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Detection of Remnant Material and Its Quantification

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Abstract*—Loading-unloading of goods is an essential task that is undertaken at every industrial site. Mines witness a large scale transportation activity. As the volume of such goods is large in size, the mode of transport used for delivery is usually dumpers. Huge cranes load the dumpers at one location with some material and then the dumper moves to the desired destination for unloading. After the unloading process, the dumper may still hold some residual matter in its dumping bed which may be misused stealthily; theft of which may amount to huge loss for the concerned industry. This paper mainly discusses attempts in the direction to devise an automatic system that will detect and quantify the remnant material which is left behind in the dump-trucks after the unloading process is formally completed. In this piece of research we have applied grey level co-occurrence matrix (GLCM) and Material specific techniques to detect the carry back for materials like aluminium, coal, copper, iron ore, manganese and lime stone. Results of both these approaches have been compared.

Index Terms*—Carry-back detection, GLCM, Material specific techniques, monochrome, r-plane, Intensity adjustment.

I. INTRODUCTION

Type and quantity of the material that a dumper is carrying should be accessed to analyse the loss that may be incurred due to the carry-back material [1], which can be used by a stealthily working group of people for their own benefit. The remnant material [1] from all the dumpers may result in a huge quantity when combined together. Thus, the concerned industry may suffer a massive loss. To keep a check on this carry-back material each dumper shall pass through a checkpoint every time it unloads the material. Cameras fitted at these checkpoints would be capturing images of the so called empty beds of the trucks. All the captured images would be processed and analysed to study the amount of residual matter present in the bed of the corresponding dumper. Some permissible limit up to which the material can be carried-back has to be predefined. If the residual matter violates this permissible limit then it is necessary to raise an alarm. The cameras would be fitted in an environment where heavy vehicles would move hence the captured images may lack clarity and sharpness due to dust and other particulate matter being suspended in the air. Presence of noise in the images may reduce the overall accuracy. Hence, denoising techniques [4] needs to be taken help of.

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II. PROBLEM DEFINITION AND LITERATURE SURVEY

Paper [1] describes an automatic system, developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) of Australia, to detect and quantify remnant coal that is left in coal rail-wagons after dumping at coal terminal facilities. The system uses scanning laser technology to build up a three dimensional profile of the interior of each coal rail-wagon. The system is under further development for commercialisation. In majority of the industrial work areas, the supervision of the wagons or dumpers is taking place manually where a person checks for the carry-back state of every dumper that leaves the unloading port. This kind of checking is not very feasible. It gives rise to a need of such a system which shall take over the control of inspection from a human supervisor. The advent of such an automated system will improve the supervision quality. The complexity of detection may increase due to various aspects like lighting conditions, noise presence, etc. To get a better view of the captured image it is necessary to perform image-preprocessing activities [5-11] to enhance the image and to extract more information from it. Once an image is pre-processed, then the steps to identify the object of interest can be performed (refer Figure.1).

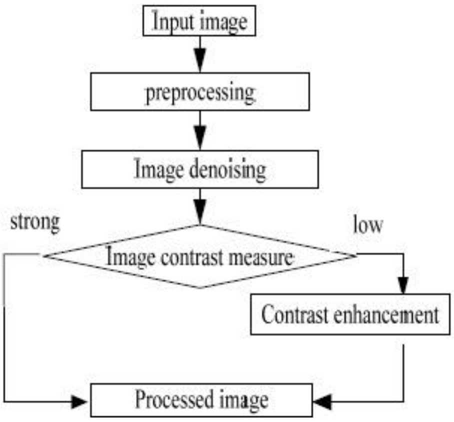

Figure 1: Preprocessing and denoising of the image [2]

An algorithm to quantify the remnant material can be implemented to detect the carry-back material. Once the process of analyzing an image is done, the next challenge lies in deciding the threshold level. If the quantified residual material is beyond this level then an alarm should be raised. Deciding this level of threshold is a challenge and finalizing on a particular value is possible only after exhaustive experiments. To make the system more accurate the kerb weight of the dumper can be considered. The weight of the dumper and the captured image can together be used to decide the quantity of the remnant material.

