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Editorial:
7th Issue – Journal of Electronic Systems and Programming

We are pleased to announce the publication of the 7th issue of the Journal of Electronic Systems and Programming (JESP).

First of all, we are pleased to report that JESP is recognized as the one of the useful Journal for dissemination of high-quality research within the Libyan academic community.

In this issue, we would like to express our gratitude to the all members of Electronic Systems and Programming Center for their unlimited support and dedication that has made JESP what it is today.

Finally, we thank our editorial board team, reviewers and authors for their fundamental contribution. We still hope authors could consider JESP to be a place where to publish their work.

Editorial Board

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Color Image Encryption Using 3D Henon Map and 3D Logistic Map

Color Image Encryption Using 3D Henon Map and 3D Logistic Map

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Abstract

In the area of information security, secure image transmission is one of the most challenging problems. This research is presented to increase color image security through an image encryption algorithm. The proposed algorithm uses circle map for key generation, 3D henon map for confusion and 3D logistic map for diffusion. To enhance the sensitivity of a plain image, SHA-1 is employed in our proposed method to calculate the hash value and use it as an input to circle map. Set of tests are used to evaluate the proposed algorithm. These tests include Key sensitivity, Information entropy, Correlation analysis, NPCR, and UACI. the results show that the proposed method efficiently improves encryption; It has good security performance and can resist common attacks.

Keywords: *3D henon map, 3D logistic map, confusion, diffusion, Chaotic Map.*

1. Introduction

Data transmission and storage are now more heavily reliant on information security [1]. Text, audio, visual, and other multimedia make up this data. Images are used frequently in most people's daily lives. Yet, the security of the images becomes more [2]. Although there are many uses for conventional encryption techniques like DES, 3DES, RC5, AES, and RSA in text encryption, they are insufficient to meet the security needs of image encryption. images have unique characteristics including the high correlation between adjacent pixels and the big size of the image [3][4]. The use of chaotic maps in cryptographic algorithms has gained a lot of interest and grown in importance [5]. For their unpredictable nature and randomness, chaotic maps are utilized in confusion and diffusion mechanisms, which provide great performance in image encryption techniques [6].

In recent years, researchers have proposed several digital image encryption algorithms. In [7] a fast chaos-based image encryption scheme using fractal and 3D henon maps (FCIES-Fr-HP) is proposed for improving the degree of security in the image transmission. This is attained by integrating the merits of the predominant fractal function with the indispensable features of henon maps to generate an effective key stream which is essential for a reliable cryptosystem and the experimental result for Lena image in entropy was 7.9982, NPCR 99.6124, UACI 33.1634 and the key space was 2^230. in [8] A color image encryption algorithm combining Henon-zigzag-based permutation and chaotic restricted Boltzmann machine-based diffusion is proposed. During the diffusion phase, three pseudo-random number sequences were generated by the chaotic restricted. Boltzmann machine are used to perform XOR operations with the R, G, and B components of the scrambled image. In [9] a novel symmetrical image encryption algorithm based on skew tent map is proposed. Utilizing a new chaos-based Line map, the proposed algorithm is suitable for the encryption of any size of the image. In order to disrupt the correlations between the R, G, B components of the true color image, these three components are encrypted at bit level and operated at the same time. The proposed algorithm realizes fast encryption and decryption of both gray-scale image and color image. Authors in [10] presented a novel bit-level image encryption algorithm that is based on piecewise linear chaotic maps (PWLCM). Firstly, the plain image is transformed into two binary sequences of the same size. Second, a new diffusion strategy is introduced to diffuse the two sequences mutually. Then, the binary elements are swapped in the two sequences by the control of a chaotic map, which can permute the bits in one bit plane into any other bit planes. A color image encryption method that is based on chaos has been suggested by authors in [11]. The method involves three chaotic maps, namely the circle map for generating the encryption key, the 3D logistic map for confusion, and the 3D henon map for diffusion. The results showed a good encryption performance. This article introduces a new encryption method for color images that is based on 3D chaos. The method involves using the 3D Henon map to scramble the image, the 3D logistic map for value transformation, and the circle map to generate a key.

This paper is structured as follows: Section 2 provides a brief overview of the fundamental principles behind the proposed algorithm. Section 3 explains the steps of the proposed encryption algorithm, while Section 4 covers the performance measures and security analysis that are conducted on the algorithm. And finally, we summarize our conclusions in Section 5.

2. Basic theory of the proposed algorithm

2.1. 3D Henon Map

The 3D Henon chaotic map is a three-dimensional map and mathematical in nature, and is used as a symmetric cryptographic system. The 3D Henon map has reversibility and simple geometric vision. Moreover, the errors in the calculation are decreased because its coefficient is an integer, and can be represented by the following formula[12]:

$$\begin{aligned} X_{i+1} &= \alpha - y_i^2 - bz_i \\ y_{i+1} &= x_i \\ z_{i+1} &= y_i \end{aligned} \qquad (1)$$

Where 1.54<| a |<2, 0<|b |<1 and the range of x_0, y_0, z_0 between 0 and 1. In the introduced method a=1.7, b=0.1 and x_0, y_0, z_0 are the keys generated by circle map.

2.2. 3D Logistic Map

The three dimensions logistic map is given by the following formula[13]

$$\begin{aligned} X_{i+1} &= \lambda x_i(1 - X_i) + \beta y_i^2 x_i + \alpha z_i^3 \\ y_{i+1} &= \lambda y_i(1 - y_i) + \beta z_i^2 y_i + \alpha x_i^3 \\ z_{i+1} &= \lambda z_i(1 - z_i) + \beta x_i^2 z_i + \alpha y_i^3 \end{aligned} \qquad (2)$$

When 0.35 < λ < 3.81; 0 < β < 0.022; 0 < α < 0.015 are set, the 3D logistic map (2) offers a chaotic behavior if the initial values $x_0, y_0, z_0 \in (0, 1)$. In the proposed method the control parameters λ ,β,α are gained chaotically from circle map, and x_0, y_0, z_0 are set to 1.

2.3. Circle Map

The circle map is a dynamic system, which is a dynamic system that simplifies the determination of mechanical rotors. The formula for calculating the circle map is denoted by an equation and it is commonly used in electronics. The circle map can be mathematically represented by (3) [13]:

$$X_{i+1} = \left\{X_i + b - \left(\frac{a}{2\pi}\right) sin(2\pi x_i)\right\} mod(1) \qquad (3)$$

In this situation, the circle map is used for key generation where a=0.2, b=0.5, $x_0 \in (0,1)$.

3. The Proposed Scheme

In this part, the proposed encryption method is demonstrated. The method is made up of three stages: key generation, confusion, and diffusion. The key that is generated in the first stage is utilized as input for the confusion and diffusion stages. It is not secure to use only one round of confusion-diffusion for image encryption. To improve the security of the proposed algorithm, multiple rounds of confusion-diffusion are used in this approach.

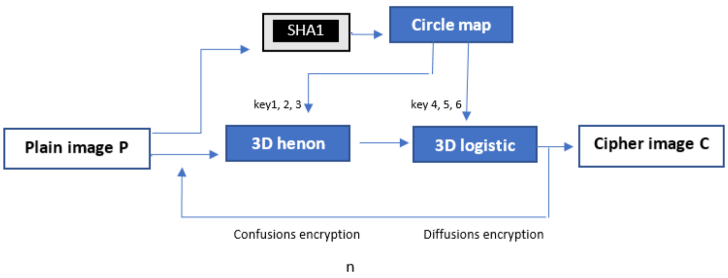


Figure 1: Block diagram of the proposed encryption algorithm.

Encryption Steps: The process of encrypting an image involves several steps, as outlined in Figure 1.

Step 1. Read the plain-image as matrix P and obtain its size m×n.

Step 2. Calculate the hash values for the plain-image using SHA-1 and convert them into hash vector h which consist of 160 bits (20 bytes).

Step 3. Generate factors h_1,$h_2, h_3, h_4, h_5$and h_6 using equation 4. all these vectors are set as initial values of the circle map where h_1, h_2 and h_3 are to generate the keys for diffusion by logistic map, h4, h5 and h6, is to generate the keys for confusion stages by henon map.

$$h1 = \frac{\sum_{i=1}^{3} h(i)}{\sum_{i=1}^{3} h(i)+1}$$
$$h2 = \frac{\sum_{i=4}^{6} h(i)}{\sum_{i=4}^{6} h(i)+1}$$
$$h3 = \frac{\sum_{i=7}^{9} h(i)}{\sum_{i=7}^{9} h(i)+1} \quad (4)$$
$$h4 = \frac{\sum_{i=10}^{12} h(i)}{\sum_{i=10}^{12} h(i)+1}$$
$$h5 = \frac{\sum_{i=13}^{15} h(i)}{\sum_{i=13}^{15} h(i)+1}$$
$$h6 = \frac{\sum_{i=16}^{20} h(i)}{\sum_{i=16}^{20} h(i)+1}$$

Step 4. Confuse the plain image P using 3D henon map.
Step 5. Apply the 3D logistic map to diffuse the pixels of the image obtained from step 4.
Step 6. Repeat steps 4 and 5 n times.
Step 8. Obtain cipher-image C.
decryption Steps: the decryption steps for our encryption algorithm are in inverse order of the encryption steps.

4. Experimental Results

To test the effectiveness of the proposed algorithm, five color images are chosen, refer to Fig. 2. Various tests are conducted to assess the impact of the proposed method on both the encrypted and decrypted images. These experiments are carried out on a computer equipped with an Intel Quad-Core i7-8550U CPU, and 16G RAM running on Windows 10 using MATLAB. The original images are encrypted using different rounds of encryption. The proposed algorithm is a lossless one, as demonstrated by the fact that the original image and the decrypted image are identical in every pixel, as represented in Figure 3.

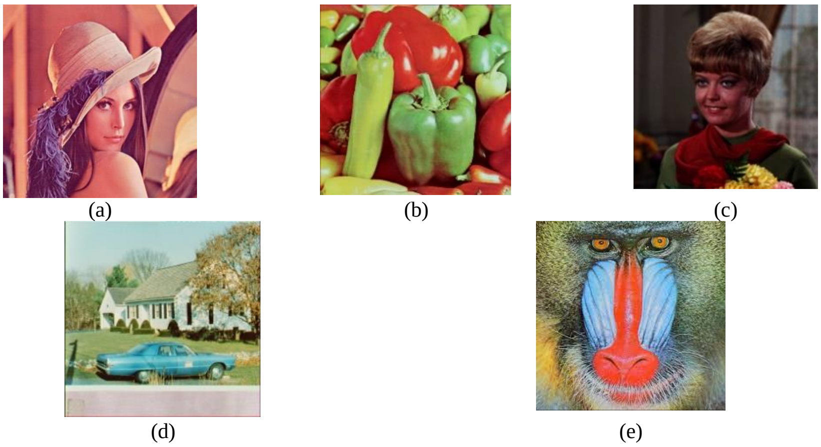


Figure 2: Original test images: (a)Lena, (b) Pepper, (c) Woman, (d) House and (e) Baboon

4.1. Statistical Analysis

Histogram and Entropy Analysis

The key feature of randomness is information entropy, which measures the level of unpredictability and uncertainty in a given dataset. In order for the histogram of an encrypted image to appear as sufficiently uniform, the information entropy should be close to 8. The formula (7) is utilized to determine the entropy H(m) of a plaintext message m.

$$H(m)= \sum_{i=0}^{L-1} p(m_i)\, log \frac{1}{p(m_i)} \qquad (7)$$

Where L is the total number of symbols, p(m_i) represents the probability of occurrence of symbol m_i and log denotes the base 2 logarithm so that the entropy is expressed in bits.

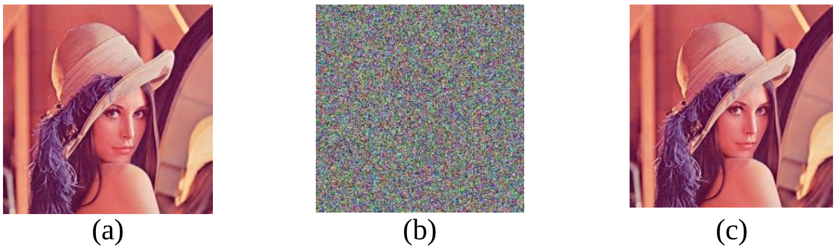


Figure 3: Image encryption result. (a) original image; (b) encrypted image; (c) decrypted image;

Table 1 demonstrates the values of entropy for cipher test images with different confusion-diffusion rounds. The results proved that the entropy values of encrypted images increase with an increase in the number of rounds and the entropy values of the proposed method and that proposed by [11] are very near to the ideal value which is eight. Based on the results, it is advised to perform five rounds for the efficiency of the proposed algorithm.

Table 1: Entropy values of encrypted images

Round / Image	1	2	3	4	5	6	7
Lena (proposed)	7.9997	7.9800	7.9956	7.9983	7.9989	7.9989	7.9991
Lena [11]	7.9990	7.9991	7.9990	7.9991	7.9991		
Baboon (proposed)	7.7968	7.9615	7.9884	7.9936	7.9953	7.9955	7.9984
Baboon [11]	7.9986	7.9987	7.9988	7.9986	7.9989		
Woman (proposed)	7.7046	7.9093	7.9802	7.9951	7.9978	7.9988	7.9990
Woman [11]	7.9984	7.9989	7.9989	7.9991	7.9991		
House (proposed)	7.8620	7.9781	7.9957	7.9987	7.9994	7.9996	7.9997
House [11]	7.9995	7.9998	7.9998	7.9997	7.9998		
Peppers (proposed)	7.7348	7.8978	7.9816	7.9948	7.9981	7.9994	7.9997
Peppers [11]	7.9997	7.9997	7.9998	7.9997	7.9998		

Figure 4 displays the histograms for the RGB channels in both the original image (figure 4a) and the encrypted image after undergoing five rounds of confusion and diffusion (figure 4b). It is evident that the histograms for the encrypted image are evenly distributed.

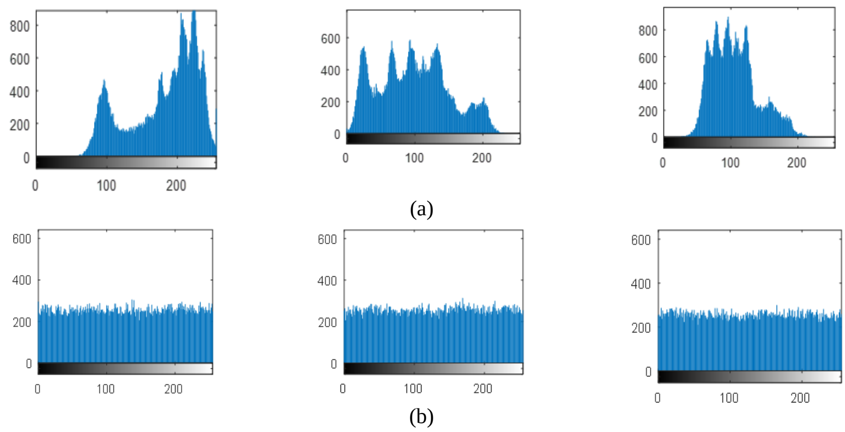


Figure 4: Histogram analysis of Lena. (a) Histogram of the original image; (b) Histogram of the encrypted image

Correlation analysis

When it comes to plain images, the neighbour pixels that are next to each other (either horizontally, vertically, or diagonally) are usually highly correlated. However, in strong cipher systems, the correlation between adjacent pixels in encrypted images must be extremely low. To determine this correlation, Equation (8) is utilized.

$$cov(u, v) = E\{(u - E(u))(v - E(v))\}$$

$$r_{uv} = \frac{cov\,(u,v)}{\sqrt{D(u)}\sqrt{D(v)}} \qquad (8)$$

Where u and v are pixel values of two adjacent pixels, $E(u)= \frac{1}{P}\sum_{i=1}^{P} u_i$, and $D(u)= \frac{1}{P}\sum_{i=1}^{P}(u_i - E(u))^2$.

The correlation coefficient close to zero indicates that a low correlation exists between the pixels. Table 2 displays the correlation coefficient values for cipher images obtained from the proposed algorithm and the algorithm in [11] with various numbers of rounds. It is evident that the correlation coefficients are extremely low in both algorithms.

