Automation of Number Plate and Weight Scale Readings at a Cane Factory Weighbridge through Image and Character Recognition Techniques

Case study of Nzoia Sugar Company, located in Western Kenya, Bungoma County

Sichangi M. Sydney

Information Technology, Jomo Kenyatta University of Agriculture and Technology, Nairobi, +254, Kenya
sichangi@jkuat.ac.ke

ABSTRACT
This research paper is focused at designing and developing a factory weighbridge system for clearance of trucks after delivering cane. The system uses Optical Character Recognition and Image Processing Techniques to read and recognize both truck registration numbers and cane weight scales. Recognized number plates are then used to identify a contractor by searching through the system file of contractor name alongside registration number (truck number plates) for a possible match. The net cane weight becomes the difference between truck load with and without weight. The system finally, then prints a delivery voucher that has the name of the contractor, the weight scales readings and time/date of delivery.

Keywords: Optical Character Recognition, Image Processing Techniques, Delivery Voucher, Net Cane Weight, System file.

1. INTRODUCTION
Invention of a retina scanner in 1870 by C.R. Carey [1], was perhaps the first time a research attempt was made to have a machine perform a reading exercise in place of humans. A retina scanner, developed using photocells, was an image transmission system and would not have received much praise and attention deserved until today. In one of his researches, Alan Turing [2] opines that AI is indeed the heart-beat of tomorrow’s major discoveries and breakthroughs in intelligent systems industry. Today, recognition of character readings from perfect images scientifically known as optical character recognition (OCR), has received a wide spread application in areas such as Bar code, Character and Optical mark reading. It’s from this application area that a system is developed to capture and recognize both Truck Registrations Numbers and Cane Weigh Scales.

2. BACKGROUND
Nzoia sugar plant is one of the largest sugar producing factories in Kenya contributing averagely 25% in metric tons of the market share each year. Actually, the government owns majority of the company shares and therefore directly involved in the company administration. The management is well aware of shortage of sugar in the country, consequently raising the government stakes in the company management in terms of future plans and very possible expansion programs. It’s because of these developments that any research attempts that would be pivotal in elating the production index and capability of production undeniably a welcome news.

3. CURRENT SYSTEM
At the time of implementation of this project, the weighbridge functionalities at the factory were mostly mechanical. Lorry trucks are used to deliver cane from the field. They have different registration numbers usually at the fore and the backside, both of which have to be recorded before and after delivery of cane. Cane weight, digitally reflected on weighing scale is recorded afterwards. Due to mechanical nature of these activities, there are time wastages causative to major delays and confusion at the weighbridge. Such delays that sometimes go for long hours encourage fuel siphoning driving contractors to further lose. Nevertheless, owing to manual recording exercise, omission and commission errors are common. Such an occurrence has always led to contractor earnings for that particular round of delivery being mislaid. The method is also prone to fraud and corruption tendencies whereby upon incentives, the
weighbridge attendants record inflated figures for a particular round of delivery as duly espoused in their recent audit report [3]. Consequently a man-less weighbridge possibility is of essence in abolishing such fraud related cases. To achieve this, it is imperative to start by automating key units such as truck registration number entry, capture of cane weight and generation of delivery reports.

4. RELATED WORK

Weighbridges have found use not only in commodity manufacturing companies but also in other areas of interest such as airports, public roads, recycling plants and energy from waste sites. At a typical sugar processing plant, a weighbridge is used to take tonnage of cane from the field as it is delivered for processing. Technological innovation has seen weighbridges move from manual and mechanical systems to the present day electronic or otherwise digitally operated systems. Most weighbridges are in a drive through manner whereby the trucks drive on at one end and off at the other. In plants where vehicles are weighed in and out, the choice has always been to operate two separate weighbridges as it the case for Nzoia sugar plant. However, this is clearly expensive and in most cases, one weighbridge with apposite software implementation is sufficiently enough. The following is a description of similar modern day systems being used as weighbridges.

4.1 The Driver Operated Weighbridge

This type of a weighbridge turns out to be the most current technology in use today. Its developed using magnetic card technology and actually completely eliminates the need of having standby weighbridge clerks at the entrance and therefore cost effective on the long term. Described as a man-less weighment [4, 5], the system has been embedded with auto-voice announcement of the quantity weighed and other information necessary to inform contractors on the clearance process. Not only does the system speed up the weighing process but it extends the working period. Operational access is via a range of smart card technologies including the designated swipe cards, key or bar codes. Being the most current and relatively effective, the technology is expensive to acquire and maintain. This system works best in a magnetic field and dust free conditions only available at customized and well maintained bridges. As a result, the system does not suit a sugar factory setting with unfriendly conditions of dust, muddy roads and rainy weather.

