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Implementation of Man-Hours Measurement System for Construction Work Crews by Image Processing Technology

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Abstract: Measuring productivity on a construction job site is not an easy task because collecting its reliable data consistently from the job site requires a lot of personnel efforts causing extra time and cost. In order to measure the job site productivity, for instance, basically two types of data such as man-hours and installed work quantities are required as an input and an output factor to calculate the values of the productivity. This paper suggests an efficient automatic man-hours measurement system for analyzing and collecting the data relating to the input factor by the analysis of video images instead of the direct observation of construction job sites by a work manager. The proposed method utilizes the image processing technologies for analyzing the video images of the construction related works operated on the job sites. An image processing based algorithm is developed for tracking the three different groups of construction work crews under the considerations of complex construction work environment. It includes the following main algorithms: BGS (background subtraction), worker detection, and worker tracking algorithm. The proposed method has been applied and verified under various indoor and outdoor experimental test environments. Around 84% of recognition rate for counting man-hours of construction work crews is achieved by the proposed algorithm. The data acquired by the proposed method can be used as an essential and valuable input data to analyze and control the productivity of construction job site subsequently.

Keywords: Construction Job-site Productivity, Automatic Data Acquisition, Image Processing Technology, Worker Detection Algorithm, Worker Tracking Algorithm, Man-hours Measurement

1 Introduction

1.1 Research background and objective

Productivity data collected from construction job site activities can be used to check up whether the construction operations on the site are well performed without any problems or not. Also, the productivity data acquired for each activity may be recorded, analyzed, and generalized to be used for planning any work schedules for future construction projects. Therefore, the productivity should be accurately measured based upon the information occurring from the operations of construction work crews, such as installed work quantities and input man-hours [1].

However, it has often been indicated that measuring productivity on a construction site is not an easy task because collecting valid data from construction sites requires a large investment of manpower causing extra time and cost [2]. In addition, it has been addressed that collecting relevant information manually is slow and inaccurate [3]. Therefore, the studies on data acquisition methods by applying IT have been performed to solve these problems in the construction industry. For instance, data acquisition methods using Bar-code, PDA (Personal Digital Assistant), RFID (Radio Frequency Identification), GPS (Global Positioning System), image processing technology, etc. have been tried on construction sites and are making some progress. Especially, image processing technology has been recently expanding its applicability on automatic data acquisition with the advantage of relatively less

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investment compared to other IT methodologies. However, it requires the efforts for developing advanced and optimized algorithm which is suitable for the specific work environments of a construction site in order to obtain more accurate data [4].

As an consideration of these conditions, this research is focusing on the development of advanced and optimized image processing algorithm, by considering the characteristics of construction work environment, particularly focusing on the analyzing and collecting of construction man-hours that can be used as the input factor for estimating productivity values accurately. These man-hours can be used for producing essential data to analyze and control construction job site productivity subsequently.

1.2 Research scope and methodology

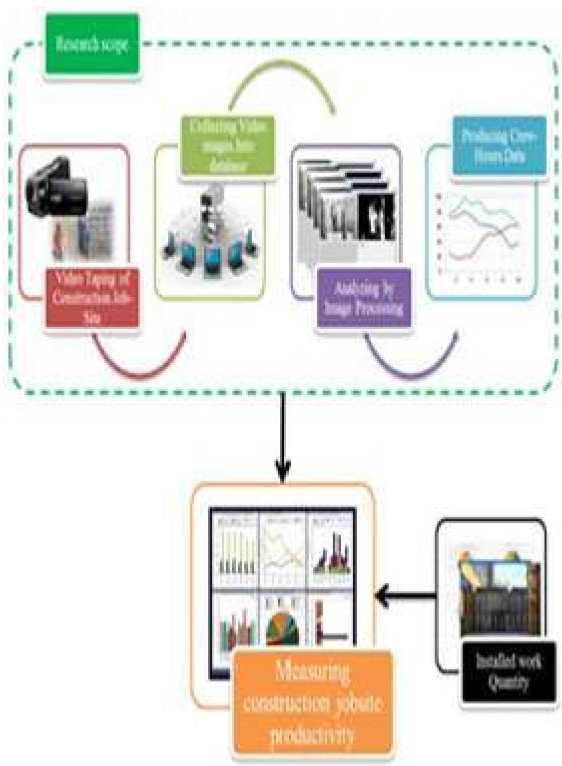

Fig. 1: Research scope

The main scope of this research is to develop an automatical and efficient method to analyze and obtain the man-hours of distinctive construction workers from the video images, instead of the direct observation of construction job sites, for producing the data which is relating to the input factor for measuring the job-site productivity ultimately as shown in Fig. 1.

