DESIGN OF ADJUSTABLE SMART VISION SYSTEM BASED ON ARTIFICIAL MUSCLE ACTUATORS

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The paper describes a proposal of positional adjustable camera system based on artificial muscles for rapidly changing products with different height and sizes on a conveyor belt. Measuring accuracy by camera system is heavily dependent on the distance of the camera system from the captured part. The ideal situation is that component occupying a largest area of the processed image. Current positioning technologies on the principle of ball screws with an electric motor do not reach sufficient speed to dynamically adjust the position of the camera system. Traditional technologies significantly increase the risk of vibration of the whole structure in the repeated resizing captured parts. Artificial muscles due to its flexibility significantly reduce the risk of vibration and noise of designed mechanism. The proposed smart camera system can be used to measure the dimensions or fault finding on manufactured parts in automated lines.

KEYWORDS

image processing, artificial muscles, segmentation, automation

1 INTRODUCTION TO IMAGE PROCESSING

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].

At present, the development of computational performance in embedded systems allows parallel image processing with advanced search for systematic errors by using clustering and machine learning classification algorithms. This data can then be used to identify the causes of these errors as well as continuous monitoring of product quality [Licev 2014].

The main problem in image processing in production system is problematics setup for different parts in size or various height. If we have part with different size the precission of recognition and next measuring is not stable becouse of resolution of camera is fixed. Different height of inspected parts needs change focus on top surface and industrial camera had fixed focus. These problems can be solved by movable mechanismus which change in very fast interval camera possion according actual part on conveyor belt [Zidek 2013], [Duchon 2014].

2 ARTIFICIAL MUSCLE ACTUATOR

Pneumatics air muscles were invented for orthotics in the 1950s. They have the advantages of being lightweight, easy to fabricate, are self limiting (have a maximum contraction) and have load-length curves similar to human muscle. The so-called McKibben artificial muscle is one of the most efficient and currently one of the most widely used fluidic artificial muscles, due to the simplicity of its design, combining ease of implementation and analogous behavior with skeletal muscles. Its working principle is very simple: The circumferential stress of a pressurized inner tube is transformed into an axial contraction force by means of a double-helix braided sheath whose geometry corresponds to a network of identical pantographs. Positioning mechanisms with artificial muscles was designed in these articles [Tondu 2012], [Hosovsky 2012].

3 INPUT PARTS FOR INSPECTION

This article describes automated methodology suitable for systematic error identification in mass production based on embedded vision system in conveyor system. The methodology verification was realized in surfaces of alluminium alloy casting where defects can be created during production of after careless manipulation. Examples of parts with different height are shown in the Fig. 1.

Figure 1. Tested casting with different height

The defects which we want to recognize real-time on conveyor system are shown on the Fig. 2.

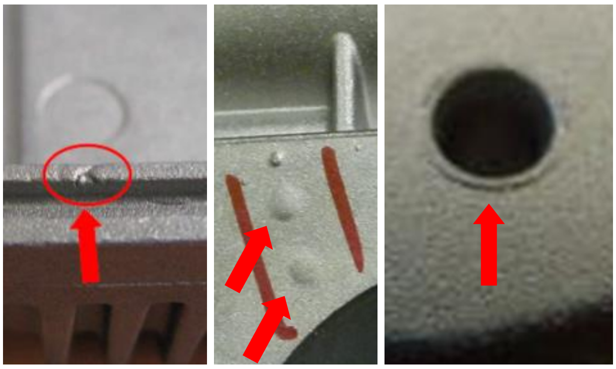

Figure 2. Tested casting with different height

We can identify production part defects, which can divided to two groups:

- defects created by wrong manipulation with parts after moulding,
- defects created during moulding,

Typical defect created during manipulation are: scratches, damaged edges and functional surface.

Typical defect created during moulding process can be: missing material in casting edges, blisters, excess material for example in holes.

