Effective Collaboration Research Project On IT Solution For Automatic Measurement Of Timber Assortment

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ABSTRACT

This paper deals with experience about the research project development with industry for the solution of specific problem. Nowadays most of higher educational institutions are particularly interested in implementing joint projects with industry, sharing experiences and resources to jointly develop new technologies and innovative products. In the University of Latvia within the framework of an effective collaboration projects program, a mutually beneficial shared cost system for the needs of scientists and businessmen's is possible for solving the tasks of the both partners. Joint Stock Company "Latvia's State Forests" were interested in development of an automatic volume measurement of logs and wood chip loads on trucks. To solve this problem, a methodology and a technological solution are needed to allow remotely perform volumetric surveys and monitoring. It is significant with the intense development of forest and logging industry. The system consists of measurement arch with video cameras and IT solution - video processing and analysis software, a graphical user interface, data communication channels and storage systems. Video information is obtained from cameras that simultaneously acquire raw data from the object of the video processing area - both sides and top. The information is transmitted to the external systems via data communication channels. The system will be used for automated volume measurement because in Latvia this process is currently performed by persons who manually measure loaded logs or wood chips on the trucks.

Keywords: an effective collaboration project, timber assortment, volume measurement, IT solution, prototype.

1. INTRODUCTION

Collaboration projects between scientists and businessman's can have both a social purpose and a strong commercial purpose. Effective collaboration in the University of Latvia is a process by at least two independent parties to exchange knowledge and technology or to achieve a common goal based on sharing of duties. Involved parties jointly determine the scope of the collaboration project, participate in its implementation and share risks and outcomes. The main aim is to promote collaboration between the University of Latvia and the project partners in order to ensure a high-quality solution to the research and development tasks demanded in the national economics. As also to develop and improve the collaboration skills and culture between the scientists and the project partners, contributing to the implementation of contractual research, research and development activities in the future. In the presented project students, new scientists and PhD candidate who worked under the leadership of senior researchers were involved.

The survey of the implementation experience of the Stanford University research projects with industry highlighted that the success of university/industry collaborations cannot be easily quantified in terms of metrics such as funding amounts. A relatively small project for a company may result in valuable lab experience and employment of students, top-quality publications or a promising new research avenue for university. A small breakthrough today may mean a significant advance in the future, as the research continues [1]. The collaboration research projects in the University of Latvia include the development and testing of new technology products and services for national economics, the involvement of new scientists and students in development processes, technology transfer and transfer of knowledge. Three times in the year a competition for funding projects is announced within the framework of an effective collaboration program where senior researchers can submit an innovative project proposals. Only top-quality project applications are supported by the university, receiving half of the funding from the total project costs. In the first call, only 33% of the total applications were funded, but in 2018 their number has increased to 53%. Not only administrative and quality criteria are evaluated, but the main focus is on the socio-economic contribution of the project and the compliance of the project to the goals of the Development Strategy of the University of Latvia, as well as the choice of the collaboration partner and the potential for further collaboration. An effective collaboration project with Joint Stock Company "Latvia's State Forests" offers a unique opportunity to solve the challenges of both partners' interests. Researchers of the University of Latvia would adapt their technological developments for use in the forestry sector, thus gaining new experience and knowledge to improve competitiveness in the European Science Area, as well as licensing of intellectual property in the open competition. By automating the entire measurement and recording system, industry in the long-term run would reduce costs and increase competitiveness.

Presented research is focused on the measurement of log and wood chips volume loaded on truck by image analysis method. An automated log volume measurement and other techniques accuracy is very important because an amount of industrial wood being produced and transferred to wood working industry for further processing is growing. Till to nowadays the level of accuracy is not high still [2]. West [3], Davis [4], Janak [5], [6] and other authors points out that the most part of techniques used in timber volume measurement are statistical coefficient and manual measurements – scalers use tape and ruler. Mainly the key element in these processes is operator [2]. Several authors highlight that most methods for measuring the volume of round timber are developed more than 60 years ago, for example, piece-by-piece volume measurement, geometric group measurement, weight group measurement, etc. [3], [7], [8], [9]. Should be noted that in articles often are mentioned that even for piece-by-piece manual techniques errors can reach ±10%, but using a measuring tape and a ruler - ±15% as well as that techniques are very time consuming [2], [5], [6].