The effective applications with image processing technologies are required to analyze these video images automatically. Therefore, this paper suggests an image processing technology based algorithm to track the different group of construction work crews under the considerations of complex construction work environments.

The proposed algorithm in this paper automatically finds out moving objects with the different values of a current frame from a previous frame using BGS algorithm, and then recognizes the different groups of work crews using the distinctive color of construction workers safety vests and safety hats. Finally, it measures how much of the man-hours of each crew are performed as they complete their designed work within the designated area.

In order to develop and test the algorithm, video images are taken on the supposition that workers are working at indoor and outdoor with different colored safety vests and hats in wear. Different colors are used to classify each distinctive group of work crews. Then, the video images are analyzed to figure out the man-hours for each different group of work crews using the proposed image processing algorithm based on OpenCV.

The research will be expanded to the development of the accurate job site productivity measurement system, in the future, with the combination of the additional productivity related data such as installed work quantities, the output factor as mentioned earlier.

2 Related research works

2.1 Productivity data acquisition methods in the construction industry

Fig.2 shows the general trends of data collection methods which have been associated with construction job-site productivity. Traditional methods such as direct observing, video editing, work sampling, surveying, etc. are still very valuable things to gather relatively reliable construction field data, but they require the consumption of so much time and cost with extra efforts throughout the data collection process. Actually, this fact is one of the main obstacles to the invigoration of various researches on construction job site productivity. Also, it is no exaggeration that this problem has caused the sharp decline of construction companies interests on accumulating and utilizing their field productivity data. IT-based data acquisition methods have been developed and applied for making these shortcomings better. Various researches have been actively performed on the practical use of IT-based utilities such as RFID, PDA, Bar code, GPS, and so on. Seokyon et al. [5] insisted that information technology tools can and will become an indispensable part of construction field data collection.

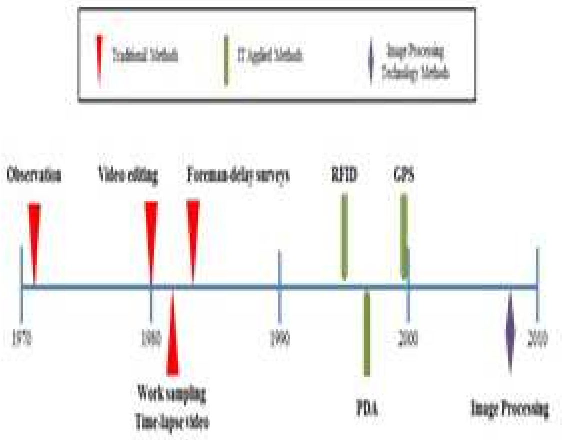

Fig. 2: The trends of job-site productivity data acquisition methods in construction field

However, these methods have some problems as weak points. For example, the PDA has been accepted by many construction job-sites to aid the management of work processes, but it requires the additional exertions of workers to achieve data. It may cause some mistakes by workers or the distortion of the productivity data when out of range of wireless network or coverage. In addition, it provides the small screen size and is not suitable to quickly enter necessary data. The RFID is a wireless communication system based on RF signals. The typical RFID system consists of tags, readers, and antennas. A microchip in a tag stores detailed information for construction materials. Although recent RFID readers can read up to a few hundred tags in a second, RFIDs have problems in tag recognition due to unpredictable shortcomings such as tag-overlap and obstacle-interference [4]. In the case of GPS, there are limitations that it can only be applied outdoor and may not permit desired accuracies in a given environment [6]. The poor accuracy may be caused by signal corruption, poor satellite geometry, or erratic ionospheric activity.

In addition, these IT-based methods are mostly applied on the management of construction materials or construction workers safety rather than productivity measurements. Under these conditions, data collection methods by image processing technology have been expanding its applicability gradually on the various construction areas including productivity management.

2.2 Review of relevant image processing technology

Recently the data acquisition methods using image processing technology have been developed to obtain reliable field data from construction job sites with speed and less effort. Jie Gong and Carlos H. Caldas [7] had applied an image processing technology to measure the productivity of concrete pouring buckets by tracing the buckets through the learning its image. They suggested a video interpretation model which was differencing between working and non-working times of construction equipments. This model was operated with the recorded video images beforehand and focused on the concrete pouring buckets.