Table 2: Correlations of the encrypted images

Image \ Round	1	2	3	4	5	6
Lena (proposed)	-0.01269	-0.01364	-0.00178	0.006244	0.000967	-0.01149
Lena [11]	-0.0030968	-0.01259	0.0147	-0.0033	0.010611	
Baboon (proposed)	0.019711	-0.00429	0.003789	0.003078	0.013915	-0.00176
Baboon [11]	-0.0116111	0.0005	0.02068	0.001756	0.023111	
Woman (proposed)	-3.3E-05	-0.01174	-0.00416	-0.01279	0.007742	-0.00724
Woman [11]	-0.0023667	-0.00284	0.015033	-0.00766	0.022467	
House (proposed)	0.1397	-0.00079	-0.01912	-0.00714	0.004522	0.015144
House [11]	-0.0166444	-0.00446	-0.00917	0.002186	0.003333	
Peppers (proposed)	0.021378	0.014811	-0.00451	-0.01496	0.018922	-0.00507
Peppers [11]	0.00005667	0.001933	-0.00164	0.003943	-0.01029	

Figure 5 displays the correlation distribution of neighbouring pixels in Lena's plain-image, both horizontally, vertically, and diagonally. On the other hand, Figure 6 shows the correlation distribution of encrypted pixels after four rounds in the same directions. The plain-image pixels are closely grouped along a straight line, indicating high correlation between pixel values in each direction. Conversely, the encrypted image pixels are scattered throughout the space, indicating a significant reduction in pixel value correlation for each direction.

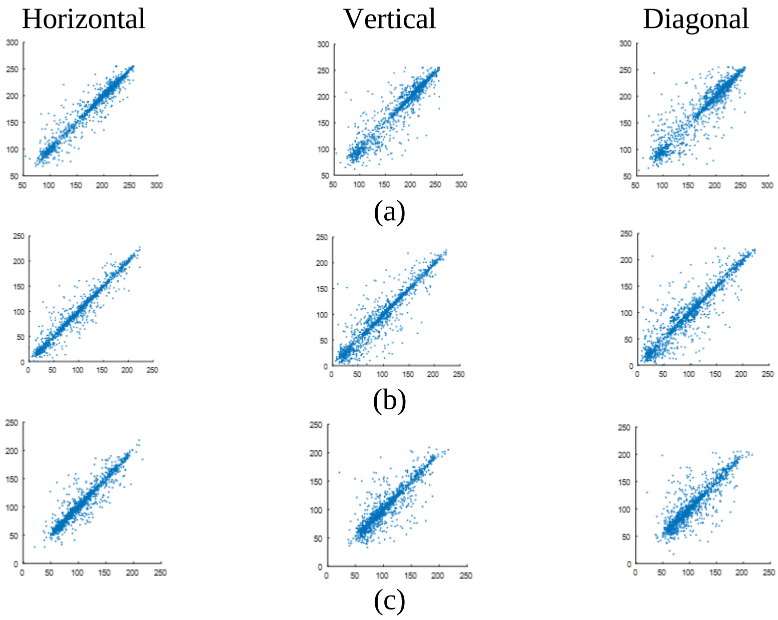


Figure 5: Correlations of two adjacent pixels in Lena plain-image. (a) Red; (b) Green; (c) Blue

The results indicate that the optimal correlation outcomes are achieved after implementing the suggested algorithm for four rounds. Nevertheless, to maintain a balance between entropy and correlation results, it is recommended to carry out five rounds of confusion and diffusion.

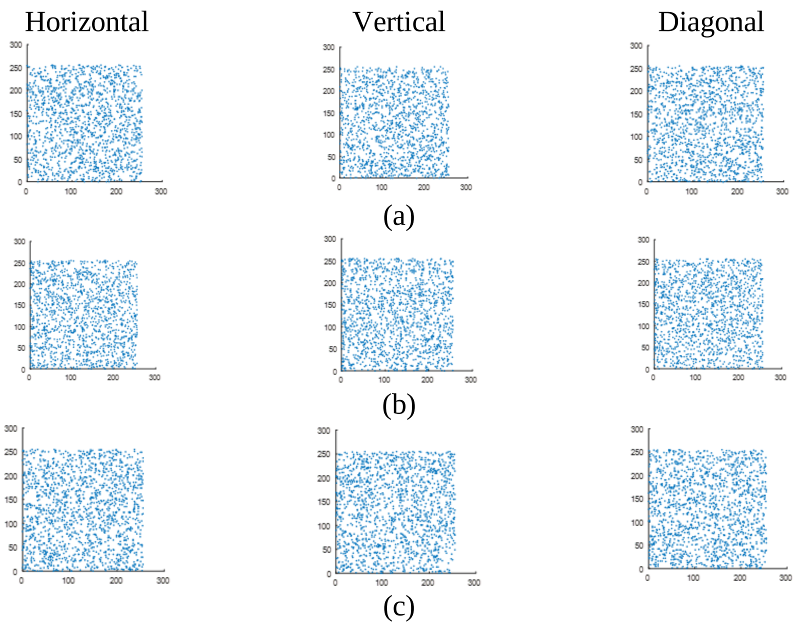


Figure 6: Correlations of two adjacent pixels in the cipher-image. (a) Red; (b) Green; (c) Blue

4.2. Differential Attack Analysis

The main purpose of this measurement is to assess how altering a single pixel in the original image affects the entire encrypted image. This is achieved through the use of the Rate of Change of Pixel Number (NPCR) and Unified Average Changing Intensity (UACI). The results of NPCR and UACI are illustrated in table 3 and table 4, respectively.

Table 3: The results of NPCR

Round / Image	1	2	3	4	5	6	7
Lena (proposed)	0.9958	0.9961	0.9960	0.9961	0.9960	0.9962	0.9962
Lena [11]	0.9960	0.9963	0.9962	0.9960	0.9961		
Baboon (proposed)	0.9962	0.9963	0.9960	0.9958	0.9959	0.9962	0.9962
Baboon [11]	0.9959	0.9959	0.9960	0.9961	0.9961		
Woman (proposed)	0.9962	0.9960	0.9962	0.9963	0.9960	0.9960	0.9960
Woman [11]	0.9962	0.9960	0.9963	0.9961	0.9960		
House (proposed)	0.9953	0.9958	0.9961	0.9962	0.9961	0.9962	0.9962
House [11]	0.9961	0.9961	0.9963	0.9962	0.9962		
Peppers (proposed)	0.9961	0.9960	0.9959	0.9960	0.9960	0.9961	0.9961
Peppers [11]	0.9962	0.9961	0.9960	0.9962	0.9961		

From table 3, it is clearly seen that the NPCR values of both algorithms are very close to 1 in all iterations.

Table-4: The values of UACI

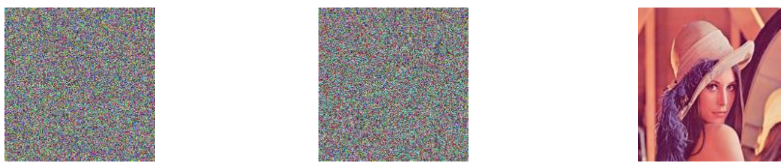
Round / Image	1	2	3	4	5	6	7
Lena (proposed)	0.3043	0.3217	0.3352	0.3347	0.3341	0.3347	0.3343
Lena [11]	0.3332	0.3342	0.3342	0.3345	0.3349		
Baboon (proposed)	0.3388	0.3310	0.3251	0.3246	0.3324	0.3392	0.3336
Baboon [11]	0.3326	0.3334	0.3347	0.3351	0.3340		
Woman (proposed)	0.3292	0.3272	0.3283	0.3347	0.3353	0.3348	0.3351
Woman	0.3347	0.3348	0.3346	0.3347	0.3339		

[11]							
House (proposed)	0.3073	0.3202	0.3312	0.3352	0.3347	0.3351	0.3344
House [11]	0.3337	0.33467	0.3346	0.3347	0.3344		
Peppers (proposed)	0.3217	0.3273	0.3317	0.3344	0.3341	0.3345	0.3341
Peppers [11]	0.3337	0.3346	0.3342	0.3354	0.3348		

In the other hand, table 4 shows that the UACI values of both algorithms are acceptable starting from four rounds.

4.3. Key sensitivity

An effective cryptosystem should be sensitive to even minor alterations in secret keys during decoding process. The sensitivity results are depicted in Figure 7 which indicates that the suggested algorithm is extremely sensitive to encryption keys. Consequently, the encrypted plain image can only be retrieved using the correct key.



(a) (b) (c)

Figure 7: Key sensitivity results. (a) Decrypted with key 1; (b) Decrypted with key 2; (c) Decrypted with the correct key

In general, to ensure the efficiency of the proposed algorithm, we need to perform five rounds of confusion and diffusion. In contrast, the algorithm proposed in [11] requires four rounds, which makes it a bit faster than the proposed one.

5. Conclusion

This paper presents a color image encryption algorithm based on 3D chaotic maps. The algorithm uses three different chaotic maps: the circle map generates the encryption key, the 3D henon map is used for confusion, and the 3D logistic map is used for diffusion. To evaluate the effectiveness of this algorithm, various tests were conducted including information entropy, histogram analysis, adjacent pixels correlation coefficient, key sensitivity, NPCR and UACI. Statistical analysis shows that the scheme can well protect the image against statistical attack. The algorithm possesses high key sensitivity and has a good ability to resist differential attack.

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2

Assessing the accuracy of train and test different artificial neural networks

Assessing the accuracy of train and test different artificial neural networks

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Abstract

This work is focused on assessing the train and test of different artificial neural networks. The different neural networks were tested in this paper were: Backpropagation Neural Network (BPNN), Radial Basis Function Neural Network (RBFNN), and Nonlinear Autoregressive model with eXogenous input Neural Network (NARXNN). The BPNN is a type of feedforward neural network; Levenberg-Marquardt algorithm used in this work to adapt the network weights to minimize the error between the desired output and the network output. The RBFNN is a type of feedforward neural network; least mean squares algorithm used in this paper to adapt the weights, and clustering algorithm used to select the centers, this lead to more accurate results. The NARXNN is a type of recurrent neural network; the network output fedback to the network input, then, the network output became a part of network training, and this will effect to weights adaption to get efficient training. The system used in this work to assessing the train and test the three types of artificial neural networks is a pH Neutralization process.

Keywords: *Artificial neural network, train, test, accuracy, NARXNN, RBFNN, BPNN, and pH***.**

1. Introduction to Artificial Neural Networks (ANNs)

The idea of a neural network was firstly considered as challenge to model the biophysiology of the human brain. Artificial neural networks (ANNs) suggestion a possible solution for complex problems which needs complex investigations and complex data analysis. Several academics researchers reported that neural networks have several applications in many fields of study including modelling, simulation, and control of nonlinear systems. Artificial neural networks are learning from example and it often used for applications where it is difficult solve using the classical rules. There are a several application fields where ANNs can be used including prediction, classification, noise reduction, optimization, and controlling [1, 2].

The neural networks consist of the input layer, an output layer and a number of intermediate layers called hidden layers such as shown in Figure 1.

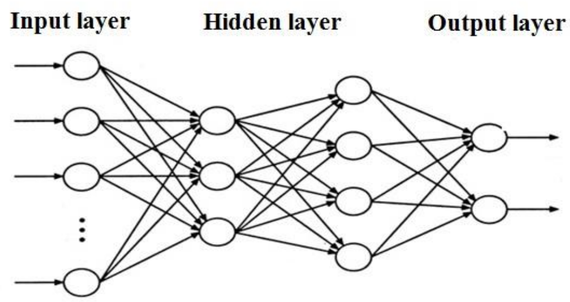

Figure 1: Neural network diagram [3]

During the train of the network, a set of data as inputs are required, and the outputs of the input layer are then fed to the inputs as weighted to the first hidden layer, after that, the outputs from the first hidden layer are fed as weighted inputs to the second hidden layer and so on; this process continues until the output layer is reached, then, the network output is compared with the actual output to calculate an error; finally, the weights of the network are adapted to minimize the error; this procedure is carried out repeatedly adjusting the weights to make the network output closer to the desired output. The work flow for the general neural network design process has seven primary steps [4]:

- Collect data
- Create the network
- Configure the network
- Initialize the weights and biases
- Train the network
- Validate the network (post-training analysis)
- Use the network

Neural networks are composed of simple elements operating in parallel. These elements are inspired by biological nervous systems. As in nature, the connections between elements largely determine the network function. Figure 2 illustrates the supervised training algorithm which is the common algorithm used to train the neural networks, it works to adjust the weights until the error tends to zero [3].

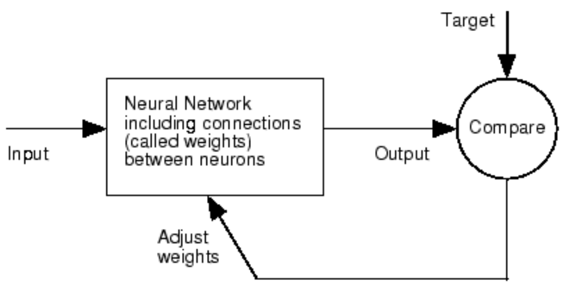

Figure 2: Supervised training algorithm [3]

There are several training algorithms to train the neural networks such as Gradient descent, Levenberg-Marquardt, Bayesian Regularization, Quasi-Newton, Resilient Backpropagation, Scaled Conjugate Gradient, Conjugate Gradient with Powell/Beale Restarts, Fletcher-Powell Conjugate Gradient, Polak-Ribiére Conjugate Gradient, One Step Secant, Variable Learning Rate Gradient Descent, and Gradient Descent with Momentum. The fastest training function is generally Levenberg-Marquardt which can be applied using “trainlm” Matlab command. There are typically two steps involved when using neural networks for control: System identification and Control design [1, 3, 4].

2. Nonlinear Autoregressive model with eXogenous input neural network (NARXNN)

A Nonlinear Autoregressive model with eXogenous input neural network (NARXNN) structure is shown in Figure 3. The NARXNN is a recurrent dynamic network, with feedback connections enclosing several layers of the network, where the output is a feedback to the input of the network. The NARXNN model is commonly used in time-series modeling. The delay line (D) is feed the neural network with the past values of inputs [5].

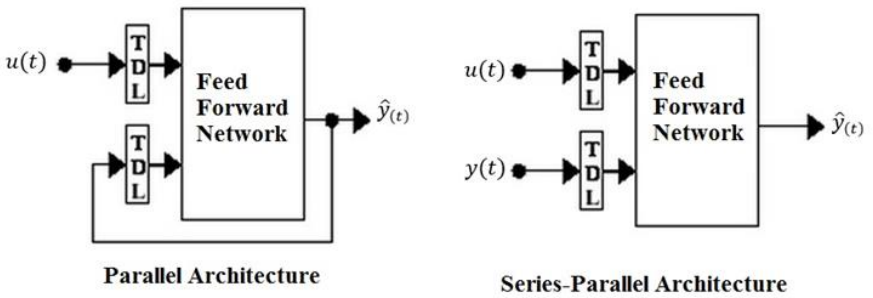

Figure 3: The structure of NARXNN [3]

The output of the NARXNN is represented using the following equation:

$$y(t) = f(u(t-1), u(t-2), \dots, u(t-n), y(t-1), y(t-2), \dots, y(t-m), W) \quad (1)$$

There are many applications for the NARXNN, but the important application it can be used as a predictor, that to predict the next value of the input signal. The use of the NARX network is demonstrated in another important application, it uses to modeling of nonlinear dynamic systems. The distinctive performance function used in train the NARXNN is the mean square error (MSE). The MSE is shown in the following equation used to reduce the error between actual output and network output [3].

$$MSE = \frac{1}{N} \sum_{i=1}^{N} (e_i)^2 = \frac{1}{N} \quad (2)$$

Where t_i the target output and y_i is the estimated output.

The most common training algorithm used to train the NARXNN is a Lavenberg-marquardt algorithm. The training of NARXNN stops when the validation error begins to rise.

