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Algorithmic Approach for E-Waste Recycling

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Abstract

Mobile phones are efficient to process millions of calculations per second. They are built with myriad parts such as printed circuit board,keypad,sensors, camera etc. According to Indian government e-waste directive 2016, in order to control the e-waste pollution,manufacturers should accumulate the end-of-life products and effectively enhance the features for recycling mechanism. Image analytics do not provide much assistance to recognize any damaged mobile phones. This paper proposes an algorithm which will help refurbishing industries to reuse undamaged parts of mobiles. This algorithm can be scaled up to all types of e-waste like laptops,desktops, refrigerators, microwavesetc.

1.0 Introduction

Mobile phones were created on 3rd April 1973 and today in India approximately 1,281,971,713mobile phones are used by the population of 1,324,245,994 people which are almost 93%population used mobile phones. Since the mobile phones are built with the integrated circuits (IC)chips, a battery which is made of lithium-ion, screen, keypad, antenna, microphone and speaker.

According to ICEA (India Cellular and Electronics Association), the manufacture of mobile phones inIndia has grown quite rapidly and by 2025 India can produce around 1.25 Billion mobile handsets. Due to which the growth of the e-waste also will increased rapidly. Since E-waste directly impacts the environment, it should beproperly recycled and also India is ranked 5th in the world for producing e-waste. According to Indiangovernment e-waste directive 2016, in order to control e-waste pollution, manufacturers shouldaccumulate the end-of-life products and effectively enhance the features for recycling mechanisms.

To recognize the model, the Image Processing tool had been used and it worked efficiently for all themodels. But while it recognizes the damaged product Image Processing technique has failed.To overcome the issue, the algorithm was created which can also be called the upgraded version ofthe Image Processing technique. So, the algorithm will first identify the model and its manufacturerusing the Image Processing Technique, if the technique is not able to identify then it will startidentifying and scanning the internal components and classify it into damaged and undamagedmodel. If the component is not damaged then it will be fed in the database and it will recognize themodel and its manufacturer and the components will be repaired and re-used and if the componentis damaged then it will not be able to identify it or repair further.

2.0 Algorithm for refurbishing industries

An algorithm is developed by taking reference of the EMARP algorithm i.e. E-waste Management and Refurbishment Prediction Algorithmwhich was developed to categorize e-waste. This algorithm is customized for mobile phones only and to a simple version.

The algorithm involves following steps:

1. Feeding the data of models (components) used for identification purpose.
2. Identify the components from the damaged handset.
3. Classify the components into damaged and undamaged.
4. Classify further if the components are functional or non-functional.
5. We define matrices to store information about the handsets, components, requirements etc.

For the purpose of this study a total 50 models were studied, 5 of each brand. Various parameters of these models were identified with special focus on sensors. Each Sensor is given a unique Id which would help in identifying the model.

We define a 50 x 32 matrix M, which represents data of 50 models and 32 components, this matrix has information whether the model has a particular

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component or not. The matrix elements are 1's and 0's, where 1 represents presence of the component and 0 its absence.

$$M=\begin{bmatrix} m_{1,1} & \cdots & m_{1,32} \\ \vdots & \ddots & \vdots \\ m_{50,1} & \cdots & m_{50,32} \end{bmatrix}$$

Following this we define a matrix of order n x 32 D, to hold sample data. The matrix holds 'n' samples and has information about presence or absence of the component.

$$D=\begin{bmatrix} d_{1,1} & \cdots & d_{1,32} \\ \vdots & \ddots & \vdots \\ d_{n,1} & \cdots & d_{n,32} \end{bmatrix}$$

We define a matrix S to hold status of the components whether they are damaged or not indicating with 0's and 1's.

$$S=\begin{bmatrix} s_{1,1} & \cdots & s_{1,32} \\ \vdots & \ddots & \vdots \\ s_{n,1} & \cdots & s_{n,32} \end{bmatrix}$$

2.1Identification of brand using Component information:

Now that we have the matrix M with model's component information and matrix D with samples data, operate each row of D with rows of matrix M till we find a match this is done as follows

1. We obtain Mi ⊕Dj, Mi denotes ith row of matrix Mi and Dj denotes jth row of matrix D, $1 \leq i \leq 50 \& 1 \leq j \leq n$ where n is no. of samples in data matrix.
2. We obtain Hamming distance of the vector obtained from the above operation, the row with distance zero or near to zero predict the possible models for identification.

2.2 Finding number of samples that can be sent for repairing/refurbishing based on Components:

Generally, mobiles can be repaired/refurbished if the damage does not affect the components majorly. For the purpose of this study we assume that a handset can be repaired or refurbished if 70% of the components are functional. We also exclude the extern al components by assuming they can be replaced. Also, if 70% components are not working then the handset goes into trash.

Now that we have the matrix M with model's component information and matrix D with samples data, operate each row of D with rows of matrix M till we find a match this is done as follows

1. We obtain no. of components in the ith Data Sample, given by Di.
2. We obtained no of non-functional components in the ith Data Sample, given by Di ⊕Si; i denote ith row of matrix $1 \leq j \leq n$ where n is no. of samples in data matrix.
3. Using 1 & 2 we obtain % of functional components that decides whether the sample should be put in trash or sent for refurbishing/repairing.