Throughout the following research study, they suggested a bag-of-video feature words model. This model provided a method for classifying the motions of a back-hoe and the carpenters installing forms [8]. It involves basically three steps as follows: feature detection and representation for recognizing objects, vector quantization for generating a codebook by assorting the features of the recognized object, and differentiation of motions by learning action models. Throughout the data analysis on real-time image frames, this model focused on classifying between working and non-working motions. In the case of this model, the recognition rate showed about 79% for the Back-hoe and 62% for the carpenter. This result implies that human detection is more difficult to recognize.

Tharindu Weerasinghe et al. [9] suggested an AMOTS(Automated Multiple Objects Tracking System) model using the latest technologies such as audio and video surveillance. This model tracks hard hat for recognizing workers, uses different colors of hard hats for classifying workers, and judges what kinds of tools are used and where the working area is based upon the audio sound data. This model required an audio equipment. If any work has no sound or many sounds, then this model may have a problem in recognition.

Peddy [10] suggested a method for recognizing the motions of workers by extracting the silhouette of workers with background modeling and then transforming the silhouette to the shape of born using skeletonizing and neural network approach. This model indicated approximately 80% of accuracy in recognition. This model was not developed with the intention of measuring the productivity of each worker.

The proposed method is based on image process approach with specific worker characteristics and requires relatively cheap computation cost to achieve productivity factors.

3 Detecting and tracking construction workers

In this paper, we suppose that there are three different work groups that we want to measure the man-hours from input video images, and these construction work crews wear differently colored safety vests and safety hats and classified as red team, green team, and blue team.

Initially, since we are interested on moving construction work crews, the proposed method is required to separate the input image into foreground and background region. Thus the BGS algorithm [11] is performed to input video data captured from a camera at work place to create foreground binary image outputs. Then the proposed method keeps tracking the construction work crews from these foreground regions which can be defined as moving fields using specific color information.

Although the moving objects can be not only construction work crews but also various construction related materials, specific color information (red, green, and blue) of vests and hats can provide the critical information to extract construction work crews from foreground regions.

Even though the RGB and HSV color models have been used diversely in the image processing field, we applied YCbCr color model to achieve robust color detection under various lighting effects and surrounding environments. Table 1 shows the range of parameter values to determine the red, green, and blue colors with YCbCr color model.

Table 1: Parameter values to determine the color of work clews

Color	Cb	Cr
Red	32 ∼ 209	159 ∼ 241
Green	86 ∼ 116	94 ∼ 135
Blue	140 ∼ 193	69 ∼ 125

In addition, the distinct features of human body structure are deeply considered to detect construction work crews from foreground areas of images. Usually human body can be divided 8 parts as shown in Fig. 3. Since the height of torso part for human body is 3 times longer than its head part, the proposed algorithm is utilized the height of both parts. To be detected as construction work crews, the estimated height of vest region should be three times longer than its hat region with same color. Also the length of estimated hat region should be two times longer than the length of estimated face and neck region and the estimated face and neck region should be located between estimated hat and vest region. When these conditions are satisfied, the proposed algorithm accepts this region as a construction worker and activates the tracking algorithm for this recognized worker.

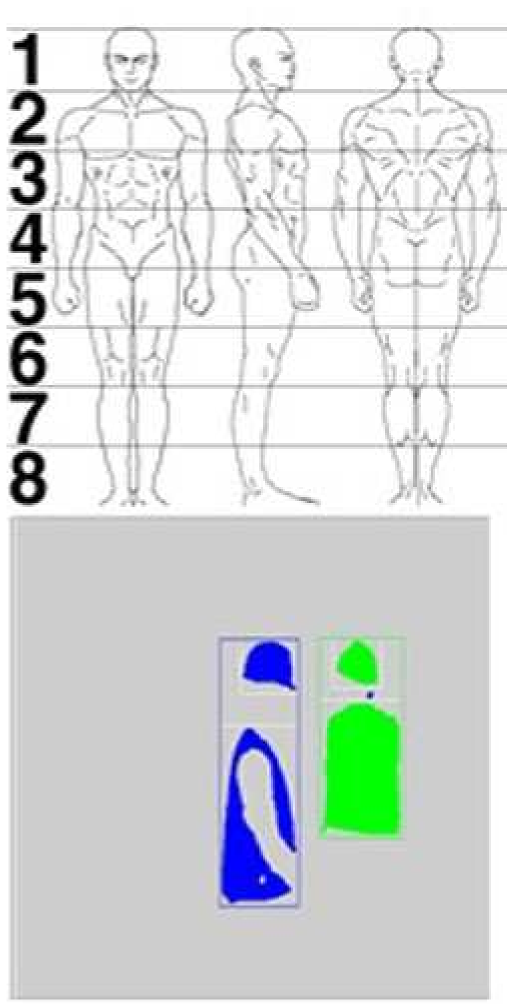

Fig. 3: Detection of construction work crews using characteristics of human body structure

The general circumstances of construction site are extremely complex with workers, construction materials, and equipment. It is not a trivial task to distinguish the collision between construction work crews because there are so many factors can cause the occultation of existing workers. Therefore, the position and moving direction information of estimated as worker regions are stored in the system when the collision between estimated workers or with construction materials for correct worker counting.