The NARXNN model used to predict future values of several applications such as a stock, chemical processes, system identification, manufacturing systems, robotics, financial, and aerospace vehicles. The NARXNN model offer better predictions than the classical models, that because it uses the additional information contained in the prior data of y(t). The data set (input vectors and target vectors) normally divided into three sets as follows: 70% used for training, 15% used to validation (it is to stop training before overfitting), and 15% used for testing. The typical NARXNN is a two-layer feedforward network, with a sigmoid transfer function in the hidden layer and a linear transfer function in the output layer. This network also uses tapped delay lines to store prior data of the x(t) and y(t) sequences. This has two advantages: The input to the feedforward network is more accurate, and the resulting network has a purely feedforward architecture, and therefore a more efficient algorithm can be used for training. If the network's performance unsatisfied with the used data, the following steps can have considered: retrain the network, increase the number of neurons and/or the number of delays, and get a more training data set. In case the performance of the training set is satisfied, but the test set performance is considerably worse, that indicate overfitting happened, then decreasing the number of neurons can improve the results. It is important to know that the increasing the number of neurons and the number of delays can cause overfit the data when the numbers are set too high, then the number of neurons must set carefully [3, 4, 5].

3. Backpropagation Neural Network (BPNN)

This section describes one of the most common types of artificial neural network. Multilayer feedforward (MLFF) neural network with backpropagation (BP) learning (multilayer perceptron). A general multilayer feedforward (MLFF) network is illustrated in Figure 3 [6].

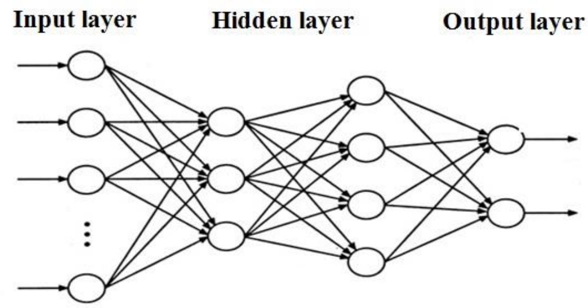

Figure 4: Backpropagation Neural Network (BPNN) [6]

The most common training algorithm which is used for training of BPNN is a Levenberg-Marquardt algorithm which adjusts the weights to reduce the error. The backpropagation training algorithm is designed to minimize the mean square error (MSE). The MSE is the function which is commonly used to optimize network performance, and it calculated using equation 5.
The weights can updated using the following equation [6]:

$$W_{ij}^{m}(t+1) = W_{ij}^{m}(t) + \eta\, \delta_{j}^{m}\, O_{i}^{m-1} \qquad (3)$$

Where $W_{ij}(t)$ is the old weight, $W_{ij}(t+1)$ is the new weight, η is the learning factor ($\eta = 0 \ldots 1$), δ is the error.

During a training of the network using supervised training functions such as the Levenberg-Marquardt backpropagation, three sets of input and target data supplied to the network, the first data set trains the network, the second data set stops training when generalization begins to suffer, and the third data set provides an independent measure of network performance. Also, the multilayer network is sometimes referred to as a backpropagation network. However, the backpropagation technique that is used to compute gradients and Jacobians in a multilayer network can also be applied to many different network architectures [3].

4. Radial basis function neural network (RBFNN)

The RBFNN consists of three layers, the first layer is input, the second layer is hidden, and the third layers is the output layer (hidden layer) as shown in Figure 5. The activation function lays in the hidden layer of the RBFNN. The training of RBFNN is consists of main two steps: select the centers and adapt the weights. The centers of the RBFNN normally selected using different strategies, but the common methods are fixed centers chosen randomly, and clustering algorithm [7].

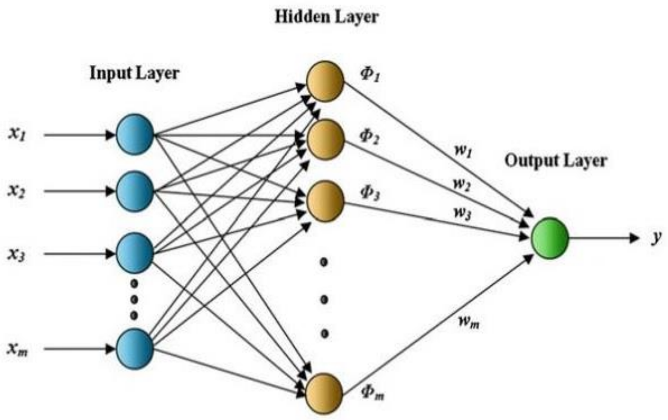

Figure 5: Radial Basis Function Network (RBFNN) Architecture [8]

Where X_m are the inputs, and C_m are the centres.

The output of RBFNN is:

$$y = \sum_{j=1}^{m} W_j \emptyset_j \quad (4)$$

Where W is the weights, and $\emptyset$ is the activation function.

In this work, the activation function of RBFNN was the Gaussian function, the Euclidean distance method used to calculate the width of RBFNN, while the least mean square algorithm (LMS) used to adjust the weights of the output layer for the RBFNN [8, 9].

The RBFNN can be designed and training using the following Matlab command (newrb). In the radial basis networks, the newrb Matlab command used in this work to create and train, and test the network, this command adds neurons to the hidden layer of a radial basis network until it meets the specified mean squared error goal: net = newrb (P,T,goal,spread,MN,DF).

Where: P is input vectors, T is target class vectors, spread is the mean squared error goal, MN is the spread of radial basis functions, and DF is the maximum number of neurons. The radial basis networks can require more neurons than standard feedforward backpropagation networks, but often they can be designed in a fraction of the time it takes to train standard feedforward networks. The Radial basis network is trained to respond to specific inputs with target outputs. However, because the spread of the radial basis neurons is too low, the network requires many neurons [10, 11, 12, 13, 14].

5. The accuracy of train and test different artificial neural networks

The following equation was used to calculate the mean absolute error (MSE) [15]:

$$\mathrm{MSE} = \frac{1}{N} \sum_{i=1}^{N} (e_i)^2 = \frac{1}{N} \sum_{i=1}^{N} (t_i - y_i)^2 \quad (5)$$

Where t_i the target output and y_i is the estimated output.

The following equation was used to calculate the mean absolute percentage error (MAPE) [16]:

$$\mathrm{MAPE} = \frac{1}{N} \sum_{i=1}^{N} \frac{|A_i - P_i|}{Ai} \text{ X } 100 \quad (6)$$

Where A_i is the actual output, P_i is the predicted output, i is time period, and N is the number of time periods (number of observed values).

The relative error calculated used the following equation:

$$\text{Errors} = \text{actual output} - \text{neural network output} \quad (7)$$

The error percentage calculated used the following equation:

$$\text{Error\_Percentage} = (\text{abs(Errors)./x}) \quad (8)$$

The error percentage and the mean absolute percentage error (MAPE) calculated used the following Matlab command:

$$\text{MAPE} = \text{mean(Error\_Percentage(}\sim\text{isinf(Error\_Percentage)))}\ 100 \quad (9)$$

The accuracy of the neural network for training and testing was calculated used the following equation:

$$\text{The accuracy} = 100 - \text{MAPE}\ \% \quad (10)$$

6. Simulation Tests, Results, and Discussion

The system was used in this work to assessing the training and test the different types of artificial neural networks are the pH Neutralization process. The pH inputs are 2001 sample (acid flow and base flow) were used to train and test the neural networks, while the output (targets) representing 2001 timesteps of the pH in the tank [3]. The following sections described the training and the testing of pH process used the three types of artificial neural networks: NARXNN, BPNN, and RBFNN. T*he dataset was divided into 70% for training, 15% for validation, and 15% for testing of* neural network. The performance function which was used in the training of neural network is the mean square error (MSE), it was used to reduce the error between actual output and estimated output. The mean absolute percentage error (MPAE) was used to calculate the neural network model accuracy for training and testing the neural network.

The actual output and neural netwrok output at the training using NARXNN are shown in Figure 6.

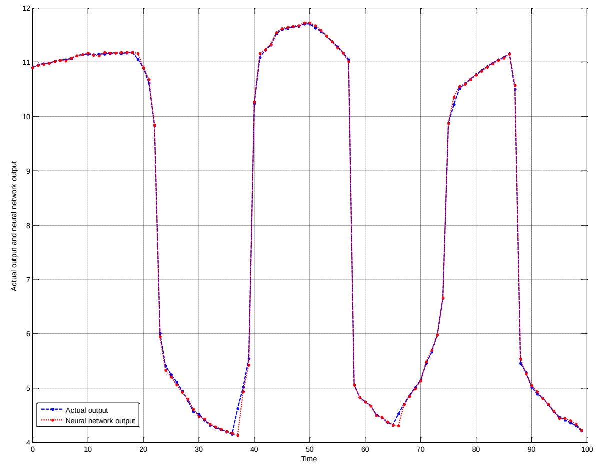

Figure 6: The actual output and neural netwrok output at the training using NARXNN

The actual output and neural netwrok output at the testing using NARXNN are shown in Figure 7.

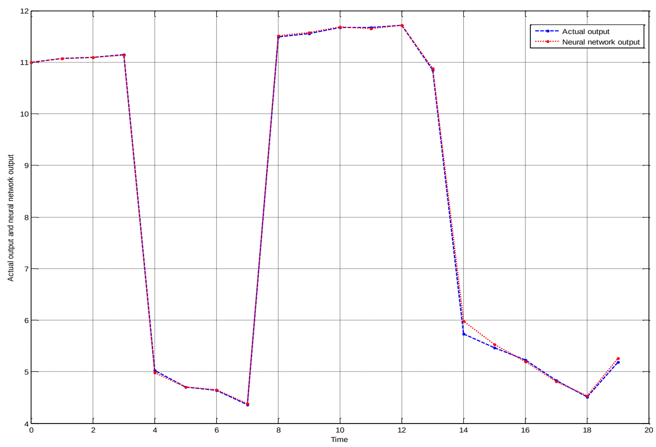

Figure 7: The actual output and neural netwrok output at the testing using NARXNN

The actual output and neural netwrok output at the training using BPNN are shown in Figure 8.

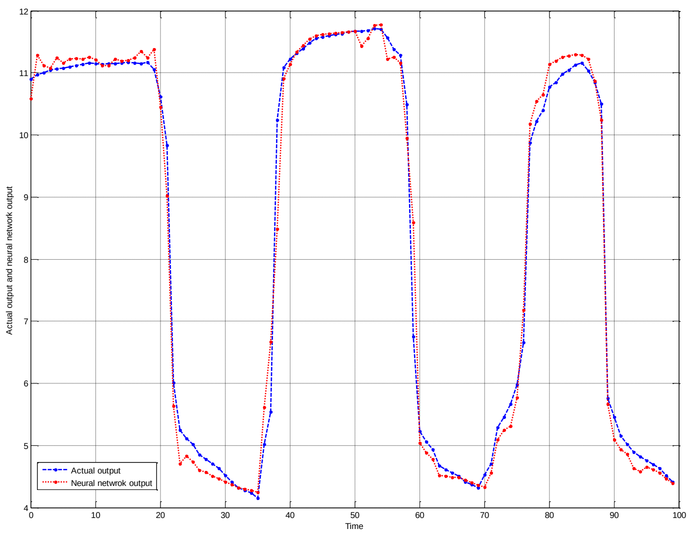

Figure 8 The actual output and neural netwrok output at the training using BPFNN

The actual output and neural netwrok output at the testing using BPNN are shown in Figure 8.

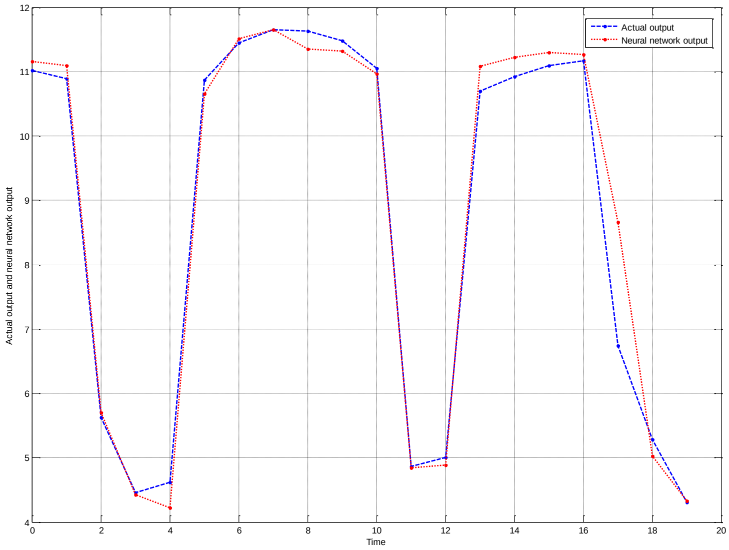

Figure 9 The actual output and neural netwrok output at the testing using BPNN

The actual output and neural netwrok output at the training using RBFNN are shown in Figure 10.

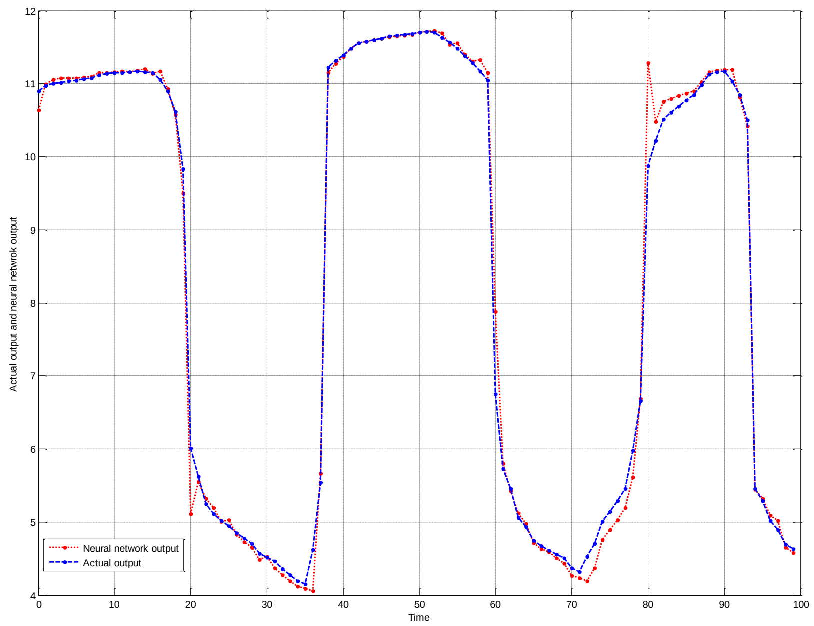

Figure 10 The actual output and neural netwrok output at the training using RBFNN

The actual output and neural netwrok output at the testing using RBFNN are shown in Figure 11.

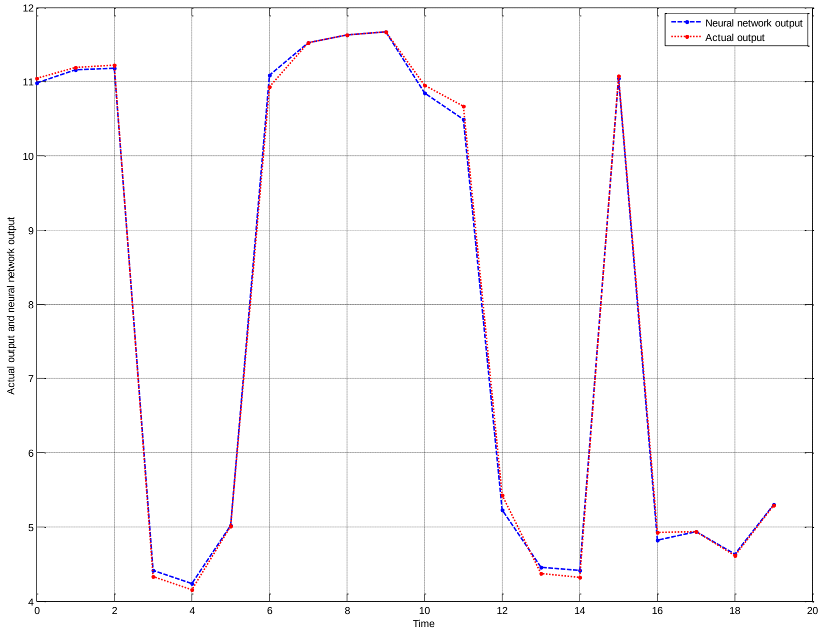

Figure 11 The actual output and neural netwrok output at the testing using RBFNN

The NARXNN, BPNN, and RBFNN performance:

When the training is complete, it is important to check the network performance and decide if any modifications want to be made to the network training process or to the network design or the data sets. The check to the network performance of NARXNN, BPNN, and RBFNN in this work carried out for the pH process prediction, simulation results show a very good network performance, that because the validation error have very similar characteristics, and it does not seem that any major over fitting has happened such as shown in Figure 12.