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Background noise, unwanted reflection from illumination and geometric distortion are very common noise sources from the acquisition system during the capturing of dumper's images by the digital cameras.These factors make the image analyses more difficult. Image enhancement [3] techniques help to restore the image to improve the overall clarity by correcting distortions from the acquisition system. Figure 1 gives a flow of how the pre-processing would be followed. Idea of denoising the image followed by contrast enhancement will give a visually better image from the captured one. These steps may be appended with some additional pre-processing techniques [5]. Spatial domain is a category of image enhancement [3] methods in which pixel values are manipulated. Some of the techniques,useful here are 'negation', 'thresholding' and grey level slicing [3]. Image enhancement algorithms offer a variety of approaches for modifying images however the choice of techniques depends on the field of interest.

III. PROPOSED METHODS

Two methods are proposed in this paper for carry back detection. A prototype model is constructed for a better understanding. For constructing the prototype model, the components shown in Figure 2 and Figure 3 are used.

Figure 2: Card paper box that represents the dumper's bed

Figure 3: Seeds or beads to represent the material

All the captured images are first processed to remove any noise that may be present. 'Arithmetic mean filter' and 'midpoint filter' [4] when applied on an image containing noise, the present noise is reduced to a great extent. For experimentation of detecting carry-back, getting the real materials was not feasible and hence substitutes have been used instead of the actual materials. Figure 4 shows the container used to measure the material and figure 5 talks about the substitutes used. It is practically not possible to measure the remnant material with the prototype. Hence dummy measurement has been used. The amount of carry-back material tested is in the multiples of 2.12cm^3 units i.e. 1 unit = 2.12cm^3, 2 units=4.24cm^3, 3 units = 6.36cm^3 and so on. For that a cylindrical container is used.

Figure 4: Container used for measurement

Figure 5: Substitutes used as materials

Material amount of unit 4 or greater is not considered because it completely occupies the dumper's bed, clearly making it a candidate for carry-back on the basis of the kerb weight of the dumper truck. This proposed work involves 2 categories of implementations: GLCM [7-9] and Material specific techniques.

GLCM studies the captured image by considering 4 parameters: contrast, correlation, energy and homogeneity. Though it provides a decent platform to analyse and find a pattern to decide the quantity of material that would be present in the bed of the dumper it fails at times, especially when the quantity difference is more in the captured images.

The second category of implementation is finding a ratio between the object-to-be-detected and the background area. The logic followed works with any coloured material and hence provides a better study opportunity in material detection. Applying the same algorithm for detecting different coloured material does not give a satisfactory pattern; therefore an algorithm customized for a specific form of material is important. Thus, the second category is further classified by implementing three techniques customized for a specific type of material.Figure 6 describes the proposed methods in the form of a flowchart.

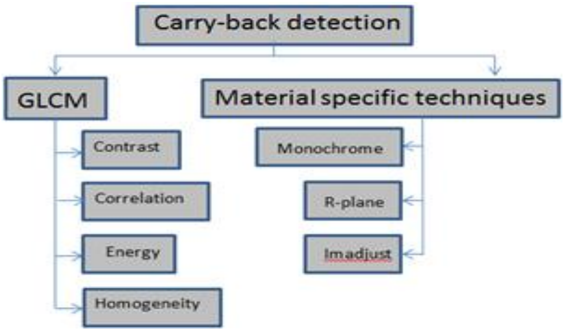

Figure 6: Proposed methods' flowchart

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IV. GLCM (GREY-LEVEL CO-OCCURRENCE MATRIX) [7-9]

It can be described as a statistical method of examining texture that considers the spatial relationship of pixels in an image. The GLCM functions characterize the texture of an image, this is done by calculating how often pixel pairs with specific values and in a specified spatial relationship occur in an image, thereby creating a GLCM. Statistical measures can then be extracted from this matrix. GLCM is created in MATLAB by calculating how often a pixel with the intensity value i occurs in a specific spatial relationship to a pixel with value j. When GLCM is applied on an image we four values: contrast, correlation, energy and homogeneity which help us to find patterns in identifying carry-back.