3.1 CONSTRUCTION

Constructions of adjustable smart vision system consist from these main parts:

- conveyor with DC motor,
- embedded board control system with driver,
- construction of position module based on artificial muscle,
- vision system with red laser marker for image processing,
- source of compressed air with terminal for pressure changing,

Conveyor with DC motor provides testing system for part detection in area view during production process.
Embedded board control system coordinates all devices: air pressure, start of image processing, movements of conveyor.
Positioning module dynamically change position of vision system for best focus to recognized surface.
Vision system grab image and provides laser marker information.
Source of compressed air with terminal and control signal provides regulated air pressure for artificial muscle actuator for fast vertical movements.

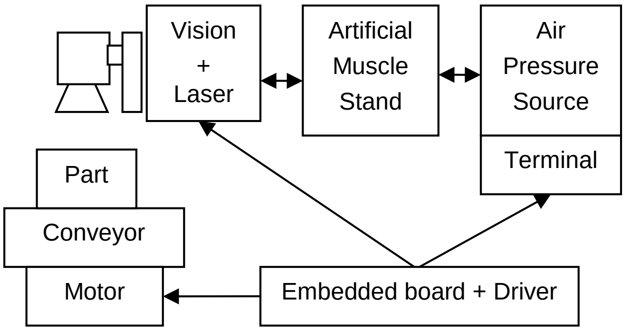

Figure 3. Tested casting with different height

3.2 3D MODEL

3D model of construction was created in 3D design software CATIA. The spatial model of designed construction with artificial muscle actuator and control and vision system and is shown on Fig. 3. Construction consists of: Main holder (1), artificial muscle (2), pneumatic spring (3), slide bearing (4). Other design is published [Wang 2016].

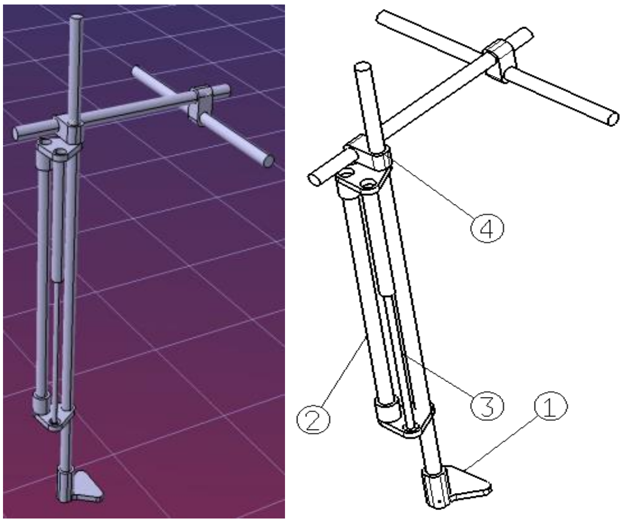

Figure 4. 3D Model of construction in CATIA software

3.3 PROTOTYPE STAND

The beams of construction are from aluminium alloy rods combined with standardized parts for production lines. The artificial muscle provides movements for camera system down during pressure increasing. Pneumatics damper provides stroke during reducing the pressure in the artificial muscle.

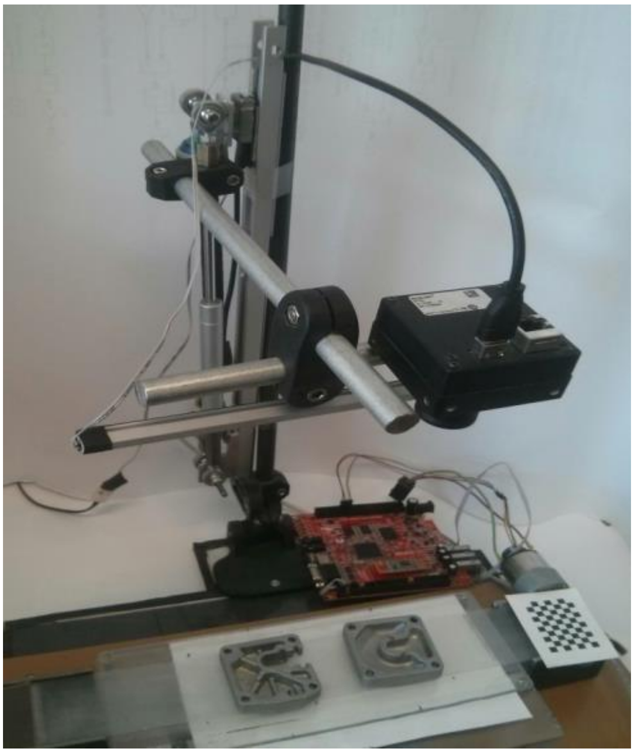

Figure 5. Tested casting with different height

The detailed view to designed vertical positioning system with artificial muscle is shown on Fig. 6.