4.2 Wireless Weighbridge

Due to the active nature of the weighbridge, a wireless concept that eliminates the need for cabling proves to be effective. According to Tonsys [6, 7], a software company, sometimes a remote weight indicator screen idea is appropriate to counter complicating site logistics. It can be time consuming and disruptive to lay underground cables and therefore wireless frequency is needed. In this system, a secure 2.4 GHZ, radio transmission is used to provide a bi-directional weight data signal transfer within a perimeter of 1500 meters. The installation comprises the weights and measures approved DIZIG/IP radio transmission system, a site DiLink digital junction box that is incomplete and would only work at the level of reading weight indicator. Nonetheless, this system is incomplete and would only work at the level of reading weight data. It is not integrated to cover all the weighbridge procedures expected at a cane factory weighbridge.

4.3 Vision-based Weighbridges

The vision technology has worked best when integrated with driver operated weighbridges, more especially in facilitation of clearance based on remote or unmanned installations [5, 8]. Westco’s VisionWeigh system [7, 9], developed under this platform, introduces a high level of site control and security, allowing pre-registered vehicles to carry weighing procedures in a highly efficient manner. It includes an integrated illuminator, high resolution camera, digital analyzer and an on-board relays, all contained in one standard security housing. For automatic or remote weighing in a typical system, the weighbridges usually have entry and exit barriers. Vehicles approaching the entrance are picked up by the camera and the number plate is checked against the database. If the vehicle is registered, it is allowed through the first barrier onto the bridge to be weighed. At this point, the driver inserts his card or key at the control terminal positioned outside the window and this initiates the weighing. The database can be programmed to contain complete details of the vehicle, including the tare weight, and this information can be used for printing weight tickets. Simple command prompts guide the driver through the weighing process and as soon as the weighing process has been successfully, the vehicle is allowed off the bridge. If the vehicle is black listed, it’s not allowed beyond the first barrier and a variety alarms can be initiated. However, the system is costly and expensive both to acquire and maintain given the financial and economic status of the company.
5. Prototype Design, Implementation and Testing

5.1 Prototype Design

The design explores the system process model and clearly outlays the three modular implementation piling for input, process output as follows.

5.1.1 Input Design

The input design clearly illustrates the model for both truck registration numbers and cane weight scale readings acquisition. For this project, a USB digital Camera, Fujifilm FinePix S200EXR was used. The Camera for truck registration is strategically placed at the weighbridge entrance to take front view image of an approaching truck. A trigger system prompts the entrance gate to slide open once the image is taken. The Camera is placed in such a manner that images are taken at 90°. For the weight readings, a second camera, indoor and also placed at 90° next to the digital weight scale meter takes the images which are temporarily in a storage device before finally being loaded to the system for processing. The diagram figure 5.1 below illustrates the input process.

![Fig. 5.1.1. Truck and weight scale image input](image)

5.1.2 The processor module

The process module emphatically draws the designation scheme for data and information flow within the system. The prototypes system’s data distribution and flow starts and stops at the point of image acquisition. Data entry consideration such as where and when, verification, method of entry and access control is critical to the overall process design [7, 10] it is the major reason why the interface is graphical and much of the controls for accuracy have been put in place. Information, in most cases being the result of transformational manipulation on data [8, 11] is output as a soft copy display through the interface. The illustration figure 5.2 below is a data flow diagram for weighbridge system.

![Fig. 5.2 Level 0 DFD for the System Process model](image)

5.1.3 The output Design

The system outputs number and letter characters that have been recognized which are displayed in word editable format. The characters are ideally the recognized number plate registration details, weight scale readings and identified contractor profile. The output is made possible through a user friendly GUI and can as well be represented in hard copy through delivery note printouts. Conversion to word editable format confirms the recognition process and brings about the much needed flexibility for further processing. The illustration figure 5.1.4 below shows the output design.