V.MATERIAL SPECIFIC TECHNIQUES

The algorithm involves preprocessing of images to remove the noise from the image and then enhancing the overall image to extract more information from it. Later, only the area of interest is highlighted, whereas the remaining area is discarded. On the basis of the highlighted area, the material present in the dumper bed can be detected and quantified. Along with the images, the kerb weight of the dumper is taken into consideration. After the dumper unloads the material its weight is checked. If the weight of the dumper after unloading is 0.3 tons more or less than the kerb weight, it is assumed that the carried-back material is within the permissible limits.

Algorithmic steps:

- Capture images with an angle perpendicular to the dumpers bed.
- Eliminate the noise in the image:
  - Arithmetic mean filter or Midpoint filter.
- Use Grey level slicing:
  - Highlight only the material area of the image.
- Use a threshold value to convert it into a distinguishable form (e.g. black and white).
- Calculate the white pixels.
- Find the ratio of the whitepixels to blackpixels.
- Weight the truck.
- If truck's weight is in permissible limits: No carry-back
- Else: Material is present in the dumper's bed.

Applying the same algorithm for detecting different coloured materials does not give a satisfactory pattern and hence an algorithm customized for a specific form of material is important. Hence, thiscategory of implementation is further classified by into 3 techniques customized for a specific type of material. Output thus generated for each technique gives 3 values [2] viz.: material representing pixels (A), background pixels (B: image area – material present), amount of material present (ratio of A to B). If the third value; which gives the percentage of material present in the dumper's bed is more than a permissible limit (threshold); than an alarm can be raised to notify the concerned authorities regarding a possible theft.

Five kinds of images are captured for each material, for 1 unit(2.12cm^3), 2 units (4.24cm^3), 3 units (6.36cm^3), 4 units (8.48cm^3) and 5 units (10.60cm^3). However, images of only until unit 3 are considered in our experiment because images of unit 4 or 5 have material content far more and can be easily detected with a weight bridge and hence no image processing is necessary in this case. Figure 7 shows a filled dumper and an empty dumper. Figure 8 shows a graph in which four different patterns of a material with same unit of weight are shown. It can be seen that the percentage increases with increasing quantity but this trend does not continue once the weight goes beyond 4 or 5 units. This is because the material occupies the entire bed of the dumper and further increase happens on the z-axis. However, we are considering only two dimensions as an image captured provides information only of the x and y axis.

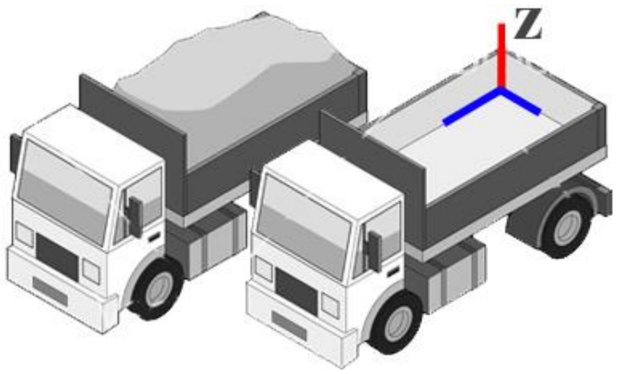

Figure 7: Filled and empty dumper (courtesy: vectorstock.com)

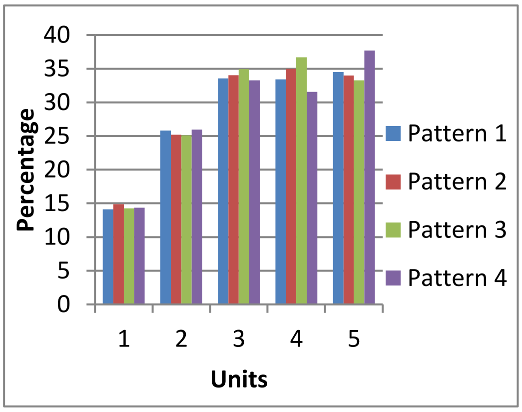

Figure 8: Graph-1 (Units measurement)

The following sub-section discusses three methods viz. monochrome, r-plane and imadjust. Figures 9 to 11 show theoutput generated of the aforementioned techniques.

