AUXILIARY DEVICE FOR ACCURATE MEASUREMENT BY THE SMARTVISION SYSTEM

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The article deals with the design of equipment for accurate measurement or checking linear dimensions using a smart vision system. Commercial smart vision systems can not accurately measure large linear dimensions because the precision of the camera sensor decreases with distance from measured object. The main benefit of the proposed solution is the possibility of continuous measuring in production lines with high precision even for very long dimensions.

KEYWORDS

automation, vision systems, measuring

1 INTRODUCTIONTO MEASURING VISION SYSTEMS

Image processing vision systems can be used in automated production processes for inspection, guidance, identification, measurement, tracking and counting, in many diverse industries. Vision systems may effectively replace human inspection in demanding cases such as nuclear industry, chemical industry, etc. In most cases, industrial automation systems are designed to inspect only known objects at fixed positions, characterized defects of faulty items and take actions for reporting and correcting these faults and replacing or removing defective parts from the production line [Davies 2012], [Duchon 2014]. Vision systems used for measuring are very limited by resolution of captured image. Thenowadayssmart vision systems uselow resolution usually 320x240 or 640x480 pixels.On the other hand precision of measurement highly depends on used resolution mainly in smart vision systems[Cognex 2016], [Sick 2016].

2 PRINCIPLE OF MEASURING

Measurement of larger dimensions by smart vision system is currently solved by moving the measured product and grabsequence of frames which are combined to one picture. This process is time consuming and usable only for checking linear dimensions on the conveyor belt. For mass production with small measuring delay for one piece is unusable.

The proposed auxiliary measuring system is suitable for use in conveyor systems and for engineering preparation, where must be rapid and accurate measurement oflarge sizes partsin mass production. The hardware of the device consists of two separate parts:split the image into two measurement areas and marking of the measurement edge byline red laser.Dividing the image into two separate fields is realized by four mirrors. The captured image from the sensor is divided into two equal parts set by the mirror edge. Fig. 1 shows the principle of dividing the image into two sensor arrays images with four sloping mirrors.

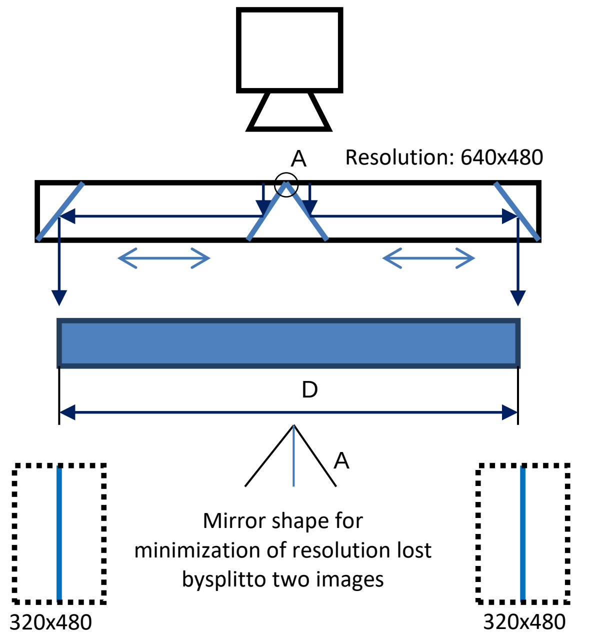


Figure 1. The principle of measurement of larger linear dimensions by vision systems

Camera lens have some angle of view and with increasing distance of sensor from captured object field of view also increases. We need for measuring very small field of view for both edges, because accuracy depends onit.The experiments usestandard CSMount (M12) lens holder with a focal length 25 mm, view of angle is only 9°.The next problem which we need to solve is how to find out place where we measure in one line on both image sections.This problem is solved byline laserprojected on the measured par surface. Laser device is placed at an angle, because the height of the part of the move laser beam projected to conveyor surface. Thisprinciple uniquely identifies edges of measured components. Laser beamprojected to the measured part provides information if measurement is perpendicular to edge of the part. If the reference laser is not perpendicular to the edge, it is possible to perform correction of measurement. The flat parts with a profile smaller than 5mm cannot use the identification of the edge by laser. The principle of the edge localization by laser beam is shown in Fig. 2.