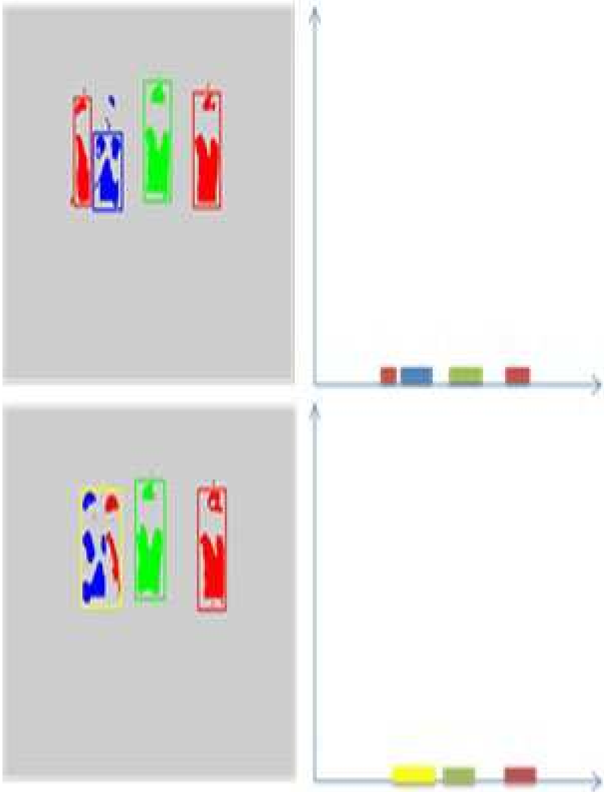

Fig. 4: Collision detection between construction work crews using projection information

The projection information of construction work crew on x-axis is applied to robustly detect the collision between construction workers or construction equipments. Fig.4 depicts the example of collision checking between construction workers. The colored lines on the light side are the position information of construction workers projected on the x-axis to decide the collision and the color of these lines stand for the group of construction workers. When the collision occurs by two different construction workers, the collision region is merged by one yellow rectangular. The algorithm keeps checking not only the collision and separation between construction work crews but also with other construction environments.

The proposed algorithm for detecting and tracking the construction work crews in construction site using the image process approach can be summarized as shown in Fig. 5. It is the way of estimating the man-hours for specific group of construction work crews based on the color of vest and hard hat. Although it requires some computational cost, the proposed method computes the optical flow at each pixel from the input frame image for motion estimation to accurately track the estimated construction workers by extracting directional motion information from the movement sequence [12].

The proposed algorithm only searches the ROI(Region of Interest) which is predicted as moving region of construction workers by BGS algorithm from the whole input image for fast computing. Therefore, the proposed construction worker detection algorithm is performed with both color information and features of human body structure. Since calculation of man-hours for each group is our major goal, we checked the collision between construction workers or equipments by robust projection approach to compensate the counting for overlapped workers.

