K_{PU}= {d, n} and K_{PR}= {e, n}.

- Digital signature at AS using SHA algorithm:

  Step 1: The AS create short size h value from finger tag.
  Step 2: The AS encrypts h value with its KS.
  Step 3: The AS pads this hashed and encrypted value with I file, h'+I.

- Private and public keys calculation for above Digital Signature by using RSA.

  Step 1: Two prime numbers p and q are selected.
  Step 2: p prime numbers with length series of bits 512, 1024 in increment of 64.
  Step 3: q prime divisor of (p-1) with bit length of 160 bits.
  Step 4: g=h(p-1)/q mod p.
  Step 5: Ensure that 1<h<(p-1) that g>1.
  Step 6: KPR=x, where 0<x<q.
  Step 7: y= gx mod p.
  Step 8: KPU=y.

- Solid Waste Bin Image Encryption at AUS using RSA algorithm

  Step 1: AS creates temporary session key, ks

Step 2: AS encrypts original waste bin image, I file using ks and creates I1
Step 3: AS also encrypts ks with public key of SWM server, KPUS which creates intermediate key, ki
Step 4: AS pads ki with I1 file.

- Image Decryption at SWM server

Step 1: SWM server decrypts intermediate key, ki with private key of SWM server, KPRS to get session key, ks
Step 2: SWM server decrypts image file, I1' by using ks

- Signature at AS by using SHA algorithm

Step 1: random number kn2 such that 0<kn2<q is found.
Step 2: Get k1= (g1kn2 mod p2) mod p2.
Step 3: compute t1i=[rn-1(H(Ii)+(x1*r1)].
Step 4: Ensure that signature is (r1, t1i). Here (Ii, k1, t1i) is sent to SWM server to verify AS's signature is as it is.

- Verification at SWM server

Step 1: SWM extracts encrypted finger tag, fi
Step 2: SWM decrypts fi using public key of AS, KPUA
Step 3: SWM creates a digest from finger tag file, fi by using shared key, KS
Step 4: SWM compares decrypt finger tag, fi with the digest created from decrypted finger tag, fi. If they match, the signature is verified.

- Image processing at SWM server

Bin Image: In this paper we have used rectangular shape bin image. For testing purpose, we have used 20 full images and 20 empties or under flow sample images. In here, we have used that to detect the bin status as full or not and the presence of the wastes in surrounding area of the bin. From this 40-total sample of bin images, 20 are clear area images and 20 are littered which means presence of wastes in surrounding area. The bin image is captured by using Tecno k7 mobile device in our sample case.

Image pre-processing: Since our bin image will be sent to server via communication, there two most common noises that will happen during this data transmission and image acquiring. These types of noise models are known as Gaussian noise and salt and pepper noises.

- Gaussian noise: this noise is caused particularly during image capturing and is evenly distributed over signal [9]. In our case, when image bin is captured by smart mobile phone, this noise will happen. If an image is represented as I, and Gaussian noise by G, the noisy image can be modeled as:

$$Noisy\ \ Image = I + N \qquad (1)$$

- Probability Density Function of Gaussian random variable Z represents the gray level, μ the mean value and σ the standard deviation, in equation 2 and figure 2.2 [1=Mine].

$$pG(z) = \frac{1}{\sqrt{2\pi\sigma}} e^{-(z-\mu)^2/(2\sigma^2)} \qquad (2)$$

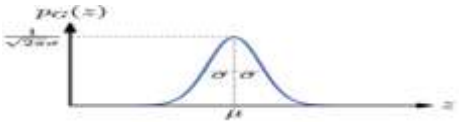

Fig. 4. Gaussian Probability Density Function of pG(Z)

- Salt and pepper noise: this noise is impulse noise type which is caused by sharp and sudden disturbance in the image signal and this phenomenon also randomly scattered white or black over image [9,10]. The reason we have used this noise type is it will be created during data transmission over communication channel so that we should denoise before it is going to segmentation and feature extraction as well. The PDF of the salt and pepper noise [10] is given by:

- $$pI(z) = \begin{cases} p_a \ for\ z = a \\ p_b \ for\ z = b \\ 0 \quad otherwise \end{cases} \qquad (3)$$

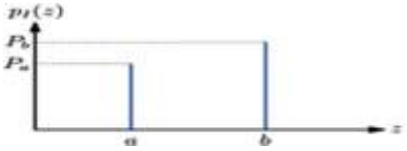

Fig. 5. Shows Probability Density Function pI(Z) of impulse noise model

If b>, gray-level b appears as a light dot (salt) in the image. On other hand, a will appear as dark dot(pepper). If either P_a, P_b is zero, the PDF is called unipolar in equation (3). Therefore, to remove such noises from our bin image, we have to have image pre-processing or removing algorithms to pre-process the noisy images.

- Therefore, in this paper the primary goal of filtering or denoising our solid waste bin image is the bin image has to be filtered by efficient image filtering techniques in order to preserve the original information. Unless and otherwise, we may loss original information because of distorted images.

Fig.6. Original Image

Fig. 7. Gaussian noise

Fig. 8. Average filtered

Fig. 9. Salt and peper noise

Fig. 10. Median filtering

Fig. 7 shows that 10% of noise distorts image quality. Fig.8 shows the results constructed by average filtering techniques. Fig. 9 shows that original image is contaminated with 10% of impulse noise and Fig.10 shows that reconstructed image by median filtering techniques.