More and more in different scientific articles authors emphasize that the IT (Information Technology) is developing very fast especially in the last decades and is rapidly entering a wide range of economic areas. IT for forest operations is used by selecting the suitable stand, harvesting operation, forwarding, storage and transport wood. Knowledge of information significantly influences planning, organization, control and duration of forestry works and improves the efficiency and performance of this sector [10], [11]. But data on the volume of timber give basic information for planning and control of production, purchase and sale and groundwork for remuneration, invoicing supplies, accounting and inventories, financing supplies and determining the productivity of stands [12].

It is well known that nowadays the technical equipment such as computers and video cameras, lasers, scanners etc. have become cheaper but personnel costs have increased. The high-tech equipment's available on the market which can help to evaluate wood stacks, log and wood chips volume on trucks measuring methods. For example, in the measuring process of log stack often is used the photogrammetric technique which make this process more accurate, convenient, fast and well documented. It is aimed to eliminate manual measurement from control process and to provide objective and accurate volume estimation [2]. It means that there is a demand for more rational wood measuring methods and it indicates that measurement will be more unmanned in the future [13].

One of the first photographic measuring system for the total volume of a loaded logs on a transport vehicle is described by R.B. Davis in 1990 [4], he used two cameras whose geometric lens characteristics, separation distance and focal lengths were known. Stereo photographs were taken on each end of a load of logs. The photos of a logs are taken at a time when the transport vehicle normally is momentarily stopped. This invention, through the designed placement and orientation of the cameras, captures not only the imagery of the logs, but also the imagery of the delivery truck or train, plus a data display containing other information; such as date, time of day, load number, location, and any other information deemed necessary.

For the precise volume measurement result of loaded logs on truck some authors suggest to pay attention to the accuracy of truck position as well as suitable cameras installation, for example in the scale houses, if it is good equipped with cameras that can record the front of the load as it arrives and the rear as it leaves [14], [15]. Cameras record every transaction that takes place in chronological order and the placement of cameras depend on what information is needed [14]. Different versions of manual and semi manual camera technology estimations of truck loaded pulpwood volume have been evaluated and reported to be efficient in M. Börjegren, 2011[13], the method for volumetric measurement is called the 5:2-method where the weight of the load is used together with experience data and subjectively assessed factors of the actual load from the video stream.

Data on dimensions and shape of logs are also provided by microwave radiation scanners. Systems equipped with scanners are often used in sawmills where information of logs is processed by computers to produce a precise 3D profile of logs, from which its volume can be determined [3], [16]. For measuring the volume of timber load on a truck different laser measuring systems also are used, for example Modus 200, Logmeter 4000 [17], [18], [19]. The measurement was done by laser scanning the periphery of the load from both sides and from above. The truck is driven through the system at a fairly constant and low speed to get as good raw data as possible.

Different algorithms, software's and platforms are developed for processing and analyzing the acquired information and data. Woodtech has developed algorithms to estimate length, diameter, stack volume and solid volume [18]. The program for calculating the volume of round timber "FoRest" is designed to measure the volume and geometric characteristics of logs stacked in pile, to determine the pile volume by one or two images of the pile ends [8]. Mobile platform Timbeter is based on image recognition and machine learning technology to determine the number of logs, volume and diameter of each log [20].

Many authors highlighted that main advantages of the photo analytical method, used in timber assortment volume measurement, are higher accuracy, faster measuring, easier documentation, stock registering opportunity, easy statistical report [15].

The placement of video cameras and lighting, as well as the required dimensions of the arch of the measuring line for its creation in real field conditions were determined using a laboratory prototype. The log and wood chips transport vehicle models, 3D printer, small size video cameras, lights and created reduced size arch were used for system prototype tests.