5.1.2 The processor module

The process module emphatically draws the designation scheme for data and information flow within the system. The prototypes system’s data distribution and flow starts and stops at the point of image acquisition. Data entry consideration such as where and when, verification,
5.2 Prototype Implementation

The whole system is made up of three major modules particularly developed to serve different clearance roles at the weighbridge. They include:

i. Number plate reading and recognition
ii. Weight scale reading and recognition
iii. Contractor identification and profiling

The implementation process looks at each of the three modules and specifically narrows down to techniques and procedures followed to achieve the results.

5.2.1 Number plate reading and recognition

The module is developed based on optical character recognition techniques and algorithms. A USB digital camera strategically placed at the weighbridge entrance takes a front view image of an arriving truck. The images are then uploaded onto the system workspace and processed to extract and record the number plate readings. Step by step implementation of the module is as described below

a) Image uploading
   The system uses the `uigetFile` function to upload number plate images for processing. The function opens a standard dialog box to retrieve the image files. The prototype actually uploads multiple file formats apart from the standard JPEG.

b) Preprocessing
   After the images have been uploaded, they are preprocessed. Preprocessing primarily prepares these images for computational processing and involves the removal of low frequency background noise, equalization, removing reflections, and masking portions of the images to enhance clarity. While a number of techniques can be applied, order and choice is crucial for better results. The prototype had separate preprocessing for both truck and the weight reader due to major differences in the background orientation, spatial location and general clarity. The blurred, noisy and complicated background nature of truck images presents a challenging scenario for recognition and therefore needs specialized algorithms for preprocessing as described below.

   i) Conversion from colormap to grayscale
      The source images are usually colored and therefore to facilitate further processing, they are converted to grayscale to grayscale intensity. The conversion process aims at eliminating image hue and saturation information while retaining the luminance. RGB images can be of class `uint8`, `uint16`, `single` or `double` [9, 12]. The syntax for conversion is as follows:

      ```
      variable i = imread('image.jpg');
      variable j = rgb2gray(variable i);
      ```

      Figure 5.2.1 is a diagram showing both colormap and grayscale image of truck registration numbers.

Fig. 5.1.4. System output design
ii) Noise reduction and Edge finding
Truck images are in most cases unclear and “Dirty” due to existence of unwanted “salt and paper” particles. As a result, the `medfilt2(2-D median filter)` function is used to clear up the images for further processing. The median filter is used due to its ability to reduce noise and at the same time preserve the edges. To clearly find the edges on the filtered image, the `edge` function is used with the `log` operator as an argument. Essentially, the `edge` function is used to detect the edges in a grayscale image. The ‘Log’ parameter is actually the Laplacian method of finding edges. the Laplacian of Gaussian method finds the edges by looking for zero crossings after filtering an image with a Laplacian of Gaussian filter [13, 14] For this prototype, a threshold value is chosen automatically by the `edge` function as it is the when unspecified.

Figure 5.6 shows a truck registration number image after the edge function and filtration.

c) Determining the region of interest (ROI)
On both truck and cane weight scale images, the region of interest is the exact location of characters. An algorithm to find this region is based on detectable edge features and their intensity within the image. Figure 5.8 below depicts such an edge feature diagram. The image has been binarized to clearly reveal the edges. An edge is precisely a transition from white to black pixels. A character region has the most number of such transitions and at the same time intense in frequency. Which is why, to identify this region, an algorithm that finds and adds up the number of black-to-white pixel transitions for every row and column is designed. A histogram graph of the number of transitions against spatial distance, for both vertical and horizontal projection clearly shows the variations of edge features and their frequency within the image. Figure 5.7 shows truck image alongside horizontal and vertical projection graphs respectively. Candidate regions with character content have the highest number of transitions, an observation clearly illustrated by both graphs. The rows and columns with highest number of transitions have highest peaks suggesting remaining areas are non-character. The algorithm filters off non-character regions to end up with character region for both truck and cane weight scale images.

d) Segmentation
Once the region of interest is identified and cut out, the next task singles out characters, one by one in a process called segmentation. It’s an image processing technique which partitions images of lines or words into individual characters [15, 16]. Its main goal is to is breaking up breaking up an image into partitions of a single character. However, before segmentation, unwanted foreign particles on the image background are filtered off. A close look at an identified number plate region, fig 5.7, reveals existence of “foreign particles” have to be cleared before a successful segmentation. For the prototype, a morphological `bwareaopen` function was applied to remove the visible small objects. Fig 5.8 (a) shows an identified number plate region after the `bwareaopen` function.

