Inspection of empty beer bottles in beer's crates

M. C. BARJAKTAROVIĆ*, S. J. PETRIČEVIĆ
School of Electrical Engineering, University of Belgrade, Belgrade, Serbia

Machine vision system can be used not only for final product checking, but for raw materials verification to reduce production cost. In this paper, method based on laser scanner usage for empty beer bottles inspection before decrating is present. The inspection aim is to detect missing and foreign bottle in beer create at bottling line. The detection of missing bottles before decrating can provide significant saving to the brewery. Another problem is a presence of the foreign bottle that can slow down or even interrupt production. Initial system design shows that both project goals are achieved.

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1. Introduction

Although beer consumption slightly declined in Europe, due to the financial crisis, beer sector is the largest with about 30 % of total beverages turnover [1]. The same states for Serbia and beer will continue to be dominated by lager brands, Serbian consumers are very conservative when it comes to beer and they are loyal customers [2]. For loyalty customer demand goods of the highest quality. The recent technological advances and cost reduction, especially for image acquisition and processing system has led to the implementation of new solutions for machine vision in various industrial fields [3]. By implementing machine vision systems management seeks to ensure a competitive advantages through improvement in productivity and quality [4]. During the last decade, automated inspection became particularly important for inspection in production lines manufacturing steel strips, plastic, fabric, paper, coated board, chip packaging and recently in food and beverages industries, e.g. checking and counting bakery products [5], measuring diameter, thickness profile, and edge defects of pizzas, measure the size and weight of biscuits, inspection label on cans [6], assessment of fruits, vegetables, cheese, noodles, meat [7], bottles inspection systems [8], [9].

Glass bottle filing lines use either single-trip or returnable bottles. In order to reduce cost factor returnable bottles are preferred, with less than 15 % new bottles added, especially in developing countries [10]. With returnable bottles advantages include not only savings in raw materials and their manufacture into a new bottle, but also reduction in the environmental impact since lest solid waste is generated reducing water and air pollution [11].

Based on statistical data of one of the largest Serbian brewery, there is great need for returnable empty beer bottle inspection before decrating. Although returnable bottles suppliers (usually big box stores) claim fulfilment of crates, historical data has shown 2% shortage. At the glance, that seems acceptable, but for bottling line with 65000 bottles per hour and 0.1 euro per returnable bottle, annually significant saving is possible. That resources could be diverted into additional investments to ensure the competitive advantages. Counting returnable bottles must be done before decrating, because suppliers keep records for every crate, but not for single bottle. Additional reason to inspect returnable empty bottles before decrating is foreign bottle detection. In the beer industry wide range of bottle shapes are used, and it possible that bottle used by another company accidentally ends in crate and find its way onto the bottling line. Foreign bottle can cause damage at the filler or just interrupt production process crating additional cost. An industrial bottling line is very complex production line with several nested loops containing many different machines, intermediate conveyor systems and a large number of instrumentation and control equipment. Due to the interdependence of the nested production loops, an interrupt at a single point has domino effect at other parts of bottling line [12] , and detecting the foreign bottle before decrating is highly desirable.

For counting empty bottles and foreign bottles detection, bottleneck could be examined. Although narrow structure of bottlenecks is very challenging for machine vision systems, surprisingly this issue has received little attention in literature [9]. Attention is given to Empty Bottle Inspector (EBI) which inspection bottles after decrating and washing, just before filling. Those system usually examine bottle body and finish. Several approaches are considered: wavelet transform and morphologic methods were used to extract features, followed by fuzzy support vector machine neural network [13], [14]; watershed transform based methods to segment defective regions of bottle wall by rules and the wavelet transform to exact features of bottle finish [8]; a method based on the histogram of edge points provided by derivative algorithm from Canny edge detector after artificial neural network is used for high-level judgment respectively [15]; the Randomized Hough transform accurate positioning of the bottle bottom and Fourier transform compensation influence of the antiskid veins of bottle bottom [16].