2. MEASUREMENT LINE PROTOTYPE

The project partner requirement determined to use only video cameras for acquisition the data needed for the process of log and wood chips volume measuring on trucks.

For designing the log and wood chips volume measurement line in field conditions, it is necessary to consider the specifics of its operation and the high requirements for performance its mostly applies to video cameras technical requirements. In order to ensure the maximum continuous operation of the volume measurement line, the influence of various environmental factors such as rain, wind, air temperature, etc. should be taken into account, which could limit the operation of the volume measurement line. For example, in the climatic conditions of Latvia, it is necessary to count on the both cases the high temperature range as well as with the wind that raises dust. The above factors need to be taken into account when evaluating the potentially applicable video cameras for measuring arch. In the case of rain and wind, more precisely wind-driven dust, video cameras should be at least IP55 class, but at least IP66 grade would be desirable. With regard to the performance of video cameras at high and low temperatures, technical equipment must be selected which is capable to operate in the range of at least -10 ° C (15° F) to + 30 ° C (86° F), but it is better to choose equipment with a temperature range of at least -30 ° C (-22° F) to + 50 ° C (122° F) or even wider.

In addition to this resistance to climatic and environmental conditions, the performance of the video cameras is very important. Exiting the desired measurement line solution - passage arc, video cameras must have a sufficiently large viewing angle both vertically and horizontally so that the arch, on which the video cameras are fixed, should not be disproportionately high and wide.

The dimensions of the arch vary depending on the number of video cameras, the position and angle of view of the cameras, and the dimensions of the imported log and wood chips on trucks. Taking into account the known parameters of log and wood chips transport vehicle models the required arches dimensions were determined using the relationships of trigonometric functions (Fig. 1).

Fig.1 Examples of the cameras location detection

To ensure homogeneous operation of the cameras for acquisition the same quality images, it must be positioned against the midpoint of the vertical axis of the sample to be measured. The required dimensions of the arch in field condition were defined by: taking into account that the usable height of the transport vehicle in real life does not exceed 3 m, the angle of view of the cameras used shall be at least 90° and the expressions of trigonometric functions.

By performing camera and lighting tests in laboratory conditions, the obtained raw data from video files were analyzed with video file analysis software to determine the best layout of cameras and lighting location in field conditions as well as the necessary dimensions of the measuring arch. In the tests were used six small cameras that were located at both sides of the log and wood chips transportation vehicle and at the top of measuring arch, see Fig. 2.

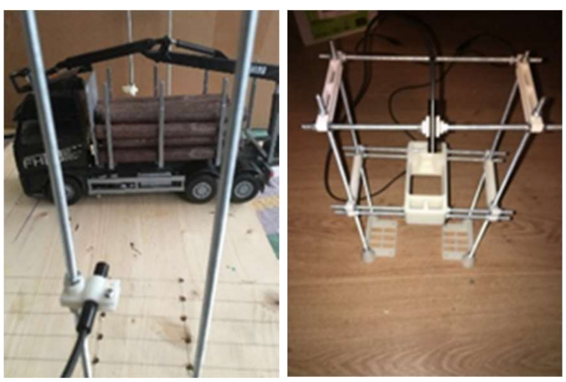

Fig.2. Testing measurement line prototype

3. SETUP FOR RAW DATA ACQUISITION

Technical setup for data acquisition and processing is shown in Fig. 3. Technical equipment for data acquisition consists of:

- 6 video cameras;
- Video storing unit;

Data processing is performed by:

- Video processing unit;
- User PC;