2.3 Internal Component Resource allocation:

It is possible to use the internal components from the damaged handset to repair/refurbish other damaged handsets possibly of the same brand. In such case we device an algorithm for resource allocation.

1. Using the above steps, we find % of functional components and locate the row with highest percentage.
2. We search for available components from the matrix holding total no. of components available for a particular time.
3. We satisfy the requirement and accordingly update the stock.
4. We continue step 1-3 till we exhaust all data samples or components which ever happens earlier.

3.0 Implementation

Sensors in Samsung model is considered as input data. Five models of Samsung: Galaxy s20, Samsung Galaxy Z Flip, Samsung Galaxy Note 10, Samsung Galaxy A71 and Samsung Galaxy M21sub models are considered. The data is as below: -

SAMSUNG						
MODEL	Sensor					
	Accelerometer	Virtual Light Sensing	Barometer	Fingerprint	RGB Light	Proximity
Samsung Galaxy S20	1	0	1	1	1	1
Samsung Galaxy Z Flip	1	0	1	1	1	1
Samsung Galaxy Note 10	1	0	1	1	1	1
Samsung Galaxy A71	1	0	1	1	1	1

Components

$$ModelsM=\begin{bmatrix} 1 & 0 & 1 & 1 & 1 & 1 \\ 1 & 0 & 1 & 1 & 1 & 1 \\ 1 & 0 & 1 & 1 & 1 & 1 \\ 1 & 0 & 1 & 1 & 1 & 1 \end{bmatrix} \text{Models (4)}$$

4 x 6

The above matrix shows that if sensor is present than it is denoted as 1 and if sensor is absent then the matrix

Assume we have test samples of 6 scrapped mobiles. Presence and absence of components in the scrapped mobile is denoted as 1 and 0.

The sample data is as follow: -

$$\text{Sample Data} D = \begin{bmatrix} 1 & 0 & 1 & 1 & 1 & 0 \\ 1 & 0 & 1 & 1 & 1 & 1 \\ 0 & 1 & 0 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 0 & 1 & 1 & 0 & 1 \end{bmatrix} \text{No. of Samples (6)}$$

6 x 6

Presence / absence of components

Performing the operation on matrices M and D as per the steps of the algorithm

Now, $M_1 \oplus D_1 = (101111) \oplus (101110)$

$= (000001)$

Calculating Hamming Distance, $|M_1 \oplus D_1| = 1$

$M_1 \oplus D_2 = (101111) \oplus (101111)$

$= (000000)$

$M_1 \oplus D_2 = 0$ ——— (1)

Likewise, ith row of M we perform operation on every jth row of D

$M_1 \oplus D_3$ $M_3 \oplus D_1$

$M_1 \oplus D_4$ ⋮

$M_1 \oplus D_5$ $M_3 \oplus D_6$

$M_1 \oplus D_6$ $M_4 \oplus D_1$

$M_2 \oplus D_1$ $M_4 \oplus D_2$

⁝⁝

$M_2 \oplus D_2$ $M_4 \oplus D_6$

At (1) when hamming distance is zero

→ Sample 2 matches with model 1

Matrix S is dependent on D

Sample data functionality

$$S = \begin{bmatrix} 1 & 0 & 0 & 1 & 1 & 0 \\ 1 & 0 & 0 & 1 & 1 & 0 \\ 1 & 0 & 0 & 1 & 1 & 0 \\ 1 & 0 & 0 & 1 & 1 & 0 \\ 1 & 0 & 0 & 1 & 1 & 0 \end{bmatrix} \text{No. of Samples (6)}$$

Compared to row in D this row represents if that content is functional or not

Now for every Di we find |Di|

∴ $D_1 = (101110)$ $|D_1| = 4$

Now $D_1 \oplus S_1 = (101110) \oplus (100110)$

$= (001000)$

$|D1 \oplus S1| = 1$

Now $\frac{|D1 \oplus S1|}{D1} \times 100 = \frac{1}{4} \times 100 = 25\ \%$

% of functioal Components

Functional %

For S

S1	1	0	0	1	1	0	25%
S2	1	0	0	1	1	0	40%
S3	1	0	0	1	1	0	75%
S4	1	0	0	1	1	0	66.66%
S5	1	0	0	1	1	0	66.66%
S6	1	0	0	1	1	0	75%

As seen from the above matrix S1 …….

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5.0 RESULT AND DISCUSSION

From the above experiment we can deduce that thus method provides with a clear categorization of the considered sample set. We are able clearly define the damaged, undamaged, functional and non-functional components of the mobile phones. For the current study the assumption of refurbishing mobiles with 70% functional components will vary because this threshold value depends on the type of e-waste (television, refrigerator etc.) present. In future if the data related to available resources is given, we can also convert nonfunctional components and refurbish a greaternumber of mobiles.

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