Empty bottle inspector importance is also recognized by the largest manufacturers of inspection equipment for beer industries, like Krones, Stratec, KHS, Heuft, KS Control, etc. Aside from bottle body, bottle finish and bottle bottom, standard inspector may include detection of foreign particles in bottles, detection of foreign materials (liquids, gas, foam,…), inspecting returnable containers for caustic residues, etc. Also, there exists a dedicated inspection system, e.g. for inspection of empty crate [17] to determine whether the crate is correct in colour and logo, whether it is damaged or broken and additional system to check if all bottles are present with correct cap [3].

Among producer of dedicated inspection equipment for beer bottling lines, only few have machine vision systems for the analysis of empty bottles before decrating. KHS GmbH offers empty bottle crate inspector which utilise ultrasound measurement and a camera system. Several features are checked in order to detect foreign bottles and avoid reduction in line efficiency if increase of foreign bottles proportions is detected [18]. Similar system is on offer by Heuft (named LX) and E2M (VISIOCRATES). Although those systems have great inspection performance, they demand lot of space and installation in considered Serbian brewery requires great amount of customisation, which increases initially huge cost of the system.

The brewery concluded that checking crates with empty bottle has great impact on efficiency of a filling line, in order to save money and avoid problems at the unpacking process. Decrating is performed with gripper and manipulation with the foreign bottle can cause its fracture if that bottle is shorter than expected bottle height more than 5 mm. To fulfil those requirements brewery opted for highly customized but affordable solution which is presented in this paper.

To achieve project goals, laser scanner is selected. With the development of laser technology, laser scanners can be used in an industrial environment and they have the scanning speed several hundred times faster than point measuring devices. Additionally, with laser-scanning technology it is possible to perform a 100% inspection of very complex shape parts [19]. Laser scanning system for non-destructive weld quality inspection was reported [20]. The measurement is based on the laser triangulation and geometrical features of the weld are obtained. Similar principle is used for analysing characteristics of whipped cream [21] and dozens examples can be found in almost every industrial filed - automotive: brake pad defect detection, tyre DOT reading, gap measurement on car bodies, position stitching on airbags; food and beverage: cookies (volume control), identify improper filled candy boxes, verify cap height and skew, meat patty Inspection; consumer electronics: PCB components inspection, device housing (thickness, flattens, etc.); traffic: railway tracks inspection, quality assurance for railway sleepers, etc. [22], [23].

In this article, the method for bottles counting and foreign bottles detection in beer crates prior to decrating is proposed. The method uses laser scanner and it is based on fact that bottles height is different among different beer producers. In section 2, method and experimental setup is described. Result are presented and discussed in section 3, and section 4 is conclusion.

2. Method

Laser scanning is standard machine vision method for acquiring 3D map of inspected object. Laser line is projected on object surface and reflected light is used to measure height. For obtaining a 3D map it is necessary to provide relative motion between inspected object and projected light profile. Principles of the laser scanning is based on the Scheimplung condition [24], which is shown on Fig. 1.

Laser beam is expanded by cylindrical lens and projected onto the target of unknown height h. After reflecting, the light beam reaches CCD at point y. By using basic trigonometry it can be written:

$$\frac{d + y\sin\beta}{a - h\sin\alpha} = \frac{y\cos\beta}{h\cos\alpha} \tag{1}$$

According to thin lens equation:

$$\frac{1}{a} + \frac{1}{d} = \frac{1}{f} \tag{2}$$

From previous two equations object height can be derived from image point y:

$$h = \frac{d \cdot f \cdot y}{(d - f)\left[d\sin\alpha + y\sin(\alpha + \beta)\right]} \tag{3}$$

Although it is possible to measure bottle height using industrial camera and appropriate lighting, laser scanning should provide more accurate results with bottle which finishing is soiled with mud or grout. With laser scanner, reflected light has enough intensity for accurate detection of bottle finishing, which is not the case for industrial camera where algorithm strongly relies on reflected light pattern.