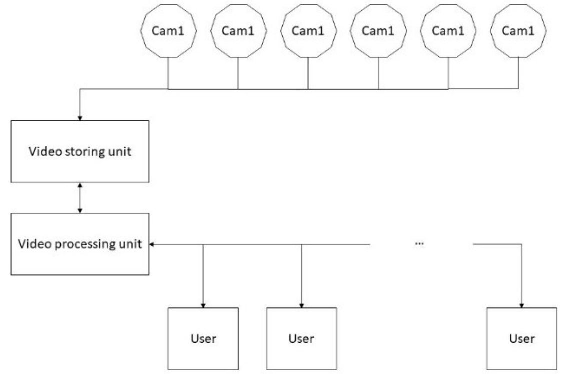

Fig. 3 Technical setup for data acquisition and processing

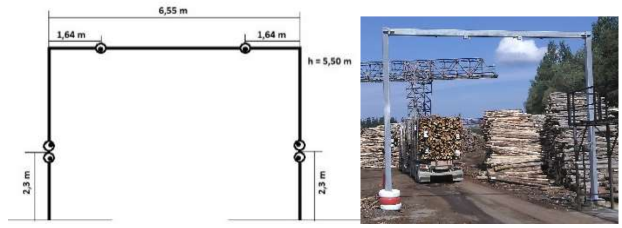

Fig. 4 Installation of cameras project (left), reality (right)

Video cameras are installed as shown in Fig. 4, standard video surveillance cameras are used. Such installation of cameras provides full vision of load on truck from different angles allowing to create a panoramic view of it, see Fig. 5. Video data from all the cameras is transferred to video storing unit via Cat cables. Video recording is initiated by the time stamp of the master camera – camera who first sees the truck. All cameras are synchronized in time which allows to tie up data corresponding to one load. Afterwards data is processed by video processing unit. During the process panoramic images of load is created (detailed description of the process is given in next chapter) and provides the view of load from both sides as shown in Fig. 5. These images are created using data from the side cameras which are installed on the vertical poles of the arch, see Fig. 4 Data from these cameras are also used for creating the images of the middle and rear of load, see Fig. 6.

Images shown in Fig. 5 allows to measure the height and length of load. As well it is possible to measure the diameter of the logs in some cases but obtained results in such case is with poor accuracy.

Images shown in Fig. 6 is for measuring the diameter of logs and width of load.

Fig. 5 Panoramic view of load from right side (up) and left side (down)

Fig. 6 View of load rear (left) and middle (right)

As it can be seen in Fig. 6 there are some problems with possibility to measure the load accurately due to distortions of the images, which in further research and development of the product is planned to eliminate.
Top cameras are used to create a panoramic image of the top of load, see Fig. 7. This image can be used to measure several dimensions of load. Mainly it is used to obtain the length measurements of logs or wood chips box and the width of load. But it is also possible to measure the diameter of logs, but accuracy level is low for such measurements and thus it is not recommended.

Fig. 7 View of load from the top cameras

4. PROCESSING AND ANALYSING OF RAW DATA

Several authors' articles highlighted different algorithms which today are capable of taking overlapping images of the same scene and quickly stitching them together to create panorama. Particular emphasis is placed that moving objects must be especially correctly handled, some authors recommends an invariant feature based approach to fully automatic panoramic image stitching [21], [22], [23], [24].
In the presented case, the raw data is obtained from the cameras which are placed at the angles defined by the prototype. In order to create the panoramic image correctly, the transformation images for each camera must be identified to ensure data processing. The image of the transformation is determined by marking four points in the video. In each of the video images a region of interest (ROI) is allocated, which includes the height of the load of truck and about 2 m in width, see Fig. 8. Selected images should contain overlapping information. In the frame created on the image it is transformed accordingly.