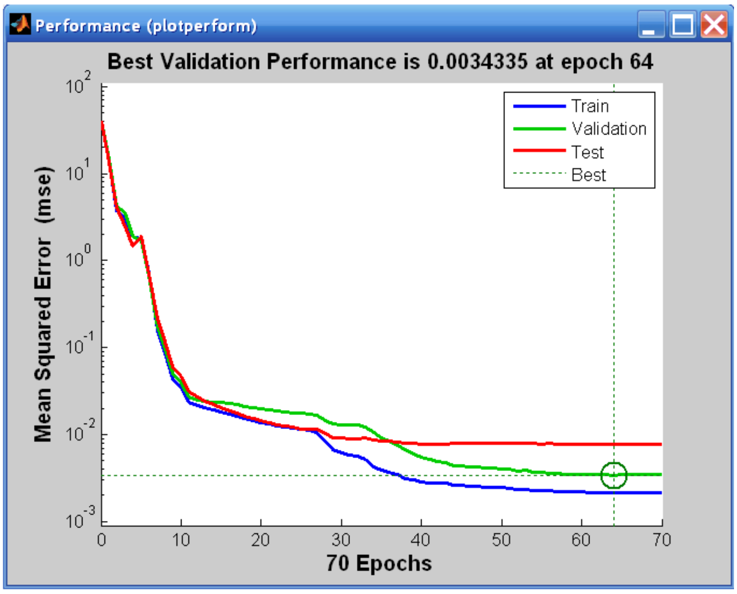

Figure 12: The performance of the neural netwrok

The Nonlinear Autoregressive model with eXogenous input neural network (NARXNN), backpropagation neural network (BPNN), and the radial basis function neural network (RBFNN) were developed to predict the pH process in the tank.

The simulation results shown in Figure 6 to Figure 11 show that the three types of neural networks achieved good pH process prediction. The percentage error was calculated, the results show that actual pH process was close to pH predicted using the neural networks. The accuracy of the neural networks for training and testing was assessed by mean absolute percentage error (MAPE).

In training stage, MAPE was 1.94% for NARXNN; therefore, the accuracy of neural network was 98.06%.

In testing stage, MAPE was 2.62% for NARXNN; therefore, the accuracy of neural network was 97.38%.

In training stage, MAPE was 3.27% for BPNN; therefore, the accuracy of neural network was 96.73%.

In testing stage, MAPE was 4.03% for BPNN; therefore, the accuracy of neural network was 95.9%.

In training stage, MAPE was 2.31% for RBFNN; therefore, the accuracy of neural network was 97.69%.

In testing stage, MAPE was 3.74% for RBFNN; therefore, the accuracy of neural network was 96.26%.

7. Conclusion

The three types of neural network were used in this work are: A Nonlinear Autoregressive model with eXogenous input Neural Network (NARXNN), Backpropagation Neural Network (BPNN), and Radial Basis Function Neural Network (RBFNN). The system was used in this work to assessing the training and test the three types of artificial neural networks are the pH Neutralization process. The accuracy of the three types of neural network for pH process prediction during training and testing was calculated, therefore, the accuracy of the NARXNN was the best, followed respectively by the RBFNN and BPNN. The accuracy of the three types of neural network was between 95.9% and 98.06%. It can therefore be concluded that the NARXNN, BPNN, and RBFNN are accurate models for pH process prediction, and it is a powerful tool for chemical process prediction.

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3

The Utilization of the Waste Heat Recovery using an Extra Condenser to the Domestic Refrigerator

The Utilization of the Waste Heat Recovery using an Extra Condenser to the Domestic Refrigerator

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Abstract

The purpose of this study is to use an extra condenser as a design to utilize the waste heat recovery from the domestic refrigerator. To get this goal, it should put some tools to measure the pressures and temperatures at some points during the cycle of operation of the refrigerator that to determine the enthalpy h. Several studies of waste heat recovery from the condenser in a household refrigerator for water heating were performed by many researchers. In this study the results shows that the maximum temperature recorded in the tank water was 50˚C.

Keywords: *heat recovery, a refrigerator, condenser, tank of water.*

1. INTRODUCTION

The purpose of this study is to use an extra condenser immersed in an external box tank filled with water as a design to utilize the waste heat recovery from the domestic refrigerator. Several studies of waste heat recovery from the condenser in a household refrigerator for water heating were performed by many researchers. As an example M.M.Rahman & Adrian Ng (2006) presented the research on the establishment of the waste heat, recovery device from the split air conditioning system. The device may increase the water temperature from 30˚C to 75˚C with 8 hours of operation [1]. P. Elmalai et al (2015) presented an investigation in heat recovery from the condenser of the vapor compression refrigerator (VCR) system through hot oven and heater which is placed between the compressor and condenser components. The system gets the temperature up to 48 in oven and 42 in water at a time period of 30 minutes continuous running [2]. Tanaji Balawant Shinde et al (2014) their study was to utilize the waste heat of the condenser by de superheating of compressor discharge gas. The results conclude that the system while operating under full load condition gives a better in coefficient of performance (COP) compared to no load condition [3]. N. B. Chaudhari et al (2015) presented a new design of the refrigeration with hot water heating system for domestic use. The results of the heat recovery and COP between the theoretical calculated and the actual results were wide variation [4]. Many researchers [5.14] were done in the field of waste heat, recovery and the effect of the heat recovery, water heater system on the performance of the domestic refrigerator and residential split air conditioner, so all results illustrate the improvement in COP and also reduction in the power consumption. In this study the results show that the maximum temperature recorded in the tank water it was 50˚C.

2. THE THEORY OF THE REFRIGERATOR

A typical domestic refrigerator system consists of four major components i.e. compressor, a condenser, an expansion device and evaporator are depicted schematically in figure 1. Figure 2 is the thermodynamic diagram of the process where numbered points correspond to the numbered points in figure 1. The operation cycle of the refrigerator system can be abbreviated in table 1.

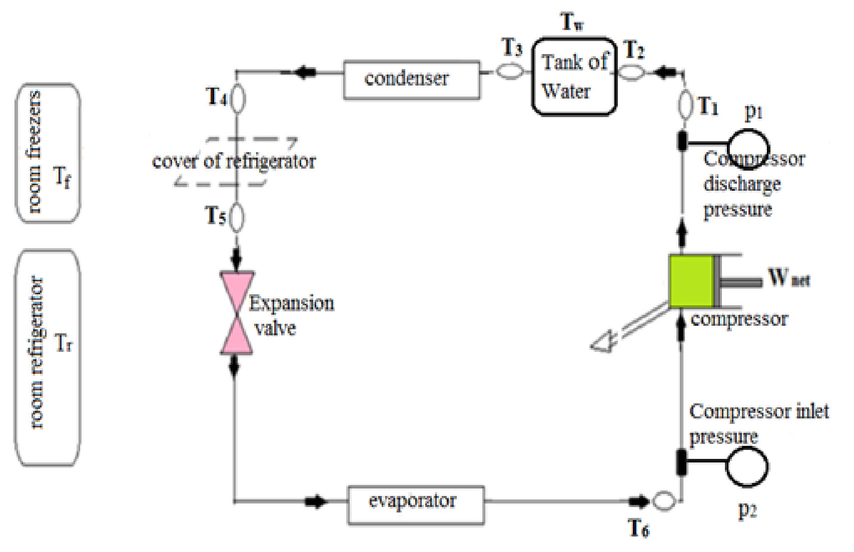

Figure 1 The operation cycle of the refrigerator system [14]

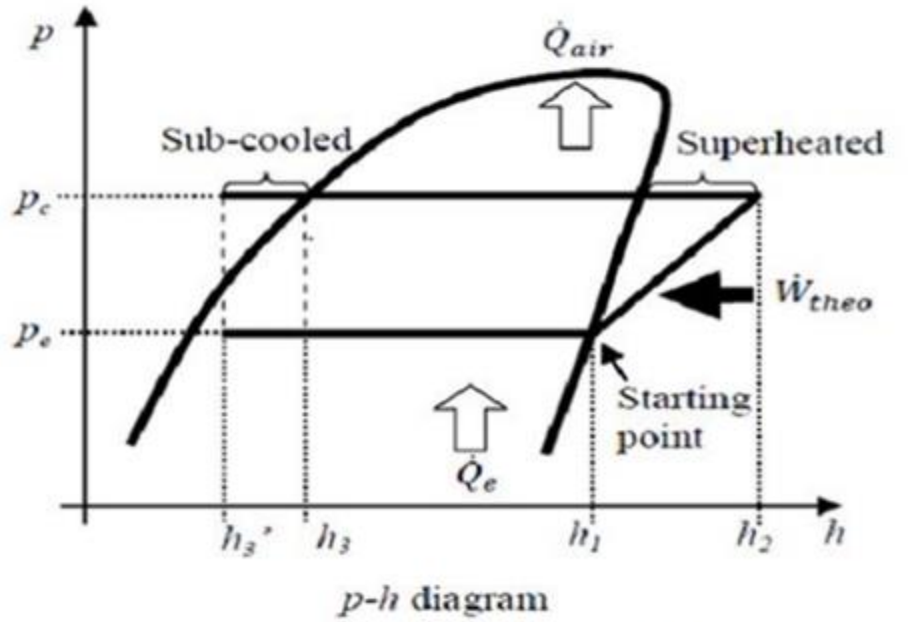

Figure 2 The thermodynamic diagram of the process [15]

Table 1: an abbreviated operation cycle of the refrigerator system

The process	The components	The equations	The power (watts) kg/kJ
The line from point 1 to 6	Compressor	$W_c = h_1 - h_6$	The power needed to do the compression
The line from point 2 to 3	heat exchanger inside box tank	$q_w = h_3 - h_2$	Absorbed heat by the water inside the tank

The line from point 3 to 4	Condenser	$q_c = h_4 - h_3$	Heat rejected
The line from point 4 to 5	Line frost, prevent	$q_d = h_5 - h_4$	
The line from point 5_e to 5_i	Expansion valve	$h_{5e} = h_{5i}$	Throttling process through the capillary tube
The line from point 5 to 6	Evaporator	$q_e = h6 – h5$	absorbed heat by the evaporator

Where the value of the enthalpy: h is determined by using the refrigerant properties database which it based on the temperature and pressure measurements. In this study we use the IRC electronic program to calculate the enthalpy h then it compared to the table of the physical properties tabulated in the Appendix of the Reference [16].

3. THE EXPERIMENTAL PROCEDURE

3.1. The experimental apparatus

The experimental apparatus unit was built from the domestic refrigerator with an extra condenser as water heater immersed in water in the box tank. The tank was made from the iron metal sheets that have 3mm thickness with (33cm x 33cm x33cm) dimensions. Figure 3 shows the picture of the out tank until that has been used in this research. Figure 4 shows the extra condenser that is used in this study.

The domestic refrigerator type is a (CODAMA) Model L58CZ unit has a cooling capacity of 260L with R-134A as working fluid. The power of the compressor was 1PH. The extra condenser was immersed in water in the tank and it put over the refrigerator as shown in figure 5.

Figure 3 shows the picture of the out box tank unit

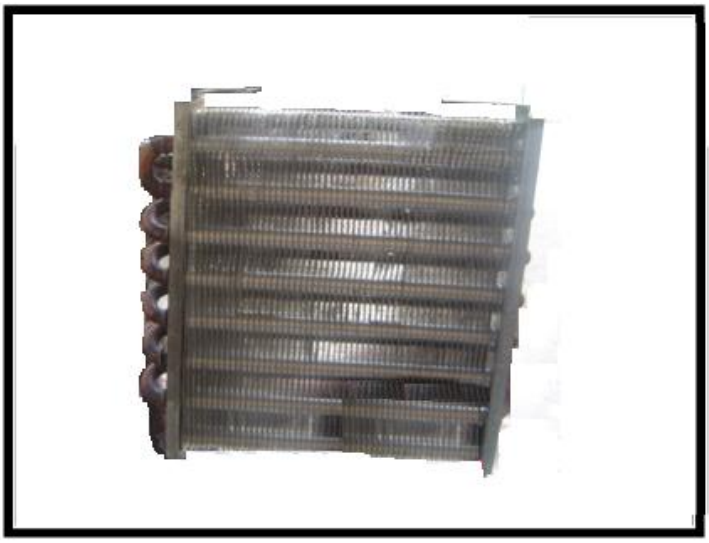

Figure 4 shows the extra condenser

Figure 5 shows the experimental apparatus unit

3.2. The Location of the Measurement Points

The data were collected manually every 5 minutes during 3 hour and the temperature measurements are obtained using thermocouple sensors type (ST10un/S57/023 thermometer), digital thermometer and they were placed at six points inside the refrigeration circuit. Also, the pressures are measured by the pressure gauge in the condenser side (high pressure) and the evaporator side (low pressure) is shown in Figure1. Table 2 shows the location of the measurement points at all points in the system.

Table 2 shows the location of the measurement points in the system

Symbol	component	Symbol	component
P_1	High pressure	P_2	Low pressure
T_1 (C°)	Temperature after compression	T_2 (C°)	Tank inlet temperature
T_3 (C°)	Tank outlet temperature	T_4 (C°)	Temperature after condensation
T_5 (C°)	Temperature of the Line frost, prevent	T_6 (C°)	Temperature of the Suction line
T_w (C°)	Water heater temperature inside tank		

4. RESULTS AND DISCUSSIONS

The experimental test rig is carried out to investigate the waste heat recovery based on the heat reject from the extra condenser which is immersed in the box tank that was filled completely by the water. The water in the storage tank is heated by the absorption of the supper heat of the refrigerant. Therefore, the calculation of the refrigeration system which to investigate the waste heat recovery, is to calculate the enthalpy h which is based on different temperatures with high pressure and low pressure. The thermodynamics properties calculation is carried out by the (IRC) software bases on pressure and temperatures. Then, data collection is compared to the tables of the physical properties tabulated on the Appendix in Ref. [15]. According to the theory of the refrigeration system; the results are plotted as in figures (6, 7, and 8) to illustrate the heat rejected and the heat gained.

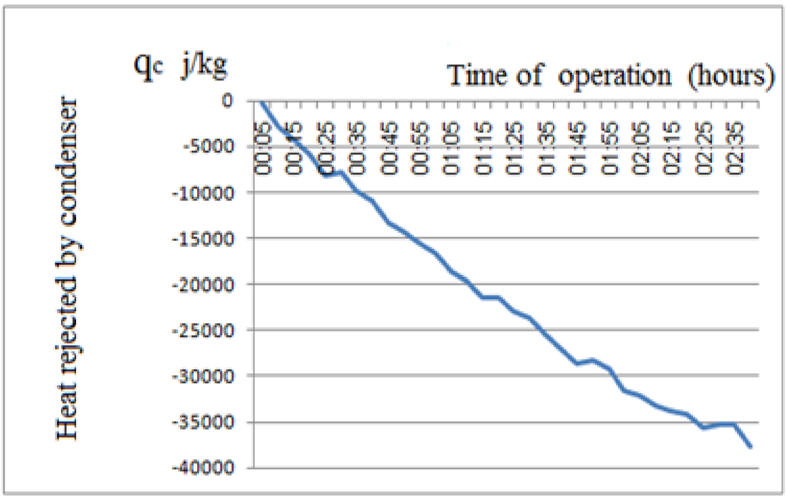

Figure 6 The heat rejected from condenser during the operation time

In figure 6 the graphs plotted indicate that the values of the heat rejected from the condenser of the refrigerator cycle increase gradually with the time operation until it reached the steady state condition after 160 minutes.