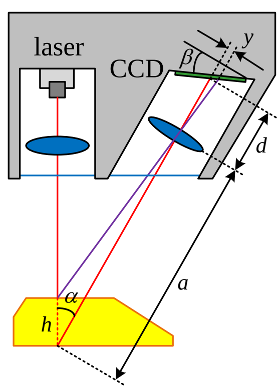


Fig. 1. Height measuring principle for the laser scanner setup

Laser scanner from Micro-Epsilon, model scan Control 2910-50 is used for initial testing and concept proof. This model can provide up to 300 lines per second with maximal measuring width of 50 mm with 640 data points which can be expanded to 1280, using interpolation. Unfortunately, maximum scanning speed is achievable only when field of view for camera is reduced, which in not possible for this application, because the goal is not only to count target bottles but to identify foreign or missing ones, too. The difference between the highest and the lowest bottle height is about 4 cm, and when the crate's rim is included measurement range extends to 5 cm and covers almost full field of view.

The bottling line has maximum speed 0.8 m/s and bottle finishing is not less than 25 mm. For full field of view, maximal scanning speed is about 145 Hz, which defines profile spacing Δy:

$$\Delta y = 0.8 \text{ m/s} \cdot \frac{1}{145 \text{ Hz}} \approx 5.52 \text{ mm} \tag{4}$$

The minimal number of profile $p_{\min}$ for the smallest bottle finishing ($D_{\min}$ = 25 mm) is:

$$p_{\min} = \left\lfloor \frac{D_{\min}}{\Delta y} \right\rfloor = 4 \tag{5}$$

The difference between two points in horizontal direction Δx is:

$$\Delta x = \frac{50 \text{ mm}}{640} \approx 78 \text{ µm} \tag{6}$$

The thickness of finishing wall is d = 5.5 mm which gives around $n_{\min}$ point for each side of finishing:

$$n_{\min} = \frac{d}{\Delta x} = \frac{5.5 \text{ mm}}{78 \text{ µm}} = 70 \tag{7}$$

For the correct identification of missing and foreign bottles, calculated number of profiles and number of point should be sufficient. The bottle finishing along with stated quantities are shown in Fig. 2a, while Fig. 2c presents one acquired profile.

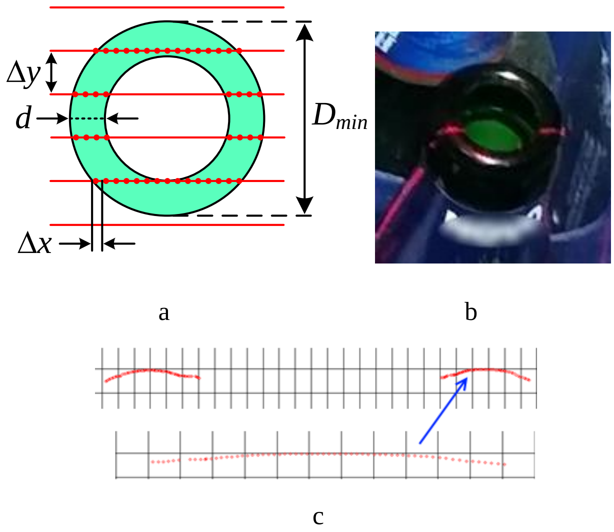


Fig. 2. a) Profiles spacing and horizontal resolution at bottle finishing. c) Laser line at bottle finishing. b) One acquired profile

Experimental setup is shown of Fig. 3. The laser scanner is positioned 120 mm above the finishing of the lowest bottle found in the brewery. The purpose of this setup is to test the concept for bottles counting and foreign bottles detection in beer crates. For that reason one scanner is used. The laser scanner is places on bottling line in the brewery. Testing on the factory floor should also reveal problems with vibrations, if they exist.

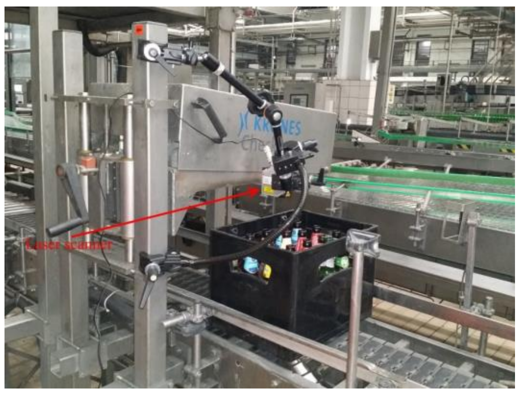


Fig. 3. Experimental setup at bottling line

The laser scanner offers several modes of operation, but in this case it is possible to choose among two of them. The first is continuous acquiring of profiles and sending data to PC. The start and the end of beer crate are detected using light switch. Only profiles between those two signals are relevant for current beer crate. The second mode of operation sends container with previously defined number of profiles and acquisition of the container start when crate's arrival is detected. When the container mode is used, the scanner sends all information together as image (or more precisely as 3D map) so algorithm can be executed without interruption. This makes the second mode a better choice.