Fig. 8 Allocation of ROI in video images

Additionally, the control position in the image is determined, which determines whether the movement of the truck takes place in the picture. The control position for the area is determined by a normalized histogram, the change of which in the base of the histogram in the previous frames determines the beginning of the movement. The coordinates of the transformation images and the motion detection area coordinates for each video position are defined and fed to the data processing process.
A vector file is created that gather basic information: video frames, pixels, coordinates of transformation, etc.
The aim of the data processing process is to create an image of a loaded truck panorama, see Fig. 5. The panorama creation module which is built into the part of the automatic image processing and analysis software is used for the process of image matching. A truck in the data acquisition area, must move at a constant speed, the image may be distorted if the speed changes.
The movement of the object in the image is determined by the Farneback optical flow analysis algorithm [25], [26]. The displacement of specific selected points in the frames are determined by the algorithm. In the case of data processing, this movement is analyzed for a transformed perspective image, and only the horizontal displacement is taken into account.
In case of homogeneous points, the displacement may not be detected, the points for which the displacement is maximum are determined, however, it falls within the statistical deviation range. In addition to the obtained panoramic image, the direct transfer values are stored in each frame.
Similarly, the wood chips load panoramic images are created.
Data processing process to improve the detection of the location place of the rear of the truck and the front of the trailer in the video frames will be continued.

5. OBTAINING MEASUREMENT RESULTS

Operator caries out the process of geometric measurement of log load volume using GUI. Some screenshots of the GUI are presented in Figure 9. Which allows to measure the height, length and width of the load. As well GUI provides possibility to measure other values of the load, such as diameter of logs (average measurement value is used) and the ratio coefficient of useful volume. Ratio coefficient is defined by inner standards of the project partner. As well it allows to automatically deduct scrapped wood volume from the total volume, display it as percentage of overall volume, show the area of scrapped wood, make measurements in several segments, etc. Process of the measurements is designed in the such way that the average value of the measurements is automatically calculated and displayed to the operator. It means that if the operator will measure the length of the load several times GUI will display the result which is the average value of all the measurements of corresponding dimension. The process of the wood chips load measurements is a little bit different, as there is no so much dimensions to measure in this case, as well there is no necessity to determine the volume of scrapped wood chips.
Volume of the log load is computed by following equation:

$$V = \left(H_{avg} + W_{avg} + L_{avg}\right) \times k_r, \qquad (1)$$

where:

H_{avg} – average value of the load height measurements;
W_{avg} – average value of the load width measurements;
L_{avg} – average value of the load length measurements;
k_r – coefficient of useful volume of the load;

The GUI was developed with the integration of the indicators for the determination of the quality, as well as the easy to operate functionality in the geometric measurement process.

In general, the GUI was developed with the possibility to choose between two types of the loads (logs or wood chips), overall concept of the measurement process in both cases is realized in very similar manner. It was made with purpose to make trainings of the involved stuff easier and logically related. Both types of the measurements have integration of inner measurement standards of the partner for load quality (each of them consists of at least from 20 different quality coefficients which affects the volume of useful load).

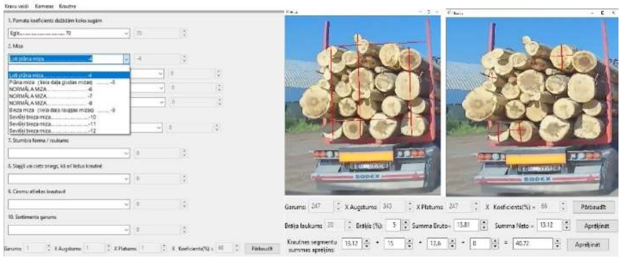

Fig. 9 Graphic User Interface Screenshots

Example of the measurement process of log load is shown in Fig. 10.

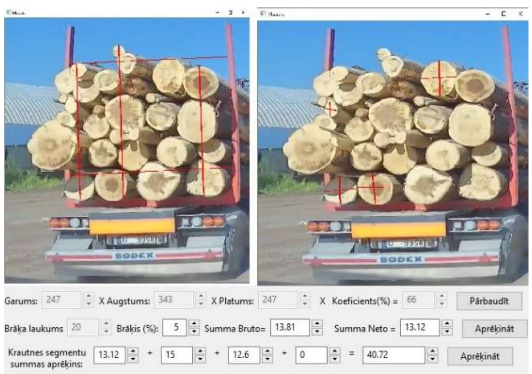

Fig. 10 Example of the geometric measurement process in GUI

In the end of geometric measurements of the load operator exports results of the measurements to .csv data file which is stored in operator's job accounting journal and on master server.