Monochrome: Pixels representing the carry-back material are converted to white whereas the remaining pixels are converted to black. A ratio of white to black pixels is found out which gives a rough estimate of the quantity of material remaining in the dumper's bed. It will help in knowing the area of the dumper's bed that is still carrying some material. Figure 9 shows the output of monochrome technique when applied on an image.

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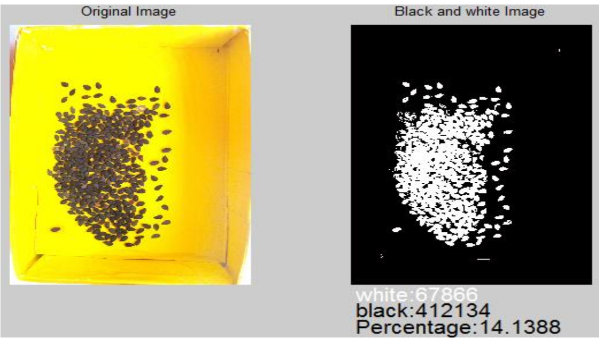

Figure 9: Sample image for monochrome

R-Plane[12-15]: All the red pixels are kept as it is. This comes from a concept known as a grey level slicing. The non-red pixels are converted to greyscale. A ratio of red to non-red pixels is found which gives a rough estimate of the quantity of material present in the dumper's bed. Figure 10 shows the output of R-plane technique when applied on an image.

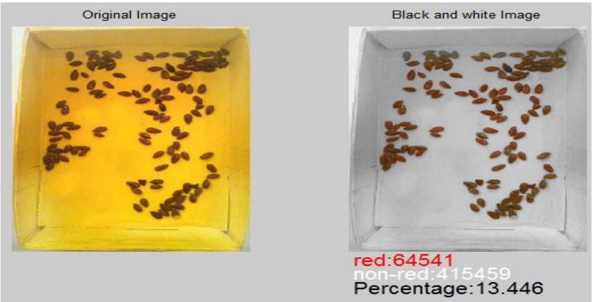

Figure 10: Sample image for R-plane

Intensity adjustment (Imadjust): It provides correct detection of the material which is not easily distinguishable from the background. The image is first processed using the Intensity adjustment function in which the material of interest is converted to black colour. The background area is then converted to another colour. After this the image undergoes thresholding. A ratio of white to black pixels is found out which gives the percentage of the material remaining in the bed of the dumper. Figure 11 shows the output of imadjust technique when applied on an image.

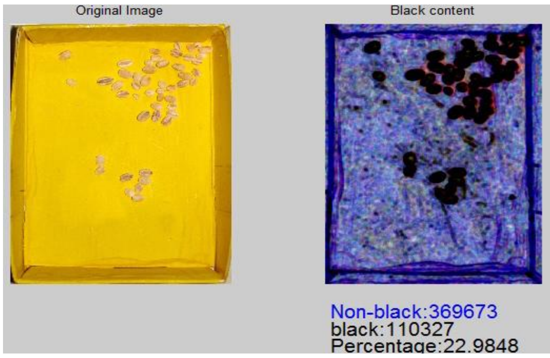

Figure 11: Sample image for imadjust

The percentage value increases with increasing quantity, thus giving a platform for estimating the amount of material that may be present in the dumper's bed. Not all techniques work well on all the materials. Each technique is specifically designed or modified to suite the material under consideration. While doing this, the colour [12-15] and texture of the materials is taken into consideration. However, some kind of error window is left open due to the incident light and luminosity around the object. The experiment of estimating the quantity of six materials with different weights generated total 120 images. But due to space constraints, it is not possible to display all the images. Hence, images of only the one unit of weight are displayed in figure 7, 8 and 9.