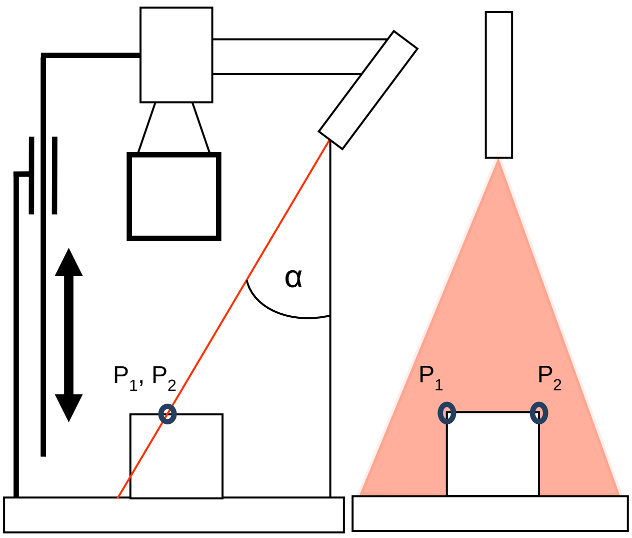


Figure 2. Principles for identification of measured edges of the article

Identificationofmeasured edges by laser provides several advantages:

- change in ambient light has no or minimal effect to reliable edge detection, because measured feature emit own high intensity light,
- distortion in edge measurementcaused by shadows from height of the partare completely eliminated,
- deviation caused by part rotation during measuring can beidentified from laser perpendicular to edge and corrected after calculation.

2.1 *Comparison With Standard Solution*

For comparison of measuringaccuracy by smart camera system and introduced new principle we will create initial assumption that measuring component has length 300 mm. A comparison of both principles isshown in Fig. 5 a), b).

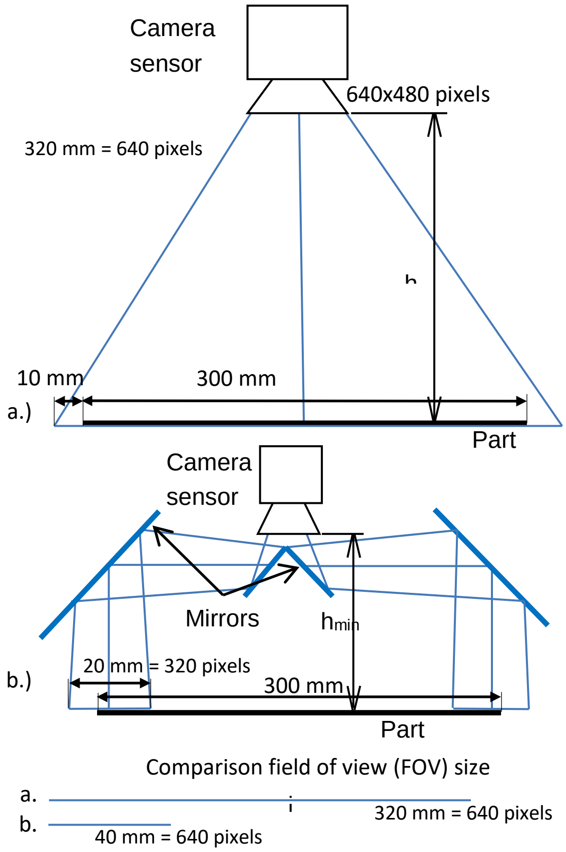


Figure 3. Comparison of measurement accuracy by standard approach and presented solution

Fig. 3a represent current principle of part measuring (320mm= 640 pixels), Fig. 3b introduces new approach for measuring long parts by vision systems. New approach decrease size of Field of View (FOV) significantly 40mm= 640pixels).For example, when we measurelength300 mm with 10 mm edges and image size 640x480 the accuracy of up to 0.5 mmcan be achieved. The example of proposed solutions has several times higher accuracy because field of view is only40 mm and calculatedprecision is 0.0625 mm. With next downsizing camera viewing angle theaccuracy of measuring could be improved with suchdevice. The accuracy for this example can be calculated from the equation:

$$\partial = \frac{d}{pix} \tag{1}$$

where: *d* – field of view size in millimetres [mm],
pix – the number of pixels a camera sensor [pixel].

New approach allowsminimizing camera height (h_{min}) from measuring objects and improving precision of measurements.

3 IMPLEMENTATION AND EXPERIMENTS

Proposed measuring system can be integrated to automated production lines with conveyor. Embedded board is used as a smart vision system with USB camera, whichprocess captured data and transforms them to measured dimension. The parts with dimensions out of tolerance can be signalized to PLC which control production line. Scheme of integration introduced device to production process is shown in Fig. 4.