Once clear, the `bwlabel` function is then used to find the connected components which essentially are characters to be recognized. The syntax for the `bwlabel` function is;

\[
[L, NUM] = bwlabel(BW,n)
\]

In which case a matrix \(L\) of the same size as \(BW\), containing labels for the connected objects in \(BW\) is returned. Figure 5.8 (b) shows a segmented image of characters to be recognized.
e) Recognition
To recognize segmented characters, they have to go through recognition process. Successfully recognized characters could be any alphanumeric symbols. Template matching, a recognition technique that compares binary feature vectors for similarity and correlation is used. Comparison is based on similarity distance measures between segmented characters and a template pixel of alphanumeric letters, compiled using Photoshop. The similarity measure is based upon the likeness of pixels in both the template and the input characters. This requires changing of the input characters to binary and resizing them to fit template size individual characters of width and length of 32 by 42. The distance measure used is the Euclidean sum of squared distance generated by equation 1 below

$$E_{m,n}(r,c) = \sum_{j=0}^{mrows-1} \sum_{i=0}^{mcolumns-1} \left[ m(j,i) - n \left( r + j - \frac{mrows}{2}, c + i - \frac{mcolumns}{2} \right) \right]^2$$

Eq. 1

Where $m(r,c)$ is the image pixel value in row $r$ and column $c$. The $n(r,c)$ is the image pixel value in row $r$ and column $c$ and $m(j,i)$ is the template value in row $j$ and column $i$. Template character size dimensions are $mrows$ by $mcolumns$ and whose center is positioned at $(r,c)$. For every similarity value found after pixel matching, the value is added to a counter whose final result would actually be the similarity distance between such an input character and the template as shown by equation 2.

$$D_{m,n} = \sum_{r} \sum_{c} E_{m,n}(r,c)$$

Eq. 2

The algorithm makes this comparisons over all the 35 alphanumeric symbols and the shortest distance is recorded as the best match. The template character identity having the best match is then stored on an array of strings displayed as recognized truck registration number or weight scale reading textboxes respectively. Figure 5.9 shows bitmap images of template characters compiled for this prototype using Photoshop.

5.2.2 Weight Scale Reading and Recognition
Weight scale reader images need different processing approach mostly because of a largely differing background orientation, image clarity and type. Actually, weight image numeric content is much more distinct in terms of character spacing and has less noise and pepper particles easing up the recognition process. The implementation process is as described below

a) Conversion from RGB to grayscale
The function, rgb2gray is used to turn RGB source images to grayscale. The function eliminates saturation and color hue while maintaining the luminance. The output is a colormap image of class double, same class as the input.

b) Conversion from grayscale to binary
The Otsu’s technique of determining a threshold value for conversion to binary is used. The graythresh function is used along with the im2bw level to effectively convert the grayscale image to binary.

c) Noise reduction
To get rid of odd particles and unnecessary noise, a morphological opening function bwareaopen is used. Specifically, all object features within the image with less than 30 pixels are removed.

d) Segmentation and recognition of numeric content
After preprocessing, a binarized image goes through the same phases and steps followed to segment and recognize truck registration numbers. Fig 6.0 shows the recognition process.
5.2.3 Contractor Identification and Profiling

The system is organized in a manner that every contractor is to be identified based on his/her truck registration numbers. Upon recognition, a search algorithm is then used to find and display contractors’ name whose registration match the recognized ones. Arrival time and date is usually automatically displayed, once a contractor is found. Recognized weight scale readings for truck with and without load are used to calculate the net weight of delivered cane.

5.3 System Design

a) Truck Registration Number Reading

A total of 228 images bearing truck registration numbers were tested for correct region of interest identification, successful segmentation and character recognition. Table 1 shows the accuracy rating for each of the tests carried out.

<table>
<thead>
<tr>
<th>character</th>
<th>Images tested</th>
<th>Successful</th>
<th>Unsuccessful</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROI</td>
<td>228</td>
<td>222</td>
<td>6</td>
<td>97.36%</td>
</tr>
<tr>
<td>Segmentation</td>
<td>228</td>
<td>228</td>
<td>0</td>
<td>100%</td>
</tr>
<tr>
<td>Recognition</td>
<td>228</td>
<td>187</td>
<td>51</td>
<td>82.16%</td>
</tr>
</tbody>
</table>

Table 1. Accuracy tests on truck registration number acquisition and recognition

Performance analysis and evaluation of individual characters is as shown in table 2.