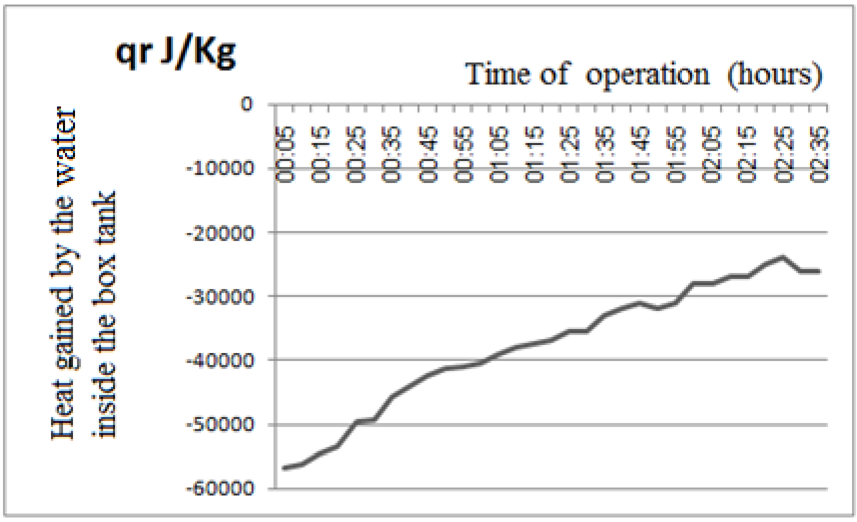

Figure 7 The heat gained by the water inside the box tank

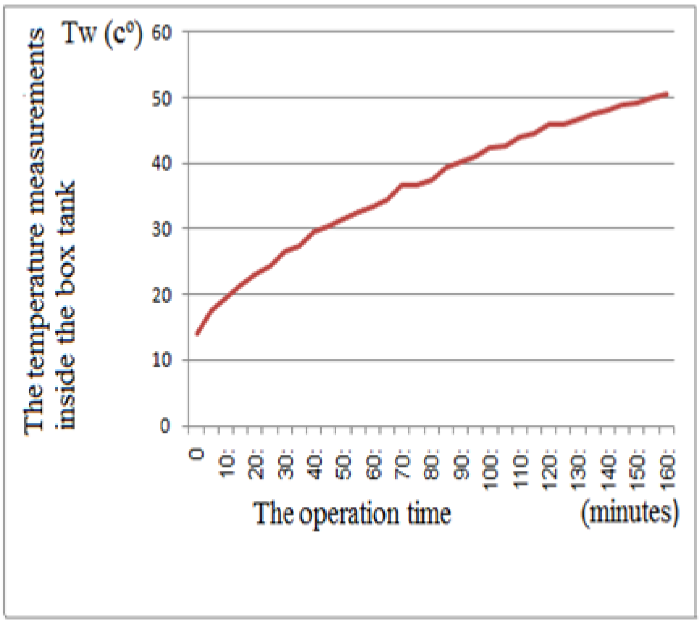

Figure 8 The increase of the temperatures at the water inside the box tank

In figure 8 the increase of the temperature of the water heat in the box tank is plotted as a function of time, which shows that during three hours of running, the water temperature is raised from 14C to 50.1C. It is noted that the temperature raising are change with the increase in working time. That increase depends on the different values between the temperature of water and the liquid refrigerant. In general, the use of heat recovery does not affect on the performance of the refrigerator and hot water products can be used in domestic uses in the kitchen like washing etc.

5. CONCLUSION

The experiment focuses in the utilizing of the heat recovery from the domestic refrigerator the temperature obtained inside the water tank it was 50˚C, and it can be used in domestic uses in the kitchen like washing etc.

Acknowledgements

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4

Theoretical Calculation of Nonlinear Current-Voltage Relationship in PEO of Al Using Multiphysics Simulation

Theoretical Calculation of Nonlinear Current-Voltage Relationship in PEO of Al Using Multiphysics Simulation

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Abstract

Plasma electrolyte oxidation (PEO) is a surface treatment process that uses an electric field to create a plasma in an electrolyte solution. This plasma reacts with the metal surface to form a hard, wear-resistant oxide coating. PEO can be applied to a variety of metals and alloys, including aluminum, magnesium, titanium, and steel. The way in which the electric field is spread throughout the electrolyser plays a crucial role in determining how PEO coatings form on substrates on complex shapes substrates. It is essential to model the treatment process before full-scale prototyping for complex-shaped components made from advanced materials. Neglecting this step could result in wastage of expensive materials, equipment deterioration, and increased labor costs. Particular attention was taken to create a mesh around the anode that accurately represents the oxide layer and discharges occurring on the surface of the sample. Additionally, three adjustment parameters were applied to simplify the 3D problem into a 2D model by taking advantage of symmetry along the axis and

estimating uneven coating growth around the perimeter of the sample. A method for calculating nonlinear current-voltage diagrams was also created, which offers a secondary current distribution that varies from the primary current distribution.

Keywords: *plasma – electrolytic– modelling – field – nonlinear - distribution*

1. Introduction

Numerical simulation can be used to evaluate the electric field distribution in a specific electrolyser and coating configuration. However, analytical models that represent the relationship between current distribution and process parameters are more advantageous for predictive design and scale-up. The thickness and morphology of PEO coatings on aluminum foil can vary, resulting in different current densities during the process due to factors such as sample shape, size, and position relative to counter-electrodes [1-4]. Substrate geometry is a key factor that affects current density values in electrochemical cells [5, 6]. While this study cannot provide a comprehensive explanation of electrochemical theory, discussing the electric field distribution during PEO treatments of complex samples can help understand how it affects current density distribution (CDD) in the electrolyser, which ultimately impacts PEO coating formation on such substrates. Electromagnetic field simulation can be used to predict the thickness distribution of electrodeposited coatings on complex shaped components [7]. However, for the PEO process, there is a lack of appropriate methodology to estimate coating uniformity on complex shaped parts. This modelling has been successfully applied to simulate processes and optimize electrolysers before physical tests. There are only a few publications that discuss PEO process modelling in terms of current density distribution and oxide layer thickness, making it an area for advanced research. The surface oxide layer formed during PEO treatment is considered as having the highest electrical resistance in the circuit, and the voltage drop over the electrolyte is often ignored. As a result, the current density at the interface between the oxide and electrolyte is assumed to be constant and averaged out, according to a study [8]. However, this approximation only works for simple electrode shapes like coaxial cylindrical cells. If there are any variations in the shape or position of the electrode, it can cause uneven coating growth, which is important to consider in modern technological processes [6]. Therefore, this research aims to develop a modelling method that takes into account nonlinear current-voltage diagrams and can be applied to more complex cell layouts. The theoretical calculations were based on a plate in a conductive cylinder configuration as an example. For experimental evaluation, a thin aluminium foil was chosen as the working electrode because its thickness is stable and known, allowing for calculation of both coating thickness distribution and metal losses after treatment.

2. Electric field modelling

2.1 General approach

The mesh method was used to solve a 2D electric field modelling problem related to electrolytic plasma polishing process [9, 10], which involved a non-linear element described as a vapour gaseous envelope. The same approach, boundary conditions and assumptions were used in this study, with particular attention paid to the mesh surrounding the anode to represent the oxide layer and discharges along the sample surface. Three adjustment parameters were also employed to reduce the 3D problem to a 2D model due to symmetry along the axis and estimate uneven coating growth over the sample perimeter.

Assumptions

Before the modelling process, certain presumptions were made. These include:

I. The PEO treatment is carried out in an anodic environment where the metal surface acts as the anode of an electrochemical cell.
II. The electrolyte is stirred to ensure uniform temperature during the system work.
III. The electrolyte is considered a linear and homogeneous conductive medium, implying that its conductivity does not change with variations in electric field or ion concentration.
IV. Finally, nonlinearity in the system arises due to resistance from the oxide layer, which increases as its thickness growths.

The modelling study utilized various electrolytes, which were created using different amounts of potassium hydroxide (KOH), sodium pyrophosphate ($Na_4P_2O_7$), and sodium silicate (Na_2SiO3). These electrolytes were labelled as E1, E2, E3, and E4 in Table 1.[11].

Table 1. Types of electrolytes used in the simulation.

Elec. code	**Concentration (g/l)**		
	KOH	**$Na_4P_2O_7$**	**Na_2SiO_3**
E1	0.75	0	0
E2	0.75	0	2
E3	0.75	2	0
E4	0.75	2	2

2.2 Boundary conditions

The issue with boundaries pertains to the way current density is distributed in the electrolyte in three dimensions. This is applicable to a rectangular sample that is positioned inside a conductive cylinder, as shown in Figure 1. Although this setup is frequently utilized in research and industrial settings, it needs to be made less complex for more accurate computations.

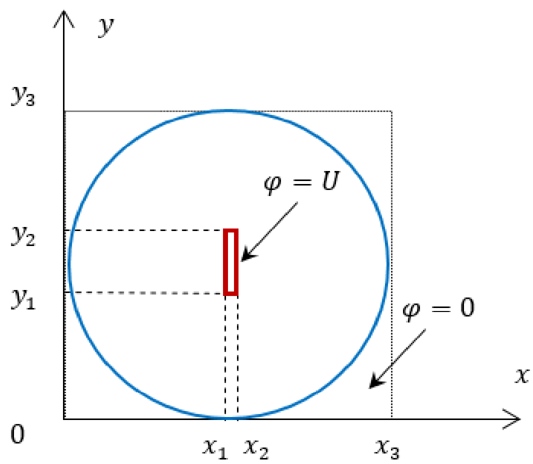

Figure 1: Anode systematic for the electric field investigation

To determine the 2D distribution of the electric field in a conductive medium, the Laplace equation (∇2φ=0) is solved numerically. This is done in Castesian coordinates (x, y, z) using the electric potential φ [1]. The problem is solved for a longitudinally invariant field φ=$\varphi(x,y)$, assuming that the system follows assumption (5). A thin rectangular anode is sited at position (x1; y1) in the center of the system, with a cathode with diameter x3=y3 forms the perimeter of the system. Dirichlet boundary conditions;

$$\varphi = 0 \; and \; \varphi = U \quad (2)$$

are adapted at the cathode and anode respectively. This explains the 2D problem shown in Figure 1.

To form a circular cathode within a rectangular matrix field, the potential of all points outside the diameter was set to zero. This allowed for the evaluation of current density distribution along the anode's perimeter in the x-y plane. The Laplace equation applicable to this case is expressed as:

$$\partial^2\varphi/\partial x^2+\partial^2\varphi/\partial y^2=0 \quad (3)$$

One way to solve this problem is by using either a finite difference or finite element approach on a mesh that covers the relevant area. This involves calculating the potential, denoted as $\varphi i, j$, for each node with coordinates (i, j) on the mesh. Various electric field modelling software such as COMSOL and ElCut can be used to obtain this solution. [12].

2.3 Equivalent circuit of the electrolyser

A simplified version of the PEO process circuit is depicted in Figure 2, consisting of two resistances: R1, which is the linear electrolyte resistance, and R2, which is the nonlinear coating resistance. When a voltage U is applied to the system, two voltage drops are produced on these resistances - U1 across R1 and U2 across R2.

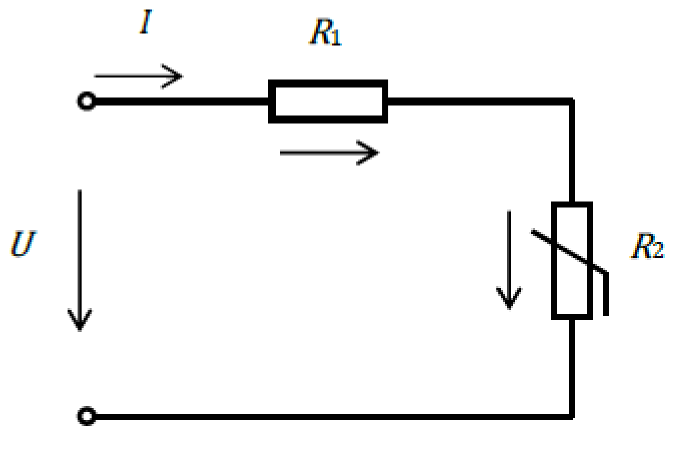

Figure 2: DC corresponding circuit of the electrolyser

Kirchhoff's voltage law: $U = U1 + U2$.
Electrolyte voltage drop: $U1 = R1 \times I$.

2.4 Nonlinearity of oxide layer

To explain the nonlinear resistance R2, an inset was added around the anode as shown in Figure 3.

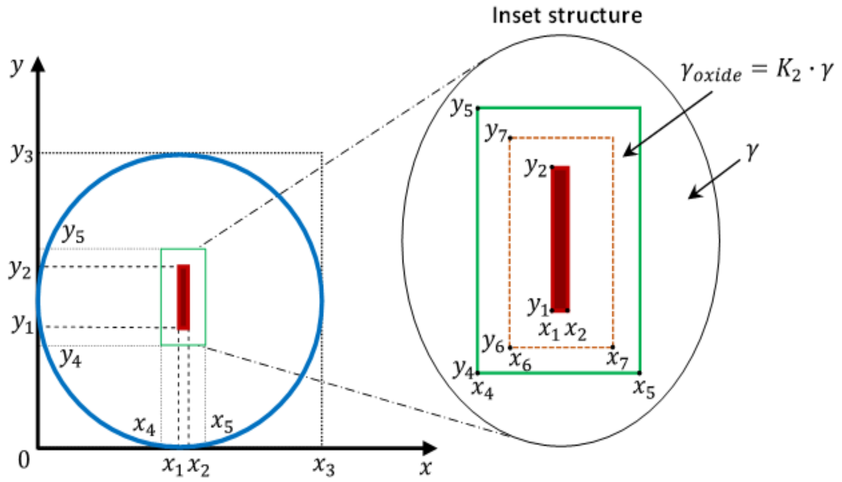

Figure 3: Electrode layout for the electric field study with anodic inset

This part of the section contains the anode, which has a potential equivalent to the cell voltage (with the cathode potential being zero). Additionally, there is a small rectangle called $Sinset$ (centrally located by $x4$, $x5$, $y4$, $y5$) that considers parameters such as vapour-gaseous media, microdischarges and oxide layer input into the electric field distribution. The boundary conditions are set at U = 550 V and Uc = $Uelectrolyte$, where $Uelectro$ is the electrolyte potential at the boundary between the potential matrix and the inset. To maintain an average current equal to $I_{exp.}$, potentials along the sample are subtracted from the electrolyser voltage and dropped to its mean value. Then the obtained voltage distribution is applied to the selected I-V diagram. Faraday's law can be utilized to qualitatively estimate the distribution of oxide layer thickness through the secondary current density distribution. This is expressed as

m=1F/Mz ($\delta\cdot s\cdot t\cdot \eta$)

where F=96484 C·mol–1 is Faraday constant; z is the number of electrons in the electrochemical reaction; M is the molecular weight of oxide; δ is the anode current density; t is process time, η is current efficiency.

3. Results and discussion

Figures 4 display the findings of computational experiments conducted to assess the electric field and corresponding CDD for E1 and E4 electrolytes. Figure 4 showcases a 2D field distribution in E1 electrolyte, with red dots indicating voltage probe positions and a maximum value of 40 V. The rectangle in the canter denotes the loop used for the anodic inset. Figure 5 presents the potential distribution bounded by the loop under experimental conditions Ua = 550 V, Linset = 6%, revealing a rapid potential decrease from anode to cathode. The majority of the voltage (510 V) drops across a relatively thin oxide layer and surrounding vapour-gaseous medium with microdischarges.

