BULK MATERIAL VOLUME ESTIMATION METHOD AND SYSTEM FOR LOGISTIC APPLICATIONS

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Abstract: This paper introduces a new method and a portable system for bulk material volume assessment on the base of machine vision technology, smart algorithms and mobile devices. The new method and algorithms are discussed on the example of the timber volume estimation system applicable for logistics companies. Practical results are demonstrated and use of algorithms for different conditions discussed and future directions for technology development outlined.

Key words: machine vision, image processing, portable system, logistics.

1. INTRODUCTION

Organizing and controlling of unpacked piece materials and goods is usually connected with many problems, one of which is difficulty and very high uncertainty of estimation the amount of the material in different checkpoints of the logistics chain [1]. Even more, in many cases it is needed to assess the amount of the material on the transport stage where the stationary equipment like weighing cannot be used.

Rapid development of mobile technology and especially capabilities of the cameras integrated into mobile phones or tablet computers and efficiency of the computing power have created new opportunities to develop advanced mobile technologies to support logistics. One of these options is use of a mobile device camera with the device itself a portable smart machine vision and communication system to determine bulk materials or goods amount or volume.

Timber is one of the most widely used materials in different applications like construction, furniture making, and joinery, etc. Organizing and managing logistics of this kind of bulk materials depends greatly on the correctness and accuracy of determining the material volume. The bulk price, quantity of the output products, transportation costs and even potential load carrying problems of trucks, ships and roads depend on the bulk materials amount allocation correctness.

There is a widespread belief that the cubic volume of timber can be calculated by measuring the high and width of the pile or truckload multiplying the result with the length of timber [2]. Nevertheless, the existing methodologies are time consuming and very inaccurate due to the fact that log like bulk material dimension (diameter) is not constant (Fig. 1).

Fig. 1. Common technique, which applied for measurement of timber volume. \( D = \frac{(D1+D2)}{2} \)

As a result, the uncertainty of such measurements can reach up to 30 percent,
which on ones turn means either paying 30 percent more or less than the actual material amount or losung transportation carrying capacity.

This paper introduces a new method and a portable system for bulk material volume assessment on the base of machine vision technology, smart algorithms and mobile devices. The new method and algorithms are discussed on the example of the timber volume estimation system applicable for logistics companies. Practical results are demonstrated and use of algorithms for different conditions discussed and future directions for technology development outlined.

2. PROBLEM STATEMENT

The main research objective is to develop machine vision based techniques, which identify the volume of the bulk materials. The method is discussed on the example of the timber volume estimation system. The nature of the problem and the methodology offers the further perspective benefit (the secondary objective) assessment the quality and other properties of the examined timbers, such as minimum and maximum diameter, the number of the timbers that are stacked in a pile.

The low processing speed, due to the huge amount of data, restricted main memory, short battery life prevent the implementation of computer vision algorithms in real-time mobile applications [3]. However, the modern cellphones and tablets provided with various devices such HD camera, GPS system, touch screen. The new technologies transform the phone to something more than simply phone. The extra challenge is the development the system for portable devices. Well known that computer vision algorithms are very sensitive to small changes in lighting conditions. The users may use the system by various weather conditions and by different climate seasons. Therefore, during the development of the system the probability of existence such kind of problems has to take into account.

2.1 Methodologies

The system consists of four major components, image acquisition, image preprocessing, feature detection, volume estimation.

2.2 Image Acquisition

Today it is difficult to find a phone or tablet without a camera. The increasing popularity of digital photography reduces significantly the camera's cost. The cameras become smaller and their properties have improved. The Android API provides access to the camera’s features and allows to control the camera and take the pictures inside the application [4].

In order to take a picture it is very comfortable to make use of an already available application provided by the operating system. For instance, android's image acquisition application has extra features, such as adjusting the auto-focus, brightness, shutter speed and aperture of the camera in fully automatic mode. At the same time, the end user is still responsible for the image quality. The user has to control the process, in order to avoid the backlighting situation, to control the picture's background and distance between the camera and scene. Conflicting with these rules leads to difficulties during the image processing stage.

2.3 Image Preprocessing

In many practical situations, the objective circumstances do not allow to take a picture ready for further processing. The image preprocessing stage aims to prepare the image for feature detection. Two main tasks have to be accomplished during this step:

• setting the region of interest (ROI) in an image;
• automatically normalize the image brightness.

The first step, ROI setting, used in order to isolate the object from the rest of the scene (Fig. 2).
Fig. 2. Setting the region of interest on the image.

The elements of the image, outside the selected region considered as a background. The second step aims to improve the image quality, for instance, brightness, as presented in Figure 3. The original image is too dark for execution of the main step, object detection, and requires brightness adjustment.