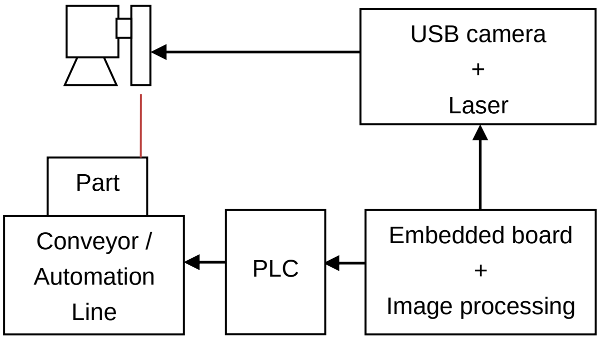


Figure 4. Scheme of implementation to production lines

Instead of used embedded board with camera acommercial smart vision systemcan be used [Belachir 2009] with measuring function with combination of auxiliary device.

3.1 *Example Of Measured Parts*

The testexperiment measurements were realized in surfaces of aluminium casting. The measurements principle we can use for any other parts with height 1mm and more.The sample objectused for length measurement is shown in the Fig. 5.

Figure 5. Tested aluminium casting

The places for measured dimensions are signed by red rectangles on the picture above.

3.2 *First Experiments*

The first primary experiment of image transfer was carried out with precision mirrors used in laser interferometer measurement system. It was tested only one branch with a camera with minimum viewing angle through two mirrors. Laser tag has been transmitted through the second mirror directly to the measured part. The experiment and result of capture image are shown in the Fig. 6.

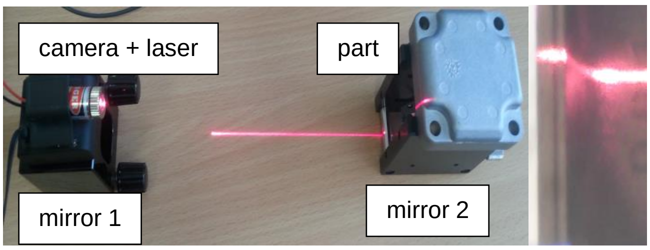
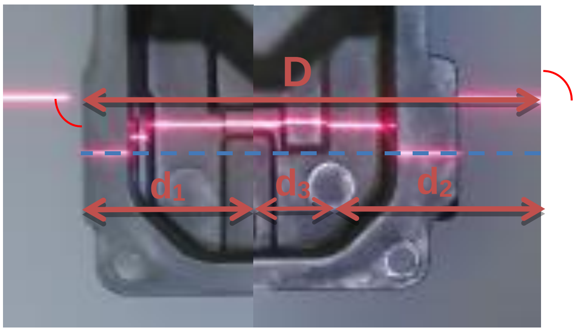


Figure 6. Experimentof image transmissionthrough mirrorsandwith laser line marker

Experiment with both sides of parts was performed on the larger casting.The final dimension consists of three dimension combination (d_1, d_2, d_3). Dimension d_3 is set by physical device, d_2, d_3 are calculated by transformation of pixel to mm. Fig. 7 a), b) shows a combined imagewith laser marker. It is necessary to check if the angle of the laser beam is perpendicular with respect to the measured edge.



a) left side of partb) right side of the part

Figure 7. Both sides measuring of a product by vision system

3.3 Image Processing Algorithm

Principle of algorithm for measuring dimension by auxiliary device is shown in Fig. 8.

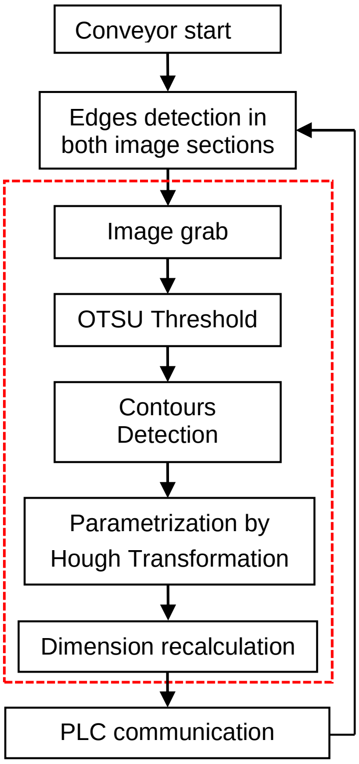


Figure 8. Flowchart of proposed algorithm

The algorithm for edge parameterization of part consists of the following four steps:

- image capture,
- thresholding by Otsu algorithm [Otsu 1979], [Sezgin 2004], [Yazid 2013](Fig. 9),
- dilatation edge detection for precise Hough transformation[Canny 1986] (Figure 10a),
- Hough transform for parameterization of line segments [Jeppe 2011](Fig. 10b),
- Pixel transformation to dimension in metrics units.