6. RESULTS

At the beginning of the project a laboratory prototype of the timber assortment volume measurement line with cameras and light layout was created. The angles for cameras and lighting were determined, as well as specifications of cameras and lights were defined.

Under laboratory conditions, camera and lighting tests were performed for obtaining raw data for further processing and analysis. Analyzing the obtained images from a prototype, the optimal layout of the video cameras and lighting system, as well as the necessary dimensions of the measuring arch for the outdoor field, were determined.

The laboratory tests had shown that video cameras must to have a sufficiently large viewing angle, both vertically and horizontally, so that the passage arch on which the video cameras will be mounted should not be disproportionately high and wide. Six video cameras are required to provide video information for image processing and analysis.

The tests of prototype showed that the desired angle of the side video cameras must be 45° in relation to the vertical arch axis. To see the both ends of the log truck, two cameras are required on each side, one facing forward, the other facing backwards. In order to obtain a qualitative image for measuring the volume of loaded logs or wood chips on a transport vehicle, top cameras are required, which are rotated 45° towards of the opposite side of the load. The use of two cameras reduce the required arch height and provides better image quality and more accurate results of the measurement.

Such layout of cameras provides the ability to pinpoint the location of the wood chips load salient against the edges of the transport vehicle box, but problems arise due to the low-quality measurement of the middle part of the load. Theoretically, a 3D image can be created with two cameras, from which it is possible to determine precise cubature, but in practice such a solution is very difficult to execute.

Results of an experimental measurements have been compared to in-situ measurements (existing measurement procedure of the project partner). Comparison showed that proposed method and used algorithms are perspective.

Further improvement of raw data acquisition is necessary to meet necessary accuracy level of the measurements defined by the project partner's inner standards. In the current solution the problems with providing a constant movement speed of the truck causes difficulties to create precise panoramic image of the load.

7. CONCLUSIONS

In presented research passage arch was created, it gives impact of non-constant truck movement speed to accuracy of measurements. Using only 6 cameras often rises situation when it is not possible to see all what is necessary for creating panoramic scenes of loads with adequate accuracy. Additional problems were synchronization of cameras, trucks weren't going through the center of the measuring line arch causing different images from each side. Also, variable speed of the trucks led to different count in ROI of the panorama creation algorithm.

To obtain more accurate measurements, it is desirable to irradiate the load from the top with structured light obtained with a grid laser. This results in a grid whose parameters are precisely known. A heterogeneous load relief causes a change in the shape of the grid. When comparing them with the reporting grid, a spatially accurate load of wood chips form is obtained.

In further studies image scaling will be done. Images will be analyzed by automated analyzing software for obtaining the height, length, width of the log truck, as well as log diameter measurements, log load and wood chips load volume on the trucks measurements will be done. Graphical user interface will be further developed and improved. Any additional GUI functionality will be highly appreciated by the potential customers and end-users as well. It is necessary to improve also the algorithms of scaling which are used for creation of panoramic images, as the field tests showed, that accuracy of current solution is subject to be improved. To a large extent this could be resolved by implementing the metric cameras into the current IT solution.

For successful run of the project it is very important that all the involved parties take active part in it.

In presented case project partner carried out all the technical work to build-up the arch and provided all other necessary technical equipment (video cameras and video storing unit) for data acquisition. As well provided consulting at several stages of the project where specific knowledges on the measurement process of the logs and wood chips were necessary.

In the developed solution the processing of the log load images is the subject to be improved as the full process takes approximately 20 minutes.

In future project partner must carry out the improvement of technical infrastructure to grant constant movement speed of the trucks, synchronization process of video cameras, reduce data delay and loss from video cameras.
Image scaling revealed problems with precise panoramic images due to different number of pixels in vertical and horizontal dimension. As the partner's requirement was to use standard video surveillance cameras which caused above mentioned problems the use of metric cameras should be considered in the future.

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