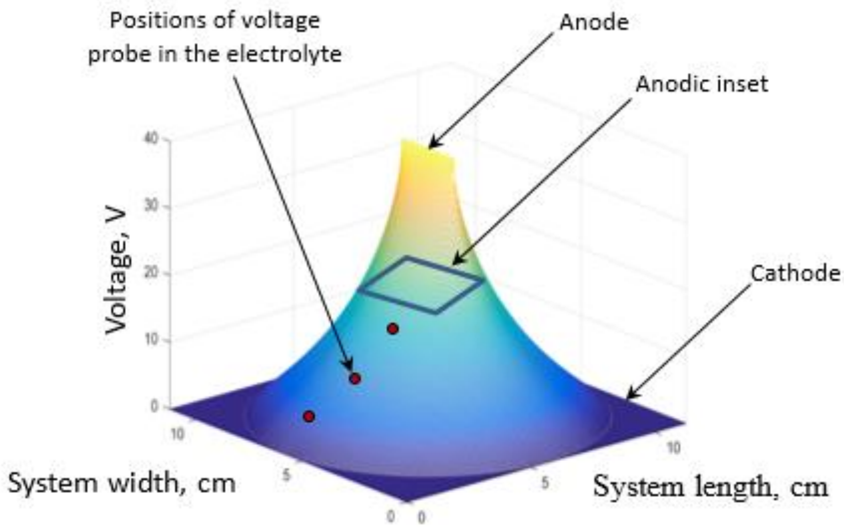

Figure 4: Potential distribution in electrolyte E1

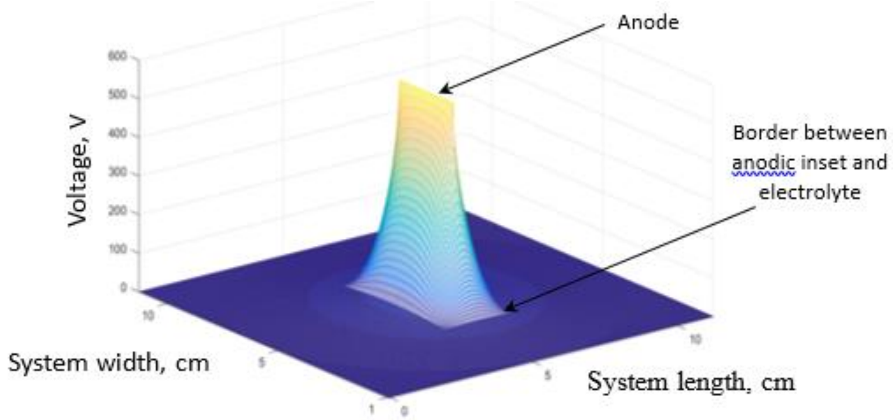

Figure 5: Potential distribution within the anodic inset in electrolyte E1. (*Ua* = 550 V, *Linset*= 6%)

The middle of the anodic inset was identified as K2 = 0.5 for all cases in the integration loop position. The maximum cell voltage of 550 V was used to select the optimal surface area Linset for the anodic inset. Figure 6 displays plots for electrolyte E1, including the voltage drop within the inset (Fig. 6a), primary CDD in the electrolyte (Fig. 6b), mean voltage drop within the inset on the current-voltage diagram (points (1), (2) and (3) in Fig. 6c), and secondary CDD within the inset (Fig. 6d). The secondary CDD curve with Linset = 6% was chosen for further calculations as it provided a shape approximation closest to the coating thickness distribution.

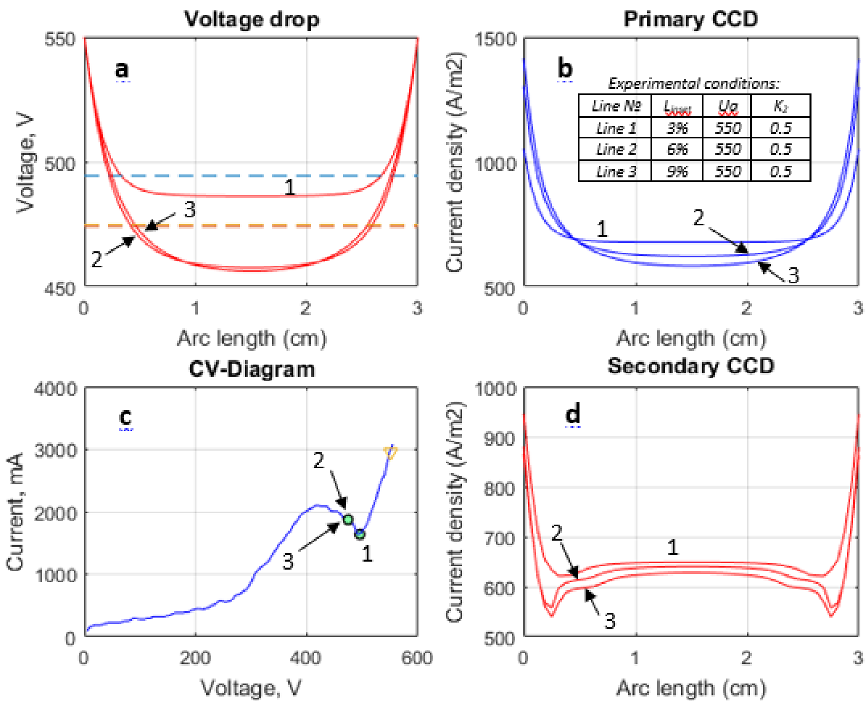

Figure 6: Modelling plots for electrolyte E1 with different anodic inset area width

After fixing the inset area width at 6% and K2 at 0.5, the cell voltage Ua was adjusted. The best option was found to be the secondary CDD curve (1) with a Ua of 510 V, as it had the highest current density on the edges and a moderate increase in the middle of the sample.

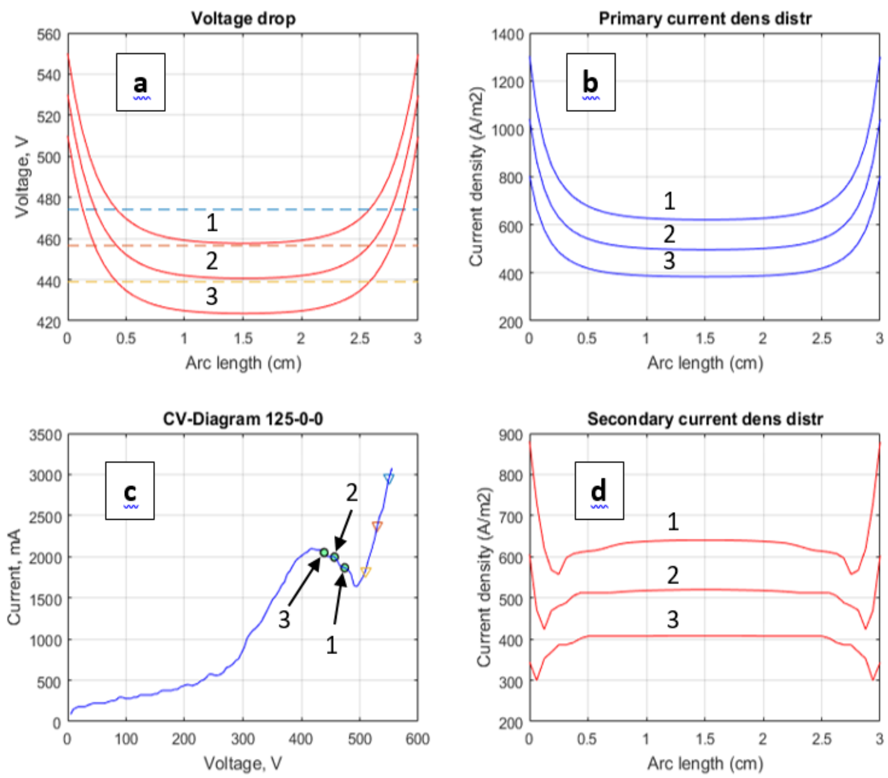

Figure 7: Modelling plots for E1 electrolyte with different treatment voltages

The diagram in Figure 7 displays the secondary CDD surrounding the anode in electrolyte E1, using the ideal parameters of Ua = 510 V, La = 6%, and K2 = 0.5. This distribution has the closest correlation with the thickness distribution of the coating and can be utilized to estimate the coating thickness distribution on complex-shaped substrates treated in electrolyte E1. In comparison to E1, electrolyte E4 has a smoother current-voltage diagram, making the calculation process much simpler. The plots in Figure 8 illustrate various CDDs for different voltages Ua in electrolyte E4. Curve (2) was selected as optimal due to moderate differences between current density on sample edges and in the middle.

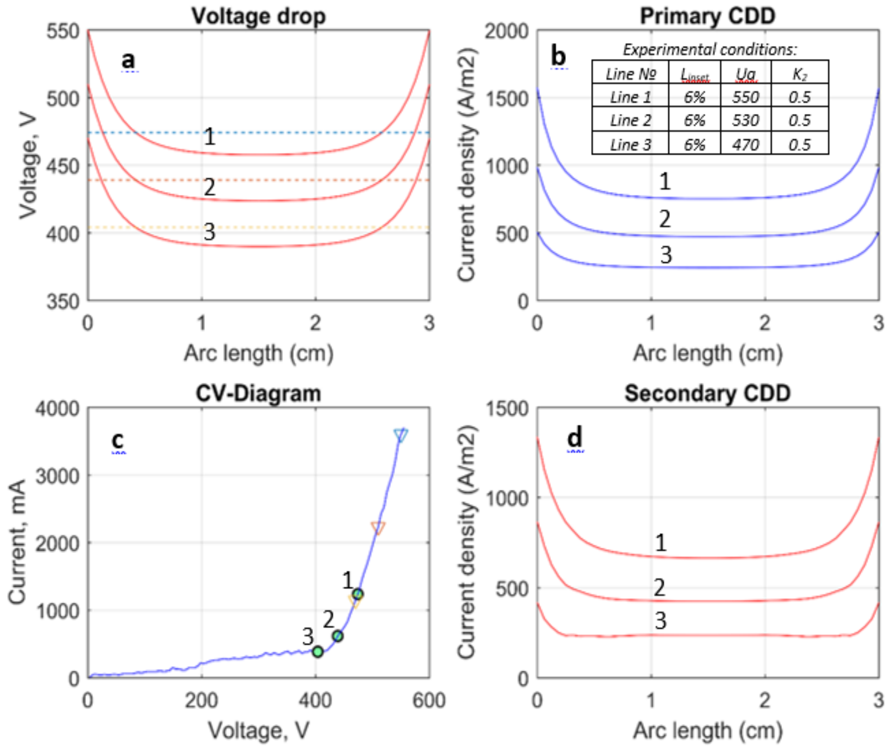

Figure 8: Modelling plots for electrolyte E4 with different cell voltage

The modelling results for electrolytes in E1 and E4 were compared, and it was found that the shape of the current-voltage diagram caused significant nonuniformity in the secondary CDD.

4. Conclusion

A technique for computing nonlinear current-voltage graphs was created, which reveals a secondary current distribution that is distinct from the primary one. The layer of oxide that forms on the part's surface during PEO treatment is considered to be the component with the highest electrical resistance in the system. The simulation outcomes for electrolytes in E1 and E4 indicate that the nonuniformity in the secondary current density distribution is significantly influenced by the shape of the current-voltage diagram.

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5

Waste management and the Internet of Things technology

Waste management and the Internet of Things technology

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Abstract

Waste management refers to the process of disposing of goods and materials in a safe and cost-effective manner. There are various waste management strategies, including reduction and reuse, animal feeding, recycling, composting, fermentation, landfilling, incineration, and land use, each divided into different categories. Fortunately, the Internet of Things (IoT) technology offers solutions to address the waste management problem at every stage.

This research highlights the important role of IoT technology in managing the disposal of various waste types, particularly solid waste, by exploring some of the techniques that can be applied in this field. The study also draws on the experiences of different countries in this area. IoT technology has played an effective role in maintaining a clean environment in residential communities in both urban and rural areas, as well as saving effort and costs.

Keywords: *The Internet of Things, waste management, solid waste, waste disposal*

1. Introduction

The process of urbanization has resulted in a multitude of challenges related to the management of the urban environment, stemming from factors such as industrialization, population growth, changing lifestyles, growing economic activities, and the introduction of new technologies, including e-waste management. Urban waste management is one such issue that has arisen due to these factors, with cities and towns struggling to cope with piles of rubbish that are left to rot in the open. This problem is not limited to daily municipal waste but also includes waste from various industries located on the outskirts of urban areas, including hazardous and non-hazardous waste, biomedical waste, and waste generated by IT and electronic sectors.

Poor waste management practices have a direct impact on the urban environment, leading to air, water, and soil pollution, long-term health effects, and indirect economic impacts. This paper aims to address the problem of urban waste management and explore the extent to which the Internet of Things (IoT) technology can be utilized to implement safe and cost-effective waste disposal programs to maintain a clean environment. The paper aims to answer questions such as: (1) what is the role of the Internet of Things in solid waste treatment? (2) What are the different ways in which this technology can be applied in waste treatment? (3) How can this technology contribute to creating a healthy and clean environment in urban areas?

2. Literature Review

It has become a common sight to see trash littering the sides of roads and overflowing from bins due to factors such as population growth, waste from hotels and industries, and the introduction of new technologies. This overflow of trash not only creates an unsightly environment but also poses health risks to the public. To address this issue, an IoT waste management system has been proposed for implementation in smart cities. This system connects multiple trash bins from different areas across cities using built-in sensors that detect the level of trash inside and send this information to the municipality control room. This information is then relayed to the truck driver responsible for waste collection. The system also includes sensors to detect the presence of toxic gases in the containers.

Municipal solid waste management is a critical concern in Indian cities, with inappropriate management of municipal solid waste creating risks for the population. An experiment was conducted to review the characteristics, generation, transportation, and disposal techniques of MSW in India and to identify key issues associated with MSWM in Indian cities. Existing waste management models were reviewed, and it was found that they primarily engage in optimizing analysis steps rather than addressing the choice of the waste management method itself.

The Smart Garbage System (SGS) is an IoT-based program designed to reduce waste accumulation. Battery-based garbage bins exchange information with other wireless mesh networks, and the router and server collect and analyze the information to provide the service. SGS incorporates several IoT technologies to increase battery life, and the system was tested in the Gangnam District of Seoul, resulting in a significant reduction in waste.

Treatment and recovery are important components of Municipal Solid Waste Management Systems (MSWMS), with a focus on the reuse, recycling, and recovery of valuable items from waste streams in developed and developing countries. Separation of waste is considered the best garbage and reusable materials management application for every municipality, and many technologies have been used since the 1980s. RFID technology is extensively used in some industrialized countries, serving as a labeling system that automatically identifies reusable items in the municipal solid waste stream. However, the environmental consequences of RFID implementation must be examined to avoid potential issues with resource management and pollution control.

Intelligent transport systems and the IoT can be applied in smart cities to provide new services, including the classification of economic waste. A developed communication network (DSS) has been proposed for the classification of economic waste in cities, integrating detection systems using radio frequencies, sensors, cameras, and actuators into information technology and policing systems. The waste classification system aims to provide high-quality service to citizens by monitoring problem areas and optimizing waste sorting and route optimization.

3. Waste disposal types and methods

The waste produced by various sectors of society can be sorted based on its composition and intended destination, a crucial step that enables selective collection, recycling, and proper disposal. Municipalities in urban areas handle a highly diverse volume of solid waste, including industrial and hospital waste that is relatively uniform in its characteristics. Selective collection has become the cornerstone of effective waste management globally, particularly when it comes to recycling. To implement an IoT-based waste management system, it is essential to pre-sort the waste, using designated containers for each type of waste.

In London, solid waste collection is performed according to selective collection standards. This involves using various colored containers or garbage bags to separate the waste, such as red for toxic waste, yellow for hospital waste, blue for disinfected hospital waste, and black for household waste. Glass containers are sorted into green, black, and brown categories based on their color and type, and placed in separate containers [6]. The various types of waste examined are described in detail below.

- **Organic waste**. Organic waste litter is produced mainly in households, restaurants, and food-related commercial establishments [7]. It must be separated from other types of waste because it is usually disposed of in municipal landfills.

- **Recyclable waste**. This type of waste refers to all materials that can be repurposed or transformed into other substances or raw materials [8]. It is generated by households, businesses, and industries, and must be sorted and collected by selective collection teams before being transported to recycling companies for final processing.
- **Industrial waste**. These residues are primarily solid waste that results from industrial production processes. They typically consist of leftover raw materials that are intended for recycling or reuse within the industrial process [9].
- **Hospital waste**. This waste is generated by hospitals and medical clinics and has the potential to cause pollution and spread diseases to those who handle it [10]. It must be treated with utmost care and processed in compliance with established standards. Companies that specialize in the treatment of this type of waste are responsible for its disposal, as it is typically incinerated.
- **Commercial waste**. This refers to waste generated by commercial establishments, including clothing, toy, and hardware stores, among others. This type of waste is highly recyclable, with nearly all of it being processed for reuse [11].
- **Green waste**. This material is primarily composed of tree trimmings, branches, trunks, bark, and leaves that fall onto streets. Being organic in nature, it can be utilized for composting and the production of compost [12].
- **Electronic waste**. This refers to waste resulting from the disposal of consumer electronic products that are either obsolete or no longer functional [13]. To dispose of such waste, designated facilities such as recycling companies exist to ensure that it is handled in an environmentally safe manner.

- **Nuclear waste**. This type of waste is primarily produced by nuclear power plants and is considered extremely hazardous due to its radioactive properties. It must be handled in strict compliance with safety standards [14].