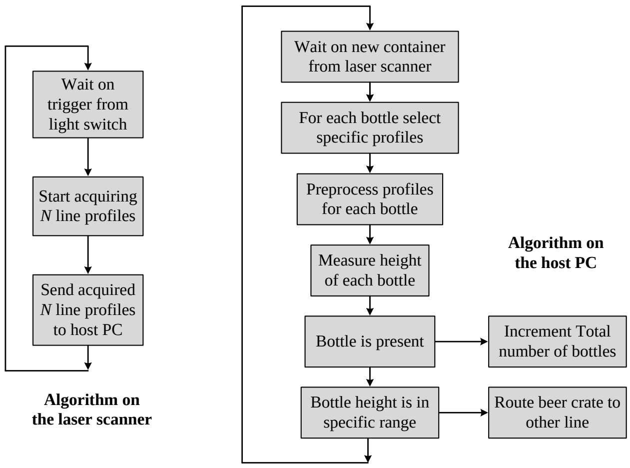


Fig. 4. Algorithms on the laser scanner and host PC

Fig. 4 shows the algorithms briefly. Scanning starts after detecting crate presence with light switch (Diffuse sensor HRTR 3B from Leuze is used). When N profiles are acquired, the scanner sends container using Ethernet connecting to host PC. Number of profiles depends on the current line production speed. All creates have the same dimension and positions of bottles finishing's are known in advance. For each of 4 bottles (there are 20 bottles in each create, placed in 5 columns and 4 rows), only profiles with specific order number are used. For example, for 0.8 m/s line speed, profiles number for the first bottle in row are 6 to 13, for the second 20 to 27, for the third 34 to 41 and for the forth 48 to 55. From each profile only point with defined y coordinates are selected, and histogram of z coordinates (the height measurements) is created, Fig. 5.

Average value of measurement in interval with maximal number of measurement represents the height of current bottle. If obtained value is outside specific interval, inspected crate is routed to the other line. If bottle is missing (very few valid z measurements) total number of bottles is not increment.

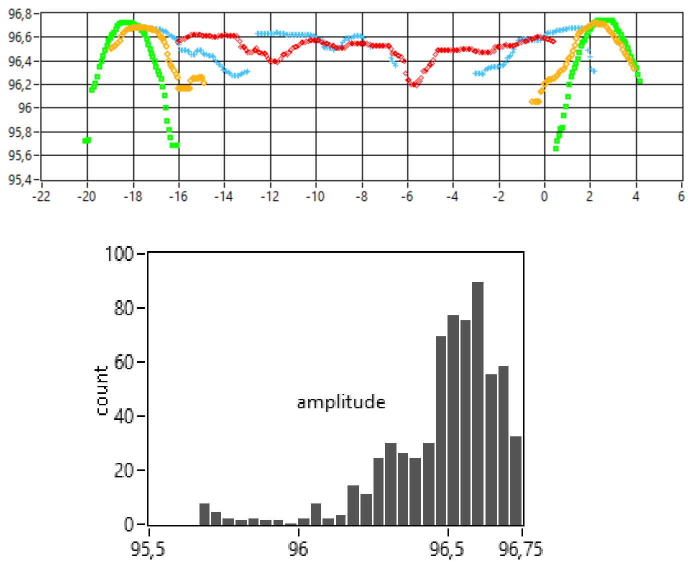


Fig. 5. Profiles for one bottle finishing and corresponding histogram z values

The pre-processing includes three steps. The first step is applying median filter to each profile to remove impulse noise which manifests as isolated point in profile, Fig. 6.