Figure 6. Tested casting with different height

4 VISION SYSTEM HARDWARE

For image processing were used embedded boards with different performance (processors, ram) for testing of computational power for part fail identification.

Figure 7. Embedded board prototype stend

Basic filters necessary for inspection tasks are: blur, thresholding, countour detection [Zhou 2016] and line approximation [Jiang 1999], [Li 1998]. This set of filters was tested for every platform, see Table 1.

Table 1. Table with description of selected embedded board

Tested embedded board	Basic parameters	Delay of filters [ms]
Raspberry PI	800Mhz/512MB RAM	123/ 9FPS
Raspberry PI2	900Mhz/1GB RAM	93 / 11FPS
Raspberry PI3	1.2Ghz/1GB RAM	47/ 20FPS

Best performance provides according expectation Rpi 3 version, but performance in comparison with other system is not so significant.

5 VISION SYSTEM SOFTWARE

The new trends in image processing systems are smart vision devices, compact device with image acquisition and image processing integrated in one device. The problem of usability these system is low flexibility to implementation of new filters by users. These devices are closed source and it is denied manipulation with software. The software solution provides usually standard set of filters. These disadvantages were basic proposals for design of our software solution for easy implementation of new filters and algorithms.

5.1 Main Monitor Of Image Processing Systems

The used software consists of two applications both cloud based, primarily developed for embedded system. Currently we can compare performance of image processing for 8 embedded systems with ARM processor to 3 desktop PC devices. The main application checks status of all camera systems on the networks in 30 seconds interval. For every device is acquired actual image and network status.

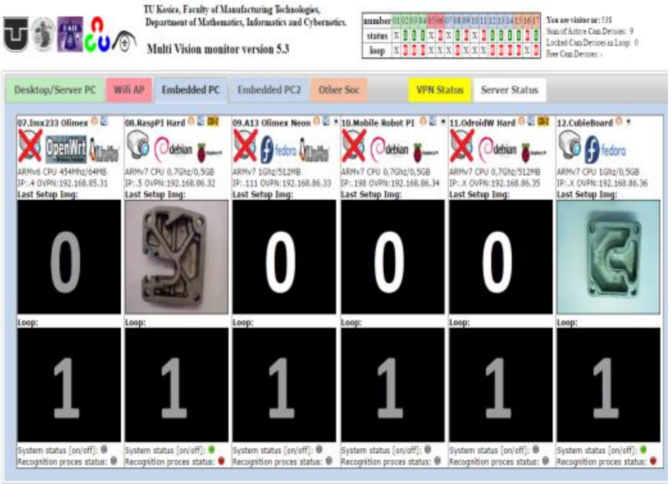

Figure 8. Principle scheme of part height calculation

All devices are connected on OpenVPN network and monitor length of run and actual data bandwidth.

5.2 Cloud Image Processing

Application for setup of image processing is based on web GUI interface (PHP, AJAX, HTML5). All tasks for image manipulation are processed by C++ with help of vision library OpenCV especially compiled for adequate ARM version processor. Set of devices contains these devices: Raspberry PI B, B+, 2, 3, Odroid C1, W, Cubie Board 1, Orange PI, PC, One.