2.4 Feature detection
The feature detection is a main part of the system and based on image segmentation. The aim is to separate the objects of interest from the background. The result of this step is very critical for the final task, volume’s assessment. Therefore, a key requirement for the applied algorithm is robustness. There are several ways for achieving this goal. Very common group of methods separate the pixels based on some homogeneous characteristic of the object such as intensity or color [5]. Color is powerful key for segmentation but due to problem with color inhomogeneity, the developers face with difficulties with the implementation such kind of methods for the outdoor application. In fact, if we consider an image, which is represented in RGB color space, the observed chromaticity varies with lighting (Fig. 4).

Fig. 3. Image of the examined scene. a) original image; b) the image after brightness adjustment.

Fig. 4. Images of the same scene, but created under different lighting conditions.

Solutions that are more robust could be achieved by considering the chromaticity in term of two characteristics: hue and saturation. The two commonly known are HSV and CIE LCh (CIE stands for “International Commission on Illumination”, and L*c*h means L – Lightness, c – Chroma or “saturation”, h- Hue) [6]. The H, S, V components presented in the Figure 5.
Fig. 5. Three components of the image in HSV color space. a) H – hue; b) S – saturation; c) V – intensity.

The graphs on the figure 6 show the range of the closest spectral color and the saturation value for timber. Using this information, we can separate object's pixels from the background pixels.

c) Fig. 6. Range of hue (H) and saturation values (S) that correspond to the timber. a) The range of the saturation corresponding to the timber. b) The hue range corresponds to the timber; c) The histogram of the hue component of the image. The pixels inside the red box correspond to the hue distribution of the timber.

Fig. 7. Resulting image example.

From the figure 7, we can see that the resulting logical image is still far from perfect. Many pixels classified as a timber. The logs have holes due to dirt, soil or
shadows from the nearest logs. We have to improve the result by applying a morphological closing and opening operation \cite{7}. The result is shown in the Fig. 8.

![Fig. 8. The result image after morphological opening and closing operation with a small kernel.](image1.jpg)

Finally, we can calculate the image area occupied with timber. The resulting image is shown in the Fig. 9.

![Fig. 9. The resulting image example. The pixels, which classified as a timber painted with random color.](image2.jpg)

3. RESULTS

The proposed algorithm was tested on the phone SONY XPERIA GO. The Table 1 presents the features and specifications for this phone.

<table>
<thead>
<tr>
<th>Processor</th>
<th>1 GHz NovaThor™ U8500 Dual-core Cortex A9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Camera</td>
<td>5 megapixel camera with auto focus</td>
</tr>
<tr>
<td></td>
<td>16x digital zoom, LED flash</td>
</tr>
<tr>
<td>RAM</td>
<td>512 MB</td>
</tr>
</tbody>
</table>

![Table 1. Specification of Phone SONY XPERIA GO](image3.jpg)

The image was taken by standard Android application and stored in SD card. The main window of the application on the phone screen is shown in the Fig. 10.

![Fig. 10. Main window of Timber Diameter app.](image4.jpg)

The user prompted to set the length of the timber and load the desired image from the memory. After the image is loaded, the user sets the ROI and pushes the menu button for the image processing (Fig. 11). The system first calibrates itself. It means the system determines the relationship between the pixel and the metric units.

![Fig. 11. Second screen for setting the ROI. The calibration standard is shown inside the box.](image5.jpg)

For this purpose, the small blue circle with known size is used. The system detects the circle and estimates the radius in pixels. Then the system estimates the area which is...
occupied by the timber in pixels and converts it to the metric unity. The resulting image is presented in Figure 12. As shown in the image almost all the timber detected and their area is used for the volume estimation. The estimated timber volume is 21.28 cubic meters. The application was tested on several examples. The estimated by the phone results were close to the actual amount of timber.

Fig. 12. The message gives the information about estimated volume of timber.

4. CONCLUSION

A new method is proposed and presented for the bulk and piece material volume estimations. This method could be successfully used for fast estimate the volume of bulk materials in logistics and storage applications. The example of the use of the method was demonstrated for timber volume estimation. The novel approach allows to use the application on the mobile devices making it therefore very convenient for the everyday use. The analysis of the application reveals some problems and future work direction that should be focused further. The accuracy of detecting object is highly depend on the size of objects. For the current application, we determined experimentally that, the timber could be measured if its diameter is more than 10 pixels on the image taken by the mobile device. If the objects are smaller on the image only the total area of the objects pile could be estimated like show in the Figure 13. The method is in developing phase and it is our estimate that the results could be used for many everyday applications starting from the home use to real industrial logistics applications.

Fig. 13. Detecting the total area of the logs in pile.

5. REFERENCES