VI. RESULTS AND DISCUSSION

In GLCM and Material specific techniques, total seven possible ways of finding a pattern to quantify the remnant material have been discussed. Each technique is applied on every material and a comparative study is made. Table 1shown in figure 12 gives a clear idea of how each method or technique fares with each material that has been taken into consideration. The first four rows talk about GLCM whereas the remaining three rows talk about Material specific techniques.

Graph-1 shown in the Figure 13 puts light on the application of the GLCM technique.From this graph we can see that the four parameters of GLCM are not very conclusive when applied on the six materials. Homogeneity is not good for any material. Energy shows a trending result i.e. value corresponding to quantity; with manganese but nothing conclusive with other materials. Correlation works fine for coal and manganese only. Contrast for manganese too is ok. In case of manganese every parameter shows a pattern that can be used to decide about the quantity of material present. In short, it can be stated that the GLCM technique fails to provide a generalized platform for materials of different colours and texture.

In case of the second category of implementation, a range acceptable for quantity of material of up to 3 units has been assumed in this work on the basis of coal. Black colour is easily distinguishable from the yellow background of the dumper's bed. So, when monochrome is applied to it, a perfect binary image is obtained highlighting only the material. On this basis a relation can be developed between the quantities of material present in the dumper to the percentage of pixels denoting it. Hence the range of 10-30 percent is assumed and is generalized for accepting carryback as far the 'method specific techniques' is concerned. Graph-2 shown in figure 14 gives us an idea of which method viz. monochrome, r-plane and imadjust are suitable for which kind of material.

Monochrome technique is best for situations where the material and the background are highly contrasted. From graph-2 in figure 14 it can be seen that the monochrome technique gives a good detection for coal and copper. Detection of manganese is also possible but the result is not very accurate. Monochrome fails for limestone. Aluminum has a shiny texture hence by converting itto a black and white image, some pixels may not be considered at all.

R-plane technique is bestfor situations where the material and the background are highly contrasted especially in terms of red content. From graph-2of figure 14, it can be seen that the R-plane technique gives a good detection for iron ore. With grey level slicing only red colour is retained; all other pixels turn to greyscale.

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The detection of coal and copper is also possible, though not on the basis of red colour but due to good level of contrast between the material and the background. However, the result is not as accurate as iron ore. R-plane technique fails for limestone and aluminum. The problem faced with aluminum is same as it was with monochrome.

Intensity adjustment technique (Imadjust) is best for situations where the material and the background are not very distinct from each other. From graph-2 of figure 14, it can be seen that the Intensity adjustment technique gives a good detection for limestone. Intensity adjustment technique gives a blotted percentage for other materials leading to false detection. Intensity adjustment technique completely fails for aluminum.

	Coal			Copper			Iron ore			Limestone			Magnesium			Aluminum		
	Unit 1	Unit 2	Unit 3	Unit 1	Unit 2	Unit 3	Unit 1	Unit 2	Unit 3	Unit 1	Unit 2	Unit 3	Unit 1	Unit 2	Unit 3	Unit 1	Unit 2	Unit 3
Contrast	0.191	1.7263	2.091	0.133	0.114	0.125	0.291	0.349	0.292	0.118	0.107	0.11	0.352	0.83	1.267	0.487	0.644	0.76
Corelation	0.761	0.5894	0.47	0.406	0.364	0.413	0.585	0.768	0.794	0.409	0.424	0.42	0.553	0.72	0.776	0.565	0.585	0.54
Energy	0.978	0.8426	0.878	0.992	0.994	0.993	0.978	0.961	0.96	0.993	0.994	0.99	0.976	0.92	0.857	0.967	0.955	0.95
Homogenity	0.997	0.9691	0.963	0.998	0.998	0.998	0.995	0.994	0.995	0.997	0.998	1	0.994	0.99	0.977	0.991	0.988	0.99
Monochrome	14.41	25.51	33.95	6.47	14.11	18.21	11.62	15.07	20.88	1.3	2.8	3.2	2.4	4.41	5.4	13.31	14.53	19
R-plane	16	28.89	38.7	8.19	17.73	25.97	13.46	22.89	30.02	0.45	0.96	0.58	0.08	0.31	0.33	3.61	4.42	4.84
Imadjust	34.69	46.95	54.76	28.92	40.58	50.68	36.16	46.7	54.51	22.31	30.5	38.9	17.51	20.7	24.45	40.17	52.84	60.8