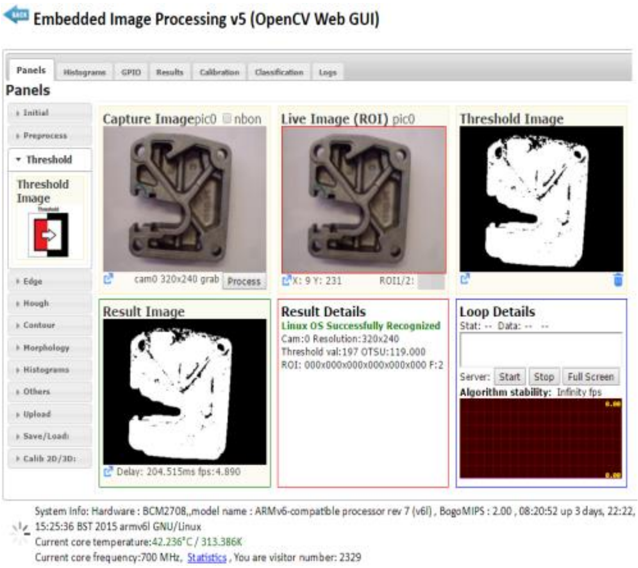

Figure 9. Program for image processing

Recognition program for image processing is web based application and all filters can be inserted to recognition process by drag and drop functions and setup parameters separately.

6 ALGORITHM PRINCIPLE

Principle setup of laser marker for industrial camera system is shown on the Figure 10. Some development in this area was conducted in [Wu 2014].

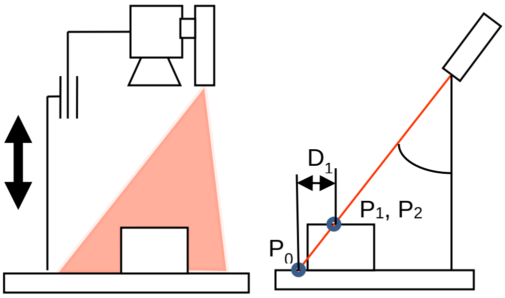

Figure 10. Principle scheme of part height calculation

The algorithm of consist of these steps:

1. Acquire image with casting product and laser line marker,
2. Threshold for isolation of 3 laser lines from complex image,
3. Calculation height of part, movement of camera system by artificial muscle.

Example of part with laser line marker is shown on Fig. 11.

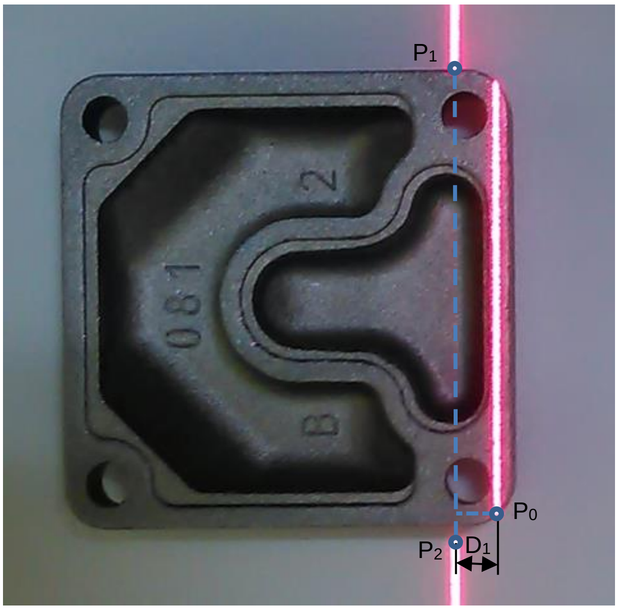

Figure 11. Angled Laser projection for height acquring

Other inspected parts with different size and height are shown on the Figure 12

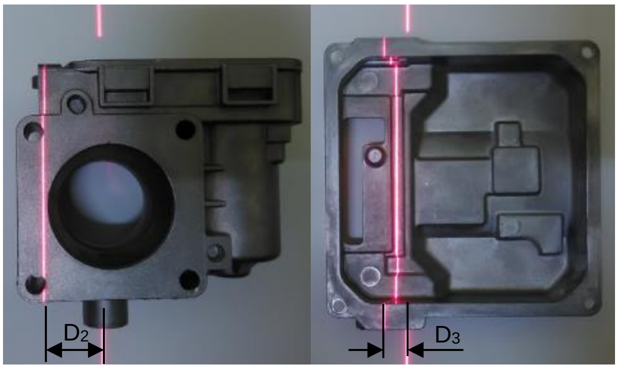

Figure 12. Other parts with different height and laser marker

We must eliminate other lines from image by thresholding based on interval selection.

Scheme image for acquiring distance is shown on Fig. 13.