4. Waste disposal methods

There are many ways to get rid of waste, and the following is an overview of some of them:

1. **Burial in the ground**

The most commonly employed waste disposal method nowadays involves dumping daily waste or garbage in landfills, which entails burying the waste in the ground. This technique is prevalent in developing countries and involves treating hazardous waste and odors before depositing it at the bottom of the landfill. Although it has been the standard method for waste disposal, this technology has been declining in popularity due to the high presence of paraffin and lowland gases, which can cause various pollution issues. Landfills contribute to air pollution, which can have severe consequences for the surrounding environment and pose a threat to humans and animals. As a result, many parties are reconsidering the use of landfills.

2. **Burning / combustion**

Incineration or combustion can be a gentle disposal technique in which waste is burned at high temperatures, so as to turn it into residue and gaseous products. The biggest advantage of this type of technology is that it will reduce the amount of solid waste to twenty to thirty percent of the initial volume, and reduce pressure on landfills. This method is also referred to as heat treatment as solid waste is converted by incinerators into heat, gas, steam and ash.

3. Recovery and use

Resource recovery is a process that involves salvaging useful objects from discarded waste. This waste material is then treated to extract or reclaim materials and resources, or transformed into usable forms of energy such as heat, electricity, or fuel. Recycling, on the other hand, involves converting waste into new products to prevent the consumption of energy and new raw materials. The concept of "use" is the third element of the waste hierarchy, along with reduce and recycle. The aim of "use" is to reduce energy usage, minimize the size of landfills, mitigate air pollution, cut down on greenhouse gas emissions, and conserve natural resources for future generations.

4. Plasma chemical change

Plasma-based chemical alteration is a waste management technique that involves altering waste using plasma, which can exist as either an electrically charged gas or a highly ionized gas. Illumination is a form of plasma that can produce temperatures in excess of 315 degrees Celsius. This waste disposal technology utilizes unique plasma torches operating at +5538°C within a container to induce a chemical reaction collar of up to 1649°C, thereby transforming solid or liquid waste into gas. During the process of plasma chemical denaturation of solid waste, the molecular bonds of the waste break down due to the high heat generated within the container and the starting elements. This method destroys waste and hazardous materials, while also providing a source of renewable energy. By using this waste disposal method, we can help eliminate waste and hazardous materials, while generating renewable energy.

5. Fertilizing

Composting is a natural and straightforward method of breaking down organic waste, such as plant, garden, and household waste, and converting it into nutrient-rich food for plants. This technique, which is commonly employed in organic farming, involves allowing organic matter to sit in one place for several months to decompose via microbes. Composting is a simple yet effective waste disposal method as it transforms hazardous organic materials into safe compost. However, it is a slow process.

6. Converting waste into energy (energy recovery)

The waste-to-energy approach involves transforming non-recyclable waste into usable forms of energy, such as heat, electricity, or fuel, through a combination of processes. This power generation method can provide a source of renewable energy, as non-recyclable waste is repeatedly utilized to generate energy. Additionally, it has the potential to reduce carbon emissions by offsetting the energy requirements from fossil-based sources..

7. Reduce waste

The most straightforward approach to waste management is to reduce the production of waste materials, thereby decreasing the amount of waste sent to landfills. This can be achieved by reusing old items such as jars and bags, repairing broken items instead of buying new ones, avoiding disposable products like plastic bags, reusing used items, and choosing products with longer lifespans.

Recycling and composting are also effective waste management strategies. At present, composting is primarily done on a small scale, either by individuals or in areas where waste is mixed with agricultural soil or used in landscaping. Recycling is widely practiced worldwide, with plastic, paper, and metal being the most commonly recycled materials. The majority of recycled materials are reused for their initial purpose.

5. Management of Solid Waste

Various published papers have explored the use of IoT technology for waste management solutions. For instance, in reference [15], the authors present an intelligent monitoring solution that aids in planning garbage collection. The Smart-M3 platform, an extension for cross-domain search for three-base information, enables interstitial applications from different information and communication fields, making implementation easy. The solution was developed in two phases: the first phase monitors waste levels within compartments continuously, while the second phase applies the collected information to enhance waste collection methods.

To create a smart waste system, the researchers utilized different components, each capable of interacting with the smart space, in line with the vision of smart cities, which need components that measure and transmit real-time context data. Two types of sensors were installed in the boxes: a proximity sensor located inside the lid or on the inside and top of the basket, and a weight sensor at the bottom of the container. The proximity sensor measures the fullness of the container, while the weighing sensor measures the amount of waste in the bin or thrown away by the user. Each enclosure has a communication unit that transmits measured physical quantity values to the nearest lamppost. A gateway component within the lamppost collects, processes, and transmits the data measured by the sensors to the control center. The gateway is powered directly by the power source used to produce the lamppost light and contains a communication module for obtaining sensor values. Additionally, it is crucial to locate the bins. Since the lamp post is located close to a small group of bins, it serves as the portal that links the GPS coordinates recorded for each bin. The control center is the component that uses sensor data to implement effective and impactful optimization strategies and to find solutions to resource management problems associated with solid waste management. It also informs a vehicle if and when they should empty the bins.

The waste management system described in this study divides the city into districts, with each district being defined by a polygon area consisting of coordinate points. During system configuration, waste vehicles are mapped to specific areas of the city. These vehicles are equipped with computers or tablets with internet access, which provide them with a daily list of bins that need to be emptied based on their area and the number of full bins. Additionally, users can interact with the smart waste system via their smartphones or tablets, which are used for authentication, collecting "green points," and accessing information about nearby bins and waste types.

In reference [16], the authors propose a dynamic waste management model that leverages smart city infrastructure services based on the Internet of Things. The system utilizes RFID sensors and actuators for monitoring and identification in three phases: (1) planning and implementing waste collection using routing solutions in trucks with dynamic route adaptation based on constraints; (2) transporting waste to a specific location based on type; and (3) recycling waste that can be reused. The system's dynamic nature enables it to adapt in real-time to factors and plans that affect waste collection. However, this study primarily focuses on planning and waste collection processes and does not delve into the advantages of sensor-based monitoring and communication methods.

In reference [17], the authors introduce a cloud-based intelligent waste management solution (Cloud SWAM) that utilizes specific containers for different types of waste (organic, plastic, bottles, metal) with sensors that continually monitor their condition and transmit the data to the cloud. Relevant stakeholders can access the information, which not only aids in waste management but also helps determine the most economical collection route within the city.

Reference [18] presents a new waste management model that focuses on identifying suitable areas for building landfills. Since landfills serve as the final destination for residential, commercial, and industrial waste, choosing the right location within urban areas requires attention to economic, environmental, and public health concerns. The solution uses data from a waste management system and applies a genetic algorithm to select appropriate landfill sites.

In reference [19], the authors discuss various waste disposal methods and introduce an integrated fill level sensor solution called the Smart Bin, which utilizes a solar-powered waste compactor to optimize the waste collection process. The sensor data is transmitted wirelessly to a cloud-based server, and stakeholders can access real-time information through smart box monitoring, which applies to any container type and size.

The study presented in reference [20] proposes an intelligent garbage recycling system that requires waste pre-separation before disposal. Glass is placed in brown packaging, paper and aluminum cans in blue packaging, and plastic products in orange packaging. The system automatically identifies the type and quantity of waste disposed of and rewards users with points that can be exchanged for items or withdrawn as virtual currency. This approach is similar to the previous studies that utilize specific containers for waste pre-segregation, with one focusing on financial gains for a diverse group and the other providing a reward for citizens who dispose of waste properly.

Reference [21] proposes a solution to the problem of overflowing landfills by utilizing a screening system based on near-infrared (NIR) spectroscopy to identify five types of resin and the remaining biodegradable waste for biogas production. The system includes a screen that triggers an alarm and notifies authorized personnel when the container is ready to be filled.

In reference [22], the authors present a garbage use information collection model to aid garbage trucks in identifying areas that require additional landfills or waste removal to other locations. Operators can better plan cleaning schedules and routes for their cleaning trucks based on daily garbage information.

Reference [23] presents a "smart box" solution where containers on the streets have unique identifiers. When a container is about to be full, a query is sent to a database to determine who is responsible for it, and a notification is sent via GSM containing the container's identification number and location. While these models focus on smart waste management, they do not provide details on the sensor components, only the communication models are described.

In reference [24], the authors highlight the drawbacks of existing waste management systems and propose a new approach that utilizes an Arduino 8051 microcontroller to read data from an infrared sensor measuring waste depth within a container. The microcontroller processes and transmits the data wirelessly to a central system based on an Intel Galileo microcontroller.

Reference [25] provides a literature review of smart waste management and compares different methodologies, focusing on the Internet of Things and its elements (definition, sensing, communication, computation, semantics, and services) and properties (connectivity, definition, and interaction).

Reference [26] presents an algorithm for decision-making during waste collection and compares various algorithm models based on performance metrics such as data reception in motion, multiple targets, and data loss during transmission. The proposed algorithm model optimizes clustering decisions and considers factors such as speed and volume of data entry, data generated by similar sensors, and the limitations of maximum container capacity.

In reference [27], a proposed waste management model utilizes information from the bins to determine optimal paths for collection by trucks, taking into account factors such as maximum container capacity and the need to optimize cost and time for waste collection. The model is based on three heuristics: nearest vehicle first, upper limit based combination, and upper and lower limit based combination.

Reference [28] presents a municipal waste management system for domestic use that focuses on applying biological and physical-chemical methodologies to eliminate or reduce the stage of waste collection and transportation.

6. Models of waste management systems

The following are examples of waste management systems implemented in various parts of the world:

Reference [29] introduces a garbage control system that utilizes LoRa technology to solve the problem of garbage spreading outside bins and leading to an unhealthy environment and increased pollution. The system employs sensors that provide accurate results and helps keep both rural and urban areas clean. The litter box node is constructed using an Arduino LoRa board, an ultrasonic sensor, and three small photodiodes. The LoRa Gateway receives data from the garbage bin node, while the ultrasonic sensor measures the level of litter waste. The system includes a dashboard that displays the litter box status and sends notifications (such as email or text) when the litter box is full. The ultrasonic sensor and three LED photodiodes (green, yellow, red) are connected to the Arduino LoRa board and powered by a 5V DC adapter.

Another waste management system [30] employs a smart waste bin consisting of eight units: a load cell, a main system, an interface, a modem, a driver, a display, an analog-to-digital (AD) converter, and an RFID reader. The load cell measures the initial analog value and sends it to the main system through the AD converter unit, which converts the analog value into a digital value. The main system then converts the value into a weighing result, which is transmitted to the interface. The interface manages all operations in the smart garbage bin, including analyzing input data from the RFID reader and commanding the motor to open or close the bin lid. The system was piloted in Gangnam District, South Korea, with 136 smart garbage bins deployed across six sub-districts. The bins were placed in locations where conventional food waste bins were previously located, and no additional construction was needed to connect them to a nearby power source since they run on battery power.

In the waste management system described in [30], each user was provided with an ID and password for their RFID card and web-based service. Users were categorized as Administrators, Collectors, or Residents, with the Administrator being able to check the current and accumulated amount of food waste per smart garbage bin (SGB), the status of all SGBs, and their time history. The Administrator could also categorize the information based on region, resident, and SGB, and register new users and RFID cards. Additionally, the Administrator had the authority to collect and receive notifications when SGB capacity exceeded 90%.

Reference [31] describes Recycle.io, a smart waste management system consisting of smart recycling bins (SRB) and smart organic bins (SOB), each equipped with an edge computing device, such as a Raspberry Pi, that connects the hardware components. The edge device includes an ultrasonic sensor and an infrared camera, which detect waste disposal and trigger the capture of images for breach detection. These images are processed locally on the edge device, which filters the data required for cloud transmission, reducing network traffic and building a scalable IoT-based solution using server less technologies.

The data collected by the sensors and camera modules in the smart boxes is sent to the analytics module, which scans and processes images for possible violations. The ultrasonic sensor enables Recycle.io to detect items as they are being inserted into the bins, while the classifier unit determines if the discarded item is considered infringing. A violation occurs when a non-recyclable item is added to the SRB, and the edge device updates the cloud-based application with a snapshot of the discarded object as evidence of the breach. The

Recycle.io dashboard displays real-time data and a map that shows all connected smart boxes.

Overall, Recycle.io takes advantage of the edge computing model, which enables the distribution of computing power at the edge of the network, reducing network traffic and building a scalable IoT-based solution. The system utilizes ultrasonic sensors and cameras to detect waste disposal and possible violations, and the edge device processes the data locally before transmitting it to the cloud-based application for further analysis and monitoring.

In reference [32], a smart city with an Internet of Things infrastructure is proposed to achieve efficient dynamic waste collection. The city is divided into multiple sectors, each containing intermediate waste depots and dumps outside the city limits for temporary waste storage. Waste is transported to processing treatment plants near landfills by a fleet of limited-capacity waste collection trucks (LCGTs) and large-capacity waste collection trucks (HCGTs). The system architecture consists of boxes equipped with RFIDs, capacity sensors, actuators, and wireless antennas to transmit sensor data to the system infrastructure. The data is processed by cloud middleware, aggregated, and cleaned before being provided to the inference engine in OpenIoT. The data is stored in a database to determine the number of filled containers and initiate dynamic scheduling and routing. Drivers receive necessary information through an Android application with a user-friendly GUI and Google Smart City Map.

Each container in the proposed system is equipped with an IoT device, weight and ultrasonic sensors, a solar cell, an RFID reader, and two LEDs. Citizens interact with the system using an RFID card linked to their mobile phone number and password. When a citizen disposes of waste into the bin, the weight and volume of the rubbish are measured and sent to the application server, and the citizen receives an acknowledgment of the transaction via SMS or a push notification in the mobile application. The citizen's credentials are used to log into the system and monitor their interaction history and points awarded, which can be transferred to municipalfacilities or services.

To summarize, the proposed system in reference [32] is a smart city infrastructure with IoT devices and sensors that enable dynamic waste collection. The system operates on a sector-based approach, with intermediate waste depots and dumps for temporary storage. The fleet of trucks includes limited and large-capacity vehicles for efficient waste collection and transportation. The system architecture includes boxes equipped with RFIDs, sensors, and actuators for monitoring and transmitting data to the cloud middleware. The data is processed using an inference engine, and dynamic scheduling and routing are initiated based on the number of filled containers. Citizens interact with the system using RFID cards linked to their mobile phone numbers and passwords, and they receive acknowledgments of their transactions via SMS or push notifications in the mobile application. Points are awarded to citizens, which can be transferred to municipal facilities or services, and citizens can monitor their interaction history through the web or mobile application.

Furthermore, each waste collection truck in the proposed system is assigned to specific geographic areas and equipped with a tablet application that displays the packing status of assigned bins on a map of the defined area. An IoT module connected to a microcontroller controls the unloading and evacuation process of each truck, ensuring that the truck cannot unload a container unless it is in the same location. Similarly, the waste evacuation process only begins once the truck reaches an evacuation station.

Each container is also equipped with an IoT module that synchronously and asynchronously sends its filling status to the application server. This status information is sent periodically and every time a citizen disposes of waste into the container. The application server then forwards this information to the waste collection truck and displays it on the tablet application map. Additionally, each waste collection truck sends simultaneous updates, such as location updates, to the application server. Asynchronous updates are also sent when the truck dumps garbage or removes waste. Each waste collection truck is equipped with an IoT module and a controller to control the waste evacuation door and unloading motor, ensuring that the evacuation door can only be opened when the truck is inside the waste evacuation station and the unloading motor only starts when the truck is in the same location as the requested box.

To summarize, the proposed waste management system includes waste collection trucks that are assigned to specific geographic areas and equipped with a tablet application that displays the packing status of assigned bins. The trucks are also equipped with an IoT module and a controller that ensures the unloading and evacuation process can only occur when the truck and the container are in the same location. Each container is equipped with an IoT module that sends its filling status to the application server synchronously and asynchronously. The application server forwards this information to the waste collection truck and displays it on the tablet application map. The waste collection truck also sends simultaneous and asynchronous updates to the application server, such as location updates and updates when dumping garbage or removing waste. Each waste collection truck is equipped with an IoT module and controller that controls the waste evacuation door and unloading motor, ensuring that they only open or start when the truck is in the correct location.