The impulse noise has origin in vibration induced accidental reflection from flat glass surface.

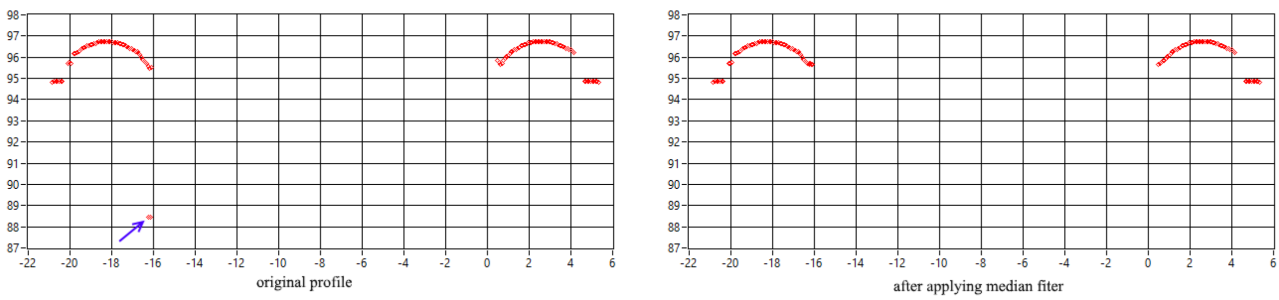


Fig. 6. Profile before and after applying median filter

Conveyor belt has surface which is not ideally flat, and sometimes the current beer crate is little tilted. This manifest as linear trend in each profile for the current beer crate. Fortunately the first 3 to 4 profiles and the final 3 to 4 contain height of the crate's rim and this profiles can be used as offset for tilt compensation as in Fig. 7.

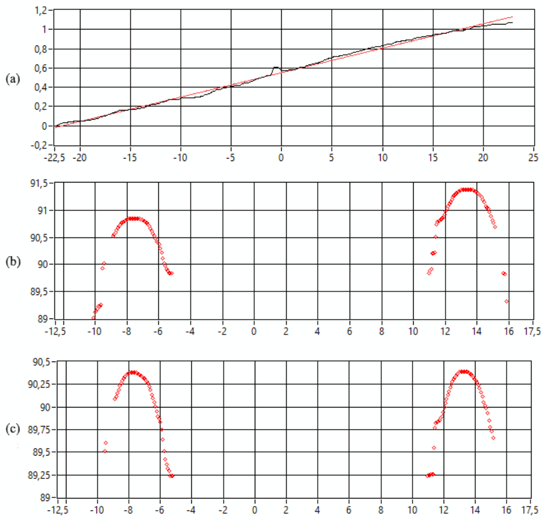


Fig. 7. (a) Offset profile. (b) Original profile and (c) profile of bottle finishing after tilt compensation

The third step is compensation of beer crate rotation on conveyor belt. The rotation cause misalignment of bottle finishing center in same row, Fig. 8a). For algorithm testing centroid of mass is used for compensation of this misalignment shown in Fig. 8b). Final solution will use five scanners and whole crate rim would be scanned at once. Lateral rim positon would give scrolling amount for every profile.

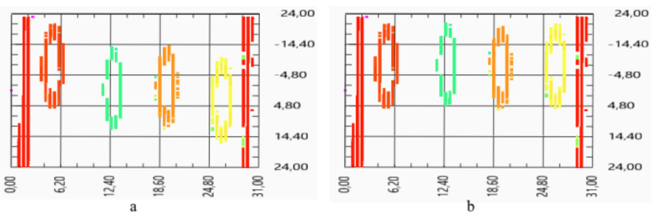


Fig. 8. Profiles for one beer crate a) before and b) after misalignment compensation

3. Results

For concept verification several tests are performed. The first experiment confirmed missing bottle detection and results are shown in Fig. 9. If an absence of height measurement is detected, algorithm shouldn't increase bottle counter.