Figure 12: Table 1- Comparison of all approaches w.r.t. various materials and its units

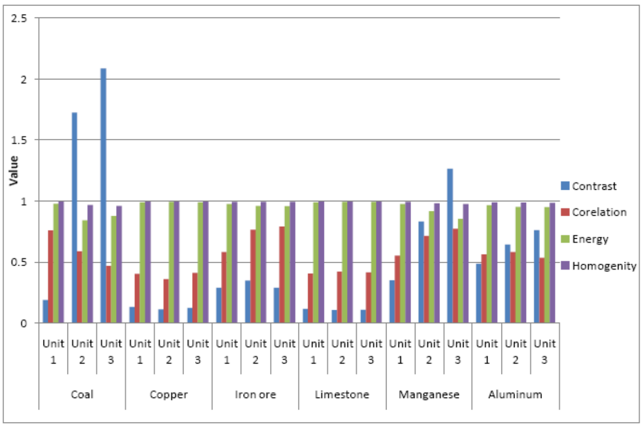

Figure 13: Graph-1(GLCM comparative graph)

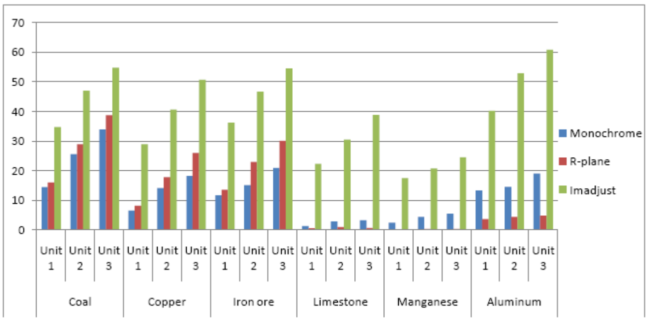

Figure 14: Graph-2 (Material specific techniques)

VII. CONCLUSION AND FUTURE SCOPE

Two different methods have been proposed for carry back detection and its quantification. Both the proposed methods have their own merits and demerits. GLCM gives a non-uniform output for different materials whereas the second technique is highly dependent on colour and texture of the materials. But still the second technique performs better than the previous one. As of now, a combination of the two techniques has not been tried. This amalgamation of the two methods may augment the overall process of carry-back detection and give better results. The system proposed only works with 3 units of load. Anything beyond it is analysed on the basis of the truck's kerb weight. The kerb weight of the truck may change due to various conditions. The kerb weight of a dumper may be in the range 15-20 tons. Assuming that the kerb weight of the dumper in considerationis 15 tons; the permissible window would be +0.3 tons to -0.3 tons. Thus the range in which the weight of the dumper may lie would be between 14.7 tons to 15.3 tons. If the weight is beyond the permissible limit then it can be concluded that the quantity of carry-back material is more; else the quantity of the carry-back material is negligible. There are certain factors which still need to be worked upon. The environment in which the system is to be implemented will have many dust and ash particles suspended in the air. As a result the camera lens may get dusty over time. Removing noise from the image will reduce the overall clarity. Deciding the fault tolerance window is difficult and needs experimental evidence to prove the best range of acceptance.Analysing the image is to be done in real-time; hence it is necessary to study the cost of computation in terms of time and effort required. Markings on the dumpers will help in knowing the exact orientation of the truck while capturing its image. Use of stereoscopic cameras will help in capturing more details with images taken from different angles. Studying the techniques that discuss video processing would be of more help as the images would be captured as a continuous process. It is necessary that these factors be studied and a solution be found for overcoming the limitations still faced by the proposed methods.

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