- Quality measures

Mean Square Error [14]: The Mean Square Error (MSE) is an image quantitative quality measuring parameter. It is used to measure the difference between the original image reconstructed image and it should be as minimum as possible. This means that when MSE is minimum, the reconstructed image has high quality.

$$MSE = \frac{1}{MN}\sum_{i}\sum_{j}(r_{ij} - x_{ij})^2 \qquad (4)$$

Peak Signal to noise ratio [14]: The Peak Signal to Noise Ratio (PSNR) is the value of the noise image with respect to that of the original image. The higher the PSNR, the better the quality of reconstructed image.

$$\text{PSNR} = 10(\log_{10}(255)^2/MSE) \qquad (5)$$

Where 255 max possible pixel value of the image.

TABLE 1: PSNR AND MSE VALUES FOR GAUSSIAN NOISE TYPE WITH DIFFERENT DECIBEL WEIGHTS.

Gaussian Noise	Average Filter		Gaussian Filter	
%	MSE	PSNR	MSE	PSNR
10	12.7	37	20.72	34.97
30	2.5	44.22	4.55	41.55
50	1.8	45.50	2.91	43.5

TABLE 2: PSNR AND MSE VALUES FOR SALT AND PEPPER NOISE TYPE WITH DIFFERENT DECIBEL WEIGHTS

Salt and pepper Noise	Wiener Filter		Median Filter	
%	MSE	PSNR	MSE	PSNR
10	675.46	19.75	689.62	19.83
30	12,521	17.2	10,261	18.01
50	19,015	15.34	28,258	15.62

By Table.1, Researchers could understand that average filter is preferable for Gaussian noise type because in Average filter, PSNR has higher value than that of Gaussian filter during in presence of 10% amount of decibel in bin image. Therefore, for this work researchers have selected that average filter is better in removing Gaussian noise which will occur during image capturing or any environmental conditions affect the image. In Table. 2 Median filtering technique is better for removing impulse noise which can occur during data transmission at the time of sending bin image to server. For both tables, when the number of noise increases, there is a high probability that researchers may loss original information from the solid waste bin. When image noise is more than 50%, researchers may totally loss information from the image. Consequently, image pre-processing must be done at highest priority in our work for solid waste bin.

- Image Segmentation at SWM server

Based on literature we have selected Canny edge detection techniques for our work in order to detect solid waste bin image correctly [15] the simulation results are shown in Fig.11 and Fig. 12.

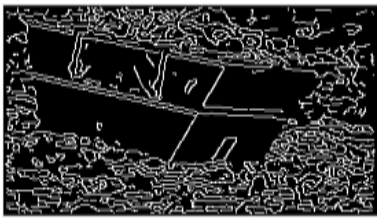

Fig. 11. Canny Edge Detected sample bin image with rubbish in surrounding area

After detecting edges of bin image by using Canny edge detection approach, researchers have used Hough line transform technique to detect straight lines in the bin image as well [15]. The Hough line transform is used to detect strong straight lines by taking the input from Canny detected edges and connect these detected edges to form line using Hough transform.

The figure 12 shows this using Hough line transform.

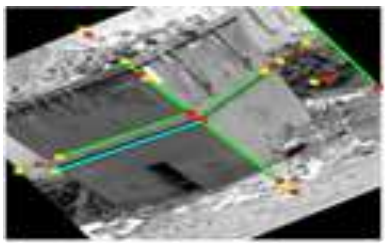

Fig. 12 shows that result of filled bin image using Hough line transform.

- Feature Extraction and image classification

In this work, researchers have used Gabor filter [16] to extract features used to detect the solid waste bin status and identify if there is waste in surrounding area.

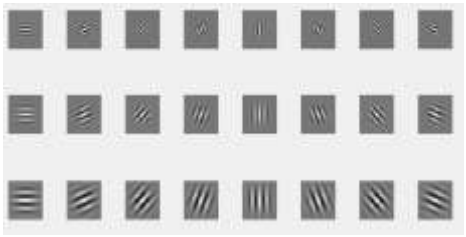

Fig.13 Shows Real part of Gabor

Figure 13 shows real part of Gabor feature to detect correctly the bin image using four corners of the bin image. To do this, the number of bin corners detected during Hough line is considered as one feature for bin level classification. Researchers have used Support Vector Machine (SVM) [17] as a classifier which is a supervised binary classifier that uses a decision function to split the data into classes accordingly. Eventually, the work performs well approached 97% accurate in detecting bin and 92% accurate in identifying the level of the bin image. The remained parts need further work to detect the bin and identify level in presence of another objects which protects and hides the four corners of the bin and surrounding area respectively.

V. CONCLUSION

The paper entitled Secure Solid Waste Bin Detection and monitoring system has two parts, security in user's authentication with image encryption between authentication and SWM servers and image processing parts. The security part is logically elaborated and image processing parts is simulated except comparison step using SVM is put theoretically.

Eventually, researchers experimented that median filter is better for denoising salt and pepper noise and average filter is better for denoising Gaussian noise in image pre-processing part for solid waste bin. And also, Canny Edge detection is preferable to segment bin image based on edge detection techniques and Hough Line Transform technique is used to detect straight lines having detected edges for identifying bin image. Gabor filter is better for extracting feature for bin image to detect bin and level as well as identify that presence of image in surrounding of the bin. Finally, Support Vector Machine is selected to classify the extracted features of the bin.

In the near future researchers will implement all parts since the researchers are doing the project as internal grant by Addis Ababa Science and Technology University so that this project will be implemented and deployed soon after few months as it is aimed. And the techniques in each of image processing for solid waste bin will also be optimized in advance as well.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this paper.

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