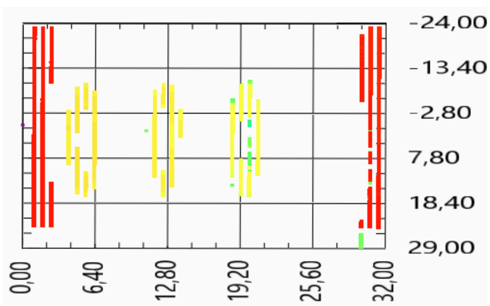


Fig. 9. 3D map for crate with one missing bottle

Next test was conducted with four bottles from different brands. Those 4 bottles are visually distinguishable by height, Fig. 10.

Fig. 10. Beer bottles from different brands used in second test

After applying previously described algorithm following results are obtained: 86.55 mm, 79.83 mm, 76.06 mm and 73.08 mm for the bottles shown in Fig. 10.

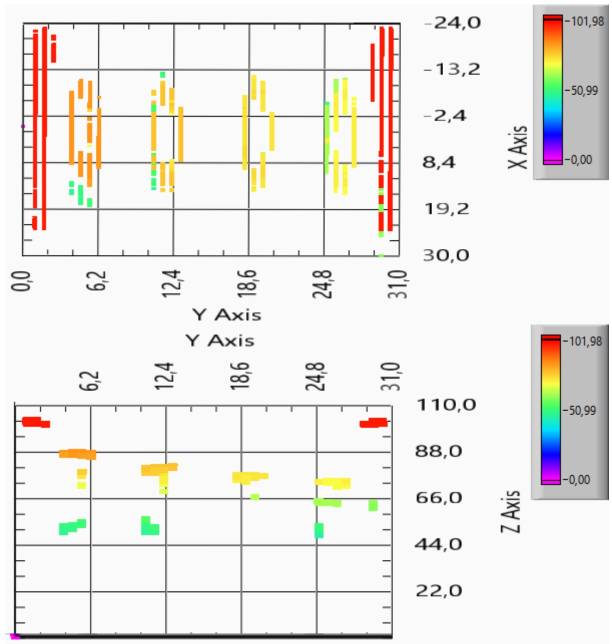
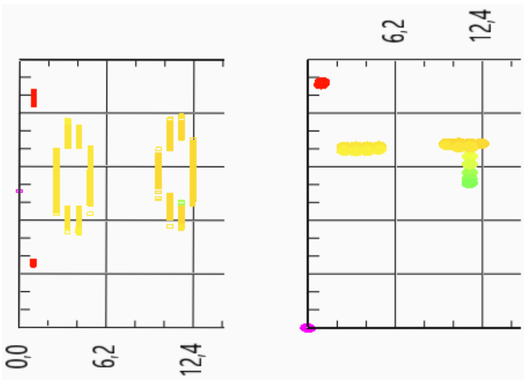


Fig. 11. Measurement data for bottles shown in Fig. 10. Left – view from above, right – side view

Using measurement data it's possible to detect foreign bottle in the crate, Fig. 11, when differences in height is more than 3 mm.

Final test was with bottles with almost identical height, about 1.5 mm, Fig. 12a.

a



b

Fig. 12. a) Two bottles from different brand with almost same height. b) 3D map for bottles in figure a).

Several identical tests were conducted, and minimal measurement difference was 1.13 mm. Although it seems that it is possible to discern those two bottles, standard deviation of height measurement is 0.63 mm and there is probability to miss foreign bottle. Fortunately, this difference in height does not produce problems with bottles manipulation, as previously stated.

4. Conclusion

In this paper, method for inspection of empty beer bottles in beer crates are presented. The proposed algorithm is capable of detecting missing bottles and to report to management how many returnable bottles are missing. Using this data, there is room for some savings, which can be invested in additional cost reduction.

Also, the algorithm can discover foreign bottle presence if the difference in height between expected and measured value is not less than 3 mm, which is almost half than the project goal. Although it's possible to distinguish even smaller differences, this cannot be guaranteed due to some vibration of the bottling line.