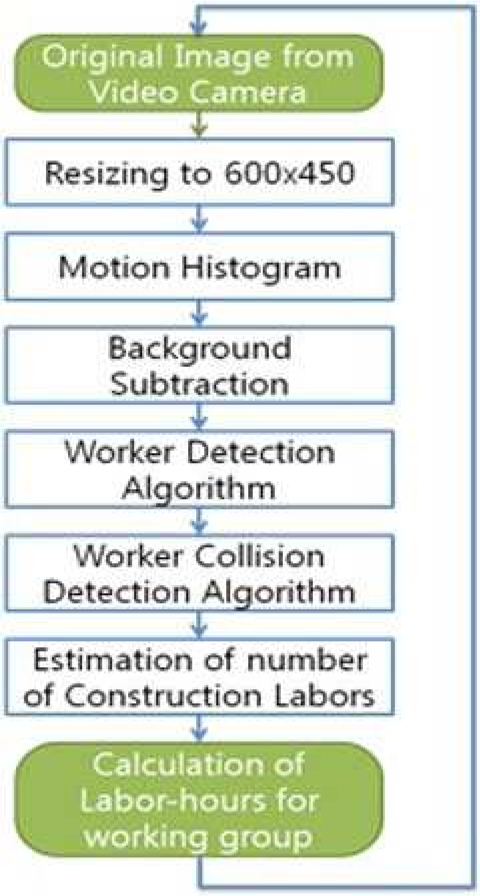

Fig. 5: Algorithm for calculating man-hours for group of construction work crews

4 Case study and results

This chapter shows the results of the case study that measured the man-hours for group of construction workers in various examples. For this purpose, sample test videos were took from inside and outside of our school and actual construction sites under various conditions such as lights, shadows, and obstacles. Some sample images are showed in Fig.6. We defined three different groups with red, green, and blue color to estimate the man-hours for each group.

Fig. 6: Sample image frames of videos for experimental tests

Fig.7 shows the snapshot of implemented system for counting man-hours of construction worker groups. The left top part provides the original frame image from the input video and the right top part shows the binary image which is generated by the BGS algorithm. The white regions are foreground which can be the candidate regions as construction workers. The left bottom part depicts the extracted construction worker with colored group information and the man-hours for group of construction work crews are calculated by this information. The right bottom part provides GUI(Graphic User Interface) to start, pause, and stop the video frames. It shows the calculated number of workers at a given frame and the percentage and man-hours of each group as well.

In this case study, we achieved around 84% of accuracy in recognition rate for counting of working groups man-hours. This result is estimated by a comparison with manually calculated man-hours by an expert construction manager and automatically calculated man-hours by the proposed system.

The RFID based approach can provide relatively detailed information for construction process including

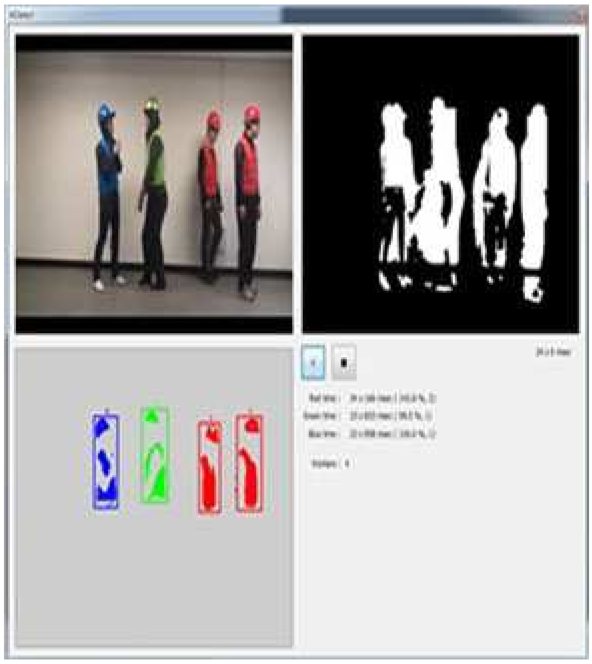

Fig. 7: Implemented system for counting man-hours of each construction worker group

man-hours per each construction workers, but it has some critical limitations such as insufficient recognition rate due to the direction or interference between RFID tags and antennas and cost burden for purchasing sufficient number of RFID tags and antennas. On the other hand, although we lost some detailed personal worker information, image process based approach requires only some cameras and provides reasonable group man-hours readily.

5 Conclusions

An optimized and robust image processing based algorithm was developed to analyze and collect the man-hours of distinctive construction workers automatically from the video images taken on construction job sites. This algorithm extracts the moving and working workers which are on the foreground of current frames using BGS algorithm and using the characteristics of human body structure, recognizes different work crews with the distinctive color of their safety vests and safety hats, and measures the man-hours of each crew as they complete their designed work are done within the designated area.

Achieved recognition rate is around 84% for counting of working groups man-hours under various experimental test environments. In addition, the proposed method only requires video information without any other extra

Table 2: Recognition rate for experimental tests

Region of Input Image	Video No.	Recognition Rate (%)
Inside of School	1	88.4
	2	82.7
Outside of School	3	83.5
	4	87.3
Actual Construction Sites	5	77.3
	6	81.2

expensive apparatuses. These measured man-hours can be used as an essential input data to analyze and control the construction job site productivity.

As a further research, more advanced and fast construction worker detection and tracking algorithm for the real-time monitoring system and various experimental tests for actual construction sites will be performed to verify the strong effect of proposed algorithm.

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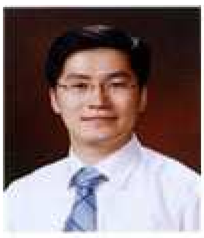

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