7. Conclusions

This research deals with the different ways in which waste is managed, so that some of this waste is utilized, especially the organic waste that can be used for composting, as well as other types of waste that can be recycled. In this research, the focus was on the role of technology in waste management, especially the technology of the Internet of Things, which contributed to waste management in ways that reduce costs and effort, and work to create a clean living environment for the residents of cities and villages. This technology is one of the ways to reach the sustainable development that all countries in the world, especially the developing countries, seek.

From this study, we can conclude the following:

1. The utilization of the Internet of Things plays a crucial and efficient role in waste treatment within urban areas, leading to a reduction in costs.
2. Exploiting this technology in the disposal and treatment of waste contributes effectively to creating a clean and healthy environment.
3. This technology helps in the waste classification process, as some types of waste can be used in the development of other industries such as organic fertilizer and the recycling of some waste.
4. This technology contributes to the monitoring of the places where waste is placed, so that violators who do not commit to putting the waste in the places designated for it can be monitored and punished.

8. Recommendations

Through what this research has dealt with regarding the use of Internet of Things technology in waste management and treatment, the following can be suggested:

1. Work on investing in modern technologies, especially the Internet of Things technology, due to the effective role that this technology contributes to sustainable development programs.
2. Work to include such technologies in education curricula, especially university and technical institutes, which contributes to learning and mastering these technologies in order to contribute to advancing the wheel of development in Libya.
3. Focusing on finding research programs at the undergraduate and postgraduate level so that we can understand these

technologies, which will open opportunities for future development and make maximum use of the potential offered by such technologies.

4. Adopting the technology of the Internet of Things and associated technologies such as artificial intelligence in contributing to the disposal of waste in Libyan cities, especially densely populated cities, in order to create a clean and healthy environment.

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6

ticipating the Risks: Taxonomy for Chatbots Forthcoming Risks

Anticipating the Risks: Taxonomy for Chatbots Forthcoming Risks

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Abstract

Recent advances in Natural Language Processing (NLP) have led to the development of Large Language Models (LLMs) such as GPT-3, which have achieved remarkable success in a wide range of tasks, including language translation, content generation, and conversational agents. Chatbot usage has grown rapidly in several areas over the last few years, including marketing, support systems, education, health care, cultural heritage and entertainment. Chatbots like any software and new technologies are not free of risks. Numerous of risks are coming with, which need to be identified, classified and managed to avoid or at least reduce their related losses. This paper identifies and classifies the main Chatbot related risks in a proposed taxonomy called Chatbot Risks Taxonomy. It is based on a review of the existing of Chatbot risks and supposed to make Chatbot related risks much easier for consideration and management by the people and scholars. This taxonomy consists of seven types (groups) of risks namely; Software Inherited Risks, Technologies Risks, Used Data Risks, Social Risks, Security and Privacy Risks, Ethical and Legal Risks and Intellectual Property Rights Risks. In fact, Chatbots have become an unavoidable reality, thus it is critical to analyze and evaluate the risks associated with them in order to address and avoid their negative impacts.

Keywords: *Chatbot risk, Software Risk, AI, Chatbot Risks Taxonomy.*

1. Introduction

The Chatbot application supports the statement made by Joseph Weizenbaum in 1966 that there is a possibility a computer program can communicate with a human via natural language, which uses a set of rules to generate responses based on keywords and patterns in the user's input [1]. Nowadays, neural generating dialogue agents have become sufficiently mature to connect with real users through programs [2]. Recent advances in Natural Language Processing (NLP) have led to the development of Large Language Models (LLMs), such as GPT-3, which have achieved remarkable success in a wide range of tasks, including language translation, content generation, and conversational agents [3]. Agents use Artificial Intelligence (AI) software and hardware as part of their process. Chatbot usage has grown rapidly in several areas over the last few years, including marketing, support systems, education, healthcare, cultural heritage, and entertainment. In fact, the Chatbots have become more popular due to their benefits for users and developers its availability for work 24/7. In many situations Chatbots are significantly faster and less costly than hiring human resources. Chatbots are able to provide customers with valuable advices and recommendations based on previous historical information. The support of multilingual makes them very comfortable and popular. In this regard, Chatbots can be considered as an interactive, effective, and an excellent way to enhance business growth and improve people’s lifestyle [4] .

However, Chatbots, like any software and new technologies, are not free of challenges and risks which need to be identified and considered [5]. They do not have a regulated ethical response which requires deep thinking before it can be acknowledged in real life [Ref]. Meanwhile, Chatbots access fewer data assets than Google and their response cannot be verified.

The Cambridge Online Dictionary [6] defines risk as "the possibility of something bad happening." Chatbot risks should be identified, classified, and managed to avoid or at least reduce their associated losses. This paper classifies the main Chatbot-related risks in a proposed taxonomy. The taxonomy has been proposed to help both individuals and scholars to identify and manage Chatbot related risks easily.

The rest of this paper is structured as follows. The related work is presented in Section II. Then, Section III introduces the taxonomy of the main identified Chatbot risks, while Section IV discusses the taxonomy of Chatbot risks from different perspectives. Finally, Section V presents the study's conclusions.

2. Related Work

In fact, a few approaches have touched the concept of the work introduced in this paper, which is the taxonomy of Chatbot risks. The following are brief descriptions of the most related approaches.

Cotton et al. [1] have previously investigated the risks associated with Chat APIs and GPT-3 in tertiary education. They argue that Chatbot tools also raise a number of challenges and concerns, especially regarding academic honesty and plagiarism. In other words, they assert that Chatbot tools can be used to facilitate cheating, and it is difficult to differentiate between AI-generated and human handwriting texts. They conclude that while there are advantages and disadvantages to employing Chatbots in higher education, these problems can be successfully resolved by higher organizations if they adopt a proactive and moral approach.

Brady et al. [2] state that Chatbots have the potential to improve both research productivity and the quality of academic throughput. Researchers pushing for these improvements have brought up various ethical issues that must be taken into account, including ownership of the generated text, the use of content from outside sources, and the enforcement of copyright laws, all of which are still ambiguous.

Malik [7] categorizes the risks of Chatbots into thirteen categories: moral issues, hallucination, transparency issues, risk of decreasing human need, excessive content, privacy (especially for medical information), risk of declining clinical skills, legal issues, interpretability issues, referencing issues, risk of academic fraud in research, incorrect content, and infodemic risk. He concludes that Chatbots should be adequately evaluated in the real world to avoid any negative consequences of potential misuse.

With the aid of knowledge and resources from computer science, linguistics, and social sciences, Weidinger et al. [8] were able to identify 21 risks of large-scale Language Models (LMs). The identified risks are categorized in the taxonomy into six areas, namely: Discrimination, Hate speech and Exclusion, Information Hazards, Misinformation Harms, Malicious Uses, Human-Computer Interaction Harms, and Environmental and Socioeconomic harms.

Christopher et al. have engaged more than 50 experts to help understand the potential deployment risks of the GPT-4 model. They conclude that GPT-4 is able to give more detailed guidance on how to conduct harmful or illegal activities. They provide an extensive system card describing some of the risks, mainly cybersecurity, proliferation, bias, disinformation, over-reliance, privacy, and cybersecurity.

3. Chatbot Risks Taxonomy

As mentioned above, the Chatbot need to be identified and classified. In order to make Chatbot risk identification an easy process, the work in this paper tries to group those risks in what called a Chatbot Risks Taxonomy (CRT). This taxonomy (Table 1-7) has been prepared based on a review of the existing Chatbot risks [7], [8], 6, 7, 9. The CRT consists of seven types (groups) of risks, namely: Software Inherited Risks, Technology Risks, Used Data Risks, Social Risks, Security and Privacy Risks, Ethical and Legal Risks, and Intellectual

Property Rights Risks. These seven groups cover the currently identified Chatbot risks in a simple way, and it is easy to add a new group if needed.

3.1 Software Inherited Risks

This type groups all risks that are inherited from traditional software development. Since Chatbot is software, so it faces many traditional software risks (See Table 1) [9].

Table 1: Software Inherited Risks

Risk Title	Risk Description
AI algorithms related risks (i.e., AI Black Box effect)	Inability to see how deep learning systems make their decisions, as well as the inability to verify new AI algorithms.
Traditional software bugs risks	Usually, software comes with unforeseen bugs which have harmful effect on the software applications.
Reliability risks	How does reliable the Chatbot?
Quality risks	Quality related risks
Availability risks	Chatbot service readiness levels (availability and unavailability) could affect people's business

3.2 Technologies Risks

This type groups all the potential technology-based risks that could affect the Chatbot process in some way. This is because the Chatbot can be affected directly or indirectly by the related technologies (See Table 2).

Table 2: Technologies Risks

Risk Title	Risk Description
Technologies changes risk	Rapid technological changes require continuous tracking to avoid associated problems.
Technologies incompatibility risk	The variety of technologies requires flexibility to comply with them. Chatbot solutions, analysis, and services should be ready for different technologies.
Response time	The Chatbot's reaction time sometimes is risky.

3.3 Used Data Risks

Chatbot depends on the data for its operations. Dataset risks, data sources, availability, and coverage of the data could have a significant effect on the Chatbot's response, so this type includes all data-related risks (See Table 3).

Table 3: Used Data Risks

Risk Title	Risk Description
Dataset risks	Collections of data might be harmful or deceptive.
Data availability and coverage	The ability to guarantee reliable access to data at a required level of performance in situations ranging from normal to disastrous

3.4 Social Risks

As the Chatbot has a direct relation with people, there are many social Chatbot risks that could affect them. Table 4 illustrated the risks under this type.

Table 4: Culture and Social Risks

Risk Title	Risk Description
Culture	The impact of users' cultural backgrounds.
Unemployment	People losing their traditional jobs.
Fake news production	Spreading fake news and rumors
Affecting social relationships	More chatting and building relationships with Chatbots rather than with ordinary people.
Entering without permission	Chatbots become part of family members, friends, colleagues, with a clear distinction from people.
Confusing the people (making wrong decisions) by adopting fast Chatbot suggestions.	Chatbots learn through massive amounts of data, which can be poisoned with incorrect data, resulting in undesirable outcomes that could lead to fast and erroneous decisions.
Limiting people thinking and creativity.	People are increasingly reliant on Chatbots.
Addicted to use and time consumption	Increasing the utilization of Chatbot even for simple issues.

3.5 Security and Privacy Risks

The risks of this type focus on security and privacy issues, which in some cases are intertwined. Examples of these risks are listed in Table 5 [10].

Table 5: Security and Privacy Risks

Risk Title	Risk Description
Security risks	Security risks could include malware attacks, phishing, information leaks, and distributed denial of service (DDoS) attacks.
Accessing people sensitive information without consent	Information theft is possible if a Chatbot cannot properly shield consumer data using measures such as encryption.

3.6 Ethical and Legal Risks

There are many Chatbot ethical and legal risks some of them are grouped in Table 6.

Table 6: Ethical and Legal Risks

Risk Title	Risk Description
Misuse	The use of Chatbots in moral matters that is harmful to individuals, institutions, or societal norms.
Legal	Existing laws and regulations in a nation may vary from those in other nations. A Chatbot assistant may be unable to accurately reflect these differences, which could lead to incorrect or incomplete advice.
Spying	Spying includes obtaining secrets and information without the owner's permission and knowledge.

3.7 Violating Intellectual Property Rights

Table 7 illustrates risks that are related to intellectual property rights and how they apply to Chatbot outputs, including plagiarism and copyright issues [2] [11].

Table 7: Intellectual Property Rights

Risk Title	Risk Description
Violating Intellectual Property (IP) Rights	Chatbots have opened the doors for more opportunities to violate intellectual property (IP).
Misuse of intellectual property rights.	More possibilities of using intellectual property (IP) inappropriately.
Plagiarism	Increase in copyright infringement or dishonesty.

Before proposing the above taxonomy and grouping the risks into the aforementioned types, a review of the identified Chatbot risks is conducted, and the most related risks are listed. It is noticed that there is currently no simple classification for Chatbot risks, which makes it difficult for users, managers, and developers to address and deal with them. In fact, the CRT (see Tables 1-7) is not a final one and needs to be regularly updated. This is due to the rapid growth of Chatbot development and use in various fields. There are other different ways to construct such a risks taxonomy, but it has been found that the CRT approach is simple, covers all aspects of Chatbot risks, and can be improved by adding new types or risks without affecting the its overall structure.

4. Discussion

Chatbots are artificial intelligence systems that can generate human-like text based on a given input. They are trained on massive amounts of text data, such as books, articles, and web content, and learn to recognize the patterns and connections between words and phrases. However, this also means that they can inherit and amplify the false or misleading information that exists in the data they study. These are some of the ways that Chatbots can generate and spread harmful and misleading information. The proposed CRT taxonomy of Chatbot risks is different from others in terms of:

- The above listed of Chatbot risks is not a final. This is due to rapid growth of Chatbot developed, type of applications, targeted fields and methods of use. Thus, the list of risks needs to be updated periodically.
- The classification focuses on aspects that affect all Chatbot stakeholders (i.e. developers, end users, jurists and decision makers, and public). As a result, everyone can benefit from and contribute to this taxonomy.
- The ease of this classification makes it suitable for identifying any new risks associated with the rapid evaluation of Chatbot applications and technologies, which could have a significant impact on people's daily life.
- The rapid development of AI systems may change the known Chatbot risks into gains or opportunities in the future.

The speed of use and acceptance of Chatbot platforms despite the risks associated with it and its great effects on the educational, generous, cultural, economic and judicial systems, humanity must reformulate laws to keep pace with this tremendous development and take into account the risks associated with it. For example, it may change the pattern of judicial pleadings to rely in the future on Chatbots in a legal way. Likewise, educational and research developments will develop in a way that absorbs and benefits from the outputs of Chatbots instead of considering them as illegal copies. It seems inevitable that Chatbot will enter our homes, businesses, and culture, and therefore we must manage the risks associated with it intelligently and professionally.

Chatbots are artificial intelligence systems that can generate human-like text based on a given input. They are trained on massive amounts of text data, such as books, articles, and web content, and learn to recognize the patterns and connections between words and phrases. However, this also means that they can inherit and amplify false or misleading information that exists in the data they study.

Generally, the introduced CRT taxonomy of Chatbot risks is different from others in terms of:

- CRT classification of risks focuses on aspects that affect all Chatbot stakeholders, including developers, end-users, jurists and decision-makers, and the public. As a result, everyone can benefit from and contribute to this taxonomy.
- The ease of CRT classification makes it suitable for identifying any new risks associated with the rapid evolution of Chatbot applications and technologies, which could have a significant impact on people's daily lives.

Despite the risks associated with Chatbot platforms and their significant effects on educational, cultural, economic, and judicial systems, there is a need for humanity to reformulate laws to keep pace with this tremendous development and account for the associated risks. For example, it may lead to changes in the pattern of judicial pleadings, relying on Chatbots in a legal manner in the future. Likewise, educational and research advancements will evolve to absorb and benefit from the outputs of Chatbots instead of considering them as unauthorized copies. It seems inevitable that Chatbots will become part of our homes, businesses, and culture, and therefore, we must intelligently and professionally manage the risks associated with them. Finally, the rapid development of AI systems may transform the currently known Chatbot risks into gains or opportunities in the future.

5. Conclusion

Chatbot concepts and technologies were introduced early since the 1960s. Nowadays, Chatbots are more advanced and able to interact intelligently with humans using natural language. They can also be trained more easily and have the ability to cover numerous fields. However, Chatbots are not free of risks; their risks can affect people's daily lives. These risks range from spreading rumors and misinformation to violating intellectual property rights. The work presented in this paper aims to introduce a taxonomy for Chatbot risks in a simple way based on available literature. This taxonomy is named Chatbot Risk Taxonomy (CRT) and it groups the Chatbot-related risks into seven types: Software Inherited Risks, Technological Risks, Data Usage Risks, Social Risks, Security and Privacy Risks, Ethical and Legal Risks, and Intellectual Property Rights Risks. In fact, Chatbots have become an unavoidable reality, so it is critical to analyse and evaluate the risks associated with them in order to address and avoid their negative impacts. On the other hand, Chatbot risks may yield unexpected benefits in the future. More studies and a focus on their risks are needed, and the list of risks must be updated regularly. In the near future, Chatbots might become members of our families, friends, or staff, so it is our responsibility to identify and manage their associated risks.

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