The proposed method is based on laser scanner usage. Commercial laser scanners are very robust device, but with very high prices. To cover full width of the bottling line, 5 scanner are needed. To reduce cost, instead of using commercial laser scanner, standard machine vision camera and industrial line projector (laser with cylindrical lens) can be used [25]. This is topic for future work. Recently, industrial machine vision camera which can provide 750 fps (frames per second) are available and with VGA resolution (same as sensor in commercial laser scanner). An initial test was conducted using AVX (Advanced Vector Extensions) instruction set [26]. For extracting profile from one full image 0.1 ms is needed and processing is not a bottleneck. One limitation is the frame rate of the camera. With more than 5 times more profiles per bottle, finishing height measurement would be more accurate. Further research would be the construction of mounts for cameras and laser, designing calibration method for height measurement and testing in industrial environment.

References

[1] European Competitiveness and Sustainable Industrial Policy ECSIP Consortium, "The competitive position of the European food and drink industry", Rotterdam, Netherlands, 2016.
[2] Euromonitor International, "Beer in Serbia – Country report", 2016.
[3] M. Campos, M. Ferreira, T. Martins, C. Santos, IECON 2010 – 36th Annual Conference on IEEE Industrial Electronics Society, Glendale, Arizona, USA, 2010.
[4] R. Santiago-Montero, G. S. Valadéz, H. Sossab, D. A. G. Hernándeza, M. Ornerlas-Rodrígueza, J. Optoelectron. Adv. M. **17**(5-6), 713(2015).
[5] Vision System Design Magazine **22**(1), 9(2017).
[6] A. Wilson, Vision System Design Magazine **17**(6), Vision Software Blends into Food Processing (2012).
[7] K. K Patel, A. Kar, S. N. Jha, M. A. Khan, J. Food, Sci. Tech. **49**(2), 123 (2012).
[8] H. Liu, Y. Wang, F. Duan, International Journal of Computer, Electrical, Automation, Control and Information Engineering **2**(8), 2682 (2008).
[9] M. Carrasco, L. Pizarro, D. Mery, Int. J. Comp. Integ. M. **23**(10), 925 (2010).
[10] P. Ghose, P. Nair, International Journal of Agriculture and Food Science Technology **4**(5), 421 (2013).
[11] J. Fisher, P. Horton, Resour. Policy **5**(4), 279 (1979).
[12] D. Troupis, S. Manesis, N. T. Koussoulas, T. Chronopoulos, Industry Applications Conference, 13th IAS Annual Meeting, Orlando, Florida, USA, 1995.
[13] H. Liu, Frontiers of Electrical and Electronic Engineering in China **5**(4), 430 (2010).
[14] H. Liu, F. Duan, Y. Wang, Proceedings of the 6th World Congress on Intelligent Control and Automation, pp. 9739-9743, Dalian, China, 2006.
[15] F. Duan, Y. Wang, H. Liu, W. Tan, Proceedings of 2004 International Conference on Machine Learning and Cybernetics, Shanghai, China 3845 (2004).

[16] B. Huang, S. Ma, Y. Lv, H. Zhang, C. Li, H. Wang, Telkomnika **11**(10), 5571 (2013).
[17] JLIVision, Inspect **8**(3), 55 (2017).
[18] KHS GmbH, "Innocheck LGKI empty bottle crate inspector", Dortmund, Germany, 2012.
[19] H. L. Kwan, P. Hyunpung, Robot Cim-Int. Manuf. **16**(4), 201 (2000).
[20] W. Huang, R. Kovacevic, Sensors **11**(1), 506 (2011).
[21] P. Liu, M. O. Balaban, J. Food. Sci. **80**(4), 750 (2015).
[22] Micro-Epsilon, "Applications for 2D/3D Laser scanners", Dorfbach, Germany.
[23] Cognex, "3D Laser Displacement Sensor Applications", Natick, Massachusetts, United States, 2016.
[24] J. Beyerer, F. P. León, C. Frese, "Machine Vision: Automated Visual Inspection: Theory Practice and Applications", Springer-Verlag, Berlin Heidelberg, Germany, 255, 2015.
[25] Y. Li, J. Zhou, F. Huang, L. Liu, Sensors **17**(4), 814 (2017).
[26] C. Lomont, "Introduction to Intel® Advanced Vector Extensions", White Paper by Intel, May, 2011.

*Corresponding author: mbarjaktarovic@etf.bg.ac.rs