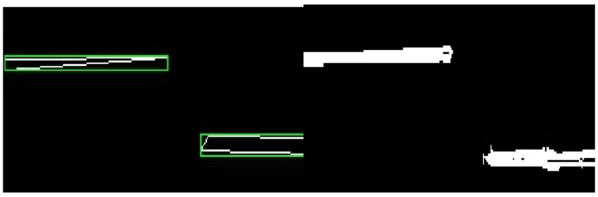


Figure 9. Image thresholdingto acquire laser marker only

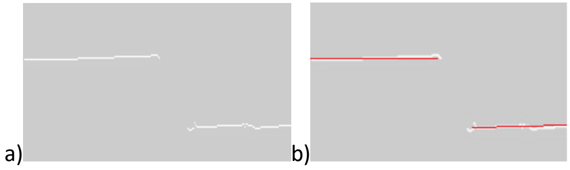


Figure 10. Hough line transformation (b) after dilatation of laser markerarea (a)

4 FUNCTION MODEL OF DEVICE

Embedded system PI Orange Lite with external USB camera was used for image processing. The default resolution of camerais 640x480 pixels. We use open source library OpenCV (C++ implementation) for image processing [OpenCv 2016]. The used vision system isshown in Fig. 11.

Figure 11. Embedded vision system used for image processing

3D model of the auxiliary image splitting device is showninFig. 12. We need to ensure the same distance for both end mirrors from the middle. This problem is solved by screw with trapezoidal thread, which guarantees the same light path from the camera to themeasured component side.

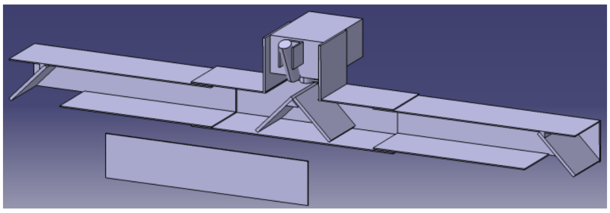


Figure 12. 3D model of measuring device

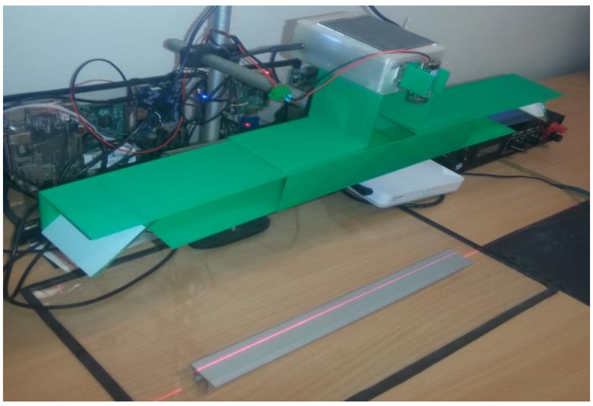


Figure 13. Stand for precise measuring

The comparison of measuring accuracy with standard camera and proposed solution by auxiliary deviceaccording to image sensor resolution is show in Table 1.

Camera resolution [Resolution/Mpix]	Accuracy with standardapproach [mm]FOV 520 mm	Accuracy with auxiliary device [mm]FOV 40 mm
320x240 / 0,07	1,62	0,12
640x480 / 0,3	0,81	0,0625
1024x800 / 0,8	0,50	0,039

Table 1. Comparison of measuring accuracy for part with length 500 mm according toresolution density

The measuring accuracy improvements are approximately 10 times better like standard approach. The comparison of measuring precision with standard camera with resolution of 320x240 and proposed solution by auxiliary deviceaccording to dimension of measured part is show in Table 2.

Measured distance [mm]	Accuracy with standard approach [mm]*12 mm angle 41°*	Accuracy with auxiliary device [mm]*50 mm angle 9°*
300 + 20	1	0,6
500 +20	1,62	0,75
900 +20	2,87	0,87

Table 2. Comparison of measuring accuracy based on part size

The accuracy with increasing measured lengthusing standard methods rapidly decreases. Measuring precision by using auxiliary device declines moderate only.The presented values were calculated from construction dimensions of device and resolution of camera sensor.

5 CONCLUSIONS

The paper introducedan auxiliary device forvision system for precise measurements. The device canmeasure large linear dimensions and is suitable for integrationto the production lines. The presented solution eliminates the maindisadvantage of vision system in small measuring accuracy for oversized parts.The system can measure with higher accuracy with a low resolution image sensor. The proposed method can relatively easy reach 2 or more times better measurement accuracy, which depends on viewing angle of used sensor. The next increase of measurement accuracy can be achieved byusingtelecentric lens or digital microscope instead of standard camera sensor. The further works will focus on measurement system with only two mirrors and subsequent correction for oversized parts with dimensions larger than 1 m.Defective parts can be removed from production process by industrial robot [Janos 2011].

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