<table>
<thead>
<tr>
<th>character</th>
<th>Appearance (hits)</th>
<th>Successful</th>
<th>Unsuccessful</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>116</td>
<td>102</td>
<td>14</td>
<td>87.93%</td>
</tr>
<tr>
<td>B</td>
<td>28</td>
<td>25</td>
<td>7</td>
<td>89.28%</td>
</tr>
<tr>
<td>F</td>
<td>28</td>
<td>25</td>
<td>3</td>
<td>89.28%</td>
</tr>
<tr>
<td>G</td>
<td>49</td>
<td>38</td>
<td>11</td>
<td>77.55%</td>
</tr>
<tr>
<td>L</td>
<td>56</td>
<td>42</td>
<td>8</td>
<td>75.00%</td>
</tr>
<tr>
<td>M</td>
<td>44</td>
<td>38</td>
<td>6</td>
<td>86.00%</td>
</tr>
<tr>
<td>N</td>
<td>73</td>
<td>58</td>
<td>15</td>
<td>79.00%</td>
</tr>
<tr>
<td>P</td>
<td>13</td>
<td>9</td>
<td>4</td>
<td>69.23%</td>
</tr>
<tr>
<td>Q</td>
<td>17</td>
<td>14</td>
<td>3</td>
<td>82.35%</td>
</tr>
<tr>
<td>R</td>
<td>31</td>
<td>28</td>
<td>3</td>
<td>74.19%</td>
</tr>
<tr>
<td>S</td>
<td>42</td>
<td>36</td>
<td>6</td>
<td>85.00%</td>
</tr>
<tr>
<td>T</td>
<td>19</td>
<td>14</td>
<td>5</td>
<td>73.68%</td>
</tr>
</tbody>
</table>

Table 2. Accuracy tests per character symbol

b) Weight Scale Reading

A total of 115 images bearing weight scale readings were used to evaluate system performance. Performance tests were carried out to find system accuracy in finding the character region, segmentation and recognition. Table 5.2 shows the accuracy rating of the weight scale reader.

<table>
<thead>
<tr>
<th>Test level</th>
<th>Images tested</th>
<th>Successful</th>
<th>Unsuccessful</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROI</td>
<td>115</td>
<td>115</td>
<td>0</td>
<td>100%</td>
</tr>
<tr>
<td>Segmentation</td>
<td>115</td>
<td>115</td>
<td>0</td>
<td>100%</td>
</tr>
<tr>
<td>Recognition</td>
<td>115</td>
<td>115</td>
<td>0</td>
<td>100%</td>
</tr>
</tbody>
</table>

6. DISCUSSION

The project’s primary goal is to make the clearance process at the weighbridge efficient, quicker and trustworthy. This is to be accomplished by automating key units in the clearance process. An optical character recognition technique is used to read and recognize truck registration numbers and cane weight scales. The success rating for truck number plate reading and recognition as shown on Table 5.1 is 82.16% for 228 images tested. This means approximately 17% of the images tested were incorrectly recognized. This is majorly attributed to the following reasons.

i. Complex background nature of truck images with high levels of noise.

ii. Low resolution images with blurry and indistinct backgrounds.

iii. Similarity of alphanumeric images both in structure and shape e.g. letter “5” and “S”, “O” and “O”, “A” and “4”.

iv. Variation of registration numbers in size, shape and type that require a wide range of template symbols to match the input character symbols for effective recognition.

v. Incapability to find region of interest in images taken at a skewed angle.

vi. Lack of uniformity of space between characters in the image.

The success rating for weight scale reading and recognition, shown in table 5.3 registers 100% accuracy for 115 images tested.
7. CONCLUSION

It is worthy and indeed factual to note that present day weighbridges more especially sugar companies lack technical and logistical basis for mechanization. It is therefore critical for transformational changes that would be instrumental for assuring in technology driven fronts, not only for truck clearance but also other related industrial chores. Such challenging scenarios coupled by unfriendly environmental and climatic conditions call for specialized solutions which will also need to be affordable considering the social and economic constraints this companies face. The Weighment system for Nzoia Sugar Company was built along these benchmarks and therefore most suitable. We strongly believe the prototype, upon fulfilling the suggested recommendations can favorably provide a commercial solution that can as well be used by other related companies in the business.

REFERENCES