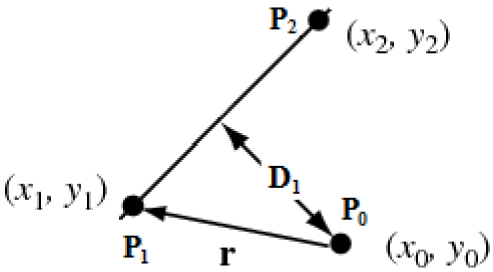

Figure 13. Other parts with different height

The equations (1) for acquiring actual height of part are calculated from distance of line and endpoint of laser marker.

$$D_1 = \frac{|(x_2 - x_1)\cdot(x_1 - x_0)|}{|x_2 - x_1|} \tag{1}$$

where - D_1 is distance represented height of inspected part,

- x_0, x_1, x_2 are coordinates of points P_0, P_1, P_2.

7 IMAGE PROCESSING BY DEVICE

Flowchart described visually algorithm of image processing is shown on Fig. 12.

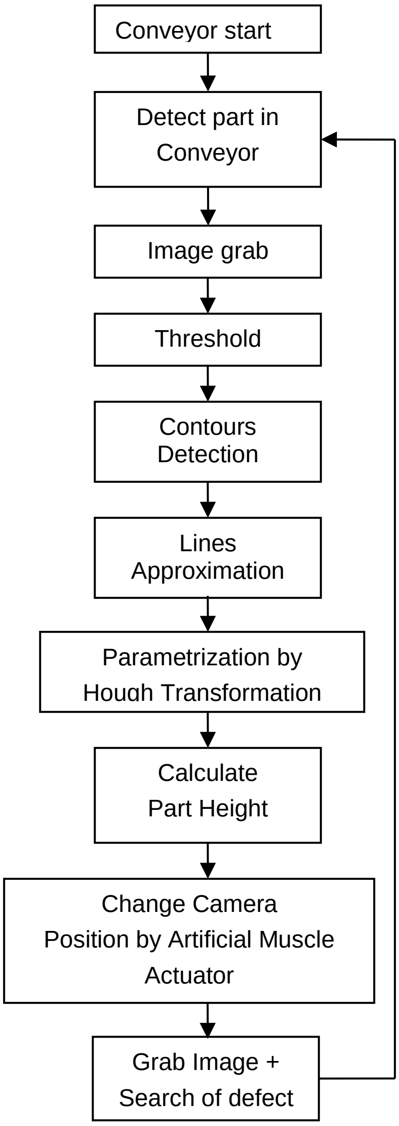

Figure 14. Flowchart of image processing algorithm

Examples of acquisition laser markers for calculation of object height are shown on Fig. 15. The image processing extract laser line markers by range threshold according red color. The lines are then converted to array of points. The contour detector separating all line objects. For parameterization it is necessary to erode points array with later approximation all lines described by two points [Hossu 2008].

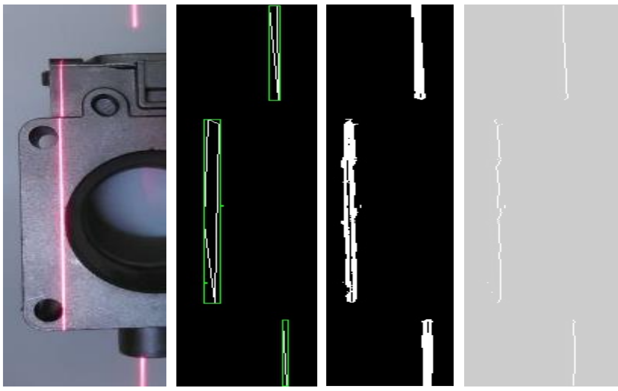

Figure 15. Image processing to height of part calculation

8 CONCLUSION

The article present new approach to detect defect on the production parts with different height by vision system in conveyor system. This idea uses artificial muscle actuator because provides dynamic response and damping for fast vertical movement of vision system. Height of parts is acquired by line laser and triangulation algorithm processed by image recognition. The height of part can vary on conveyor belt during production without complicate setup of vision system, because introduced solution provides automatized position to ideal field of view to surface of inspected production part. We can achieve precision 0,1 mm with resolution 640x480 by determining height of the inspected part.

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