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APPROACHES FOR THE 3D CAMERA SYSTEM IMAGE PROCESSING AT AUTOMATED WORKPLACES

Urgency of the research. *It is important to point out the application possibilities of the 3D camera system at the automated workplaces. At the same time, we want to provide an overview of the principles of 2D and 3D image processing.*

Target setting. *Purpose of the article is to give some form of instruction on correct approach of visioning that can be applied at the automated workplace.*

Actual scientific researches and issues analysis. *Currently, there are already many innovative and user-friendly 3D and 2D camera solutions. Due to its prices, it is necessary to realize a well-priced solution that can be affordable for the smallest companies.*

Uninvestigated parts of general matters defining. *The manufacturer's dealing with the image processing and vision system as a whole, provides an expensive an (obviously) closed solution of image processing without any adjusting. Therefore, we consider it is necessary to address at this issue.*

The research objective. *The aim of article is to provide the price-affordable solution based on the two CCD cameras that will be implemented at automated workplace.*

The statement of basic materials. *For realization of such cheaper solution is good to have a suitable example how to solve image processing and data collection based on process adjusting.*

Conclusions. *Published article presents the price-affordable solution that can be applied at the automated workplace. Presented article provides a closer view to some image processing solution regarding the target object capturing that are not often and sufficient described by manufacturers.*

Keywords: *vision system; camera; automated workplace.*

Fig.: 2. References: 12.

Introduction. Existing classical approaches and techniques for the determination of some necessary sensing object characteristic did not meet the relevant customer needs [1]. Existing classical approaches and techniques for determination of the some necessary sensing object characteristic did not meet relevant needs of the material engineering and end customers, as a whole. 3D vision sensor as the main representative of vision systems is an important device for the automated manufacturing workplaces for enlargement of its peripheral abilities and possibilities in the sense of industry 4.0 concept. Currently ongoing research and the development in this area is focused on the determining the parameters of a 3D model based on at least two image signal sensors (cameras), from which it is possible to the subsequently compile the necessary process data of the scanned object. Beside this, in all technological processes can be a situation when the non-oriented objects are at the workplace output, the standard workplace program process cannot be used and the palette deployment are nonsystematic [2].

In such (and similar) cases, it is suitable to determine the properties of objects that are stored on the pallet by the CCD camera usage. Standard industrial CCD camera are sensing and transmit the recorded image by its interface such as Camera Link or IEEE 1394, into the connected PC or into the next advanced systems for image processing. This obtained images are subsequently evaluated with regards to the necessary information extraction of the relevant scanned object. In addition, the intelligent cameras still more and more supports the material engineering and simplified it, because the image analyzing are realized directly inside the camera system. Their core is usually equipped by the processor that is responsible for whole algorithm set needed for sensing. Image sensor which is used inside the intelligent cameras are in basic a high quality CCD sensor that are able to sense a monochromatic pictures in necessary resolution with the sufficient speed (60 per sec). It can produce a sharp image that lead to the increasing of algorithms precision such as "edge detection" and "pattern recognition". Such intelligent vision system (camera) can be useful in order to the provide a faithful information about the sensing objects followed by the data sending directly to the control system of robotic arm with the requirement to correct object gripping [3].

The ratio between the prices of visual system versus its achieved qualitative contribution in the technology manufacturing gradually stabilized into a form of innovative and nonconventional solution based on the higher processors for data flow processing and the image information with higher computing power. Therefore, it can be stated that the vision systems are nowadays considered as a standard device at almost every bigger manufacturing workplaces [4]. In addition, where it is necessary to implement a total check of the individual object (TQM) are the vision systems right thing for their irreplaceable ability. Their most often usage is in the object quality check with respect to their parameters, see Fig. 1. Obviously, object quality check is realized via comparison of its shapes and geometric characteristics with etalon. This necessary information is stored inside the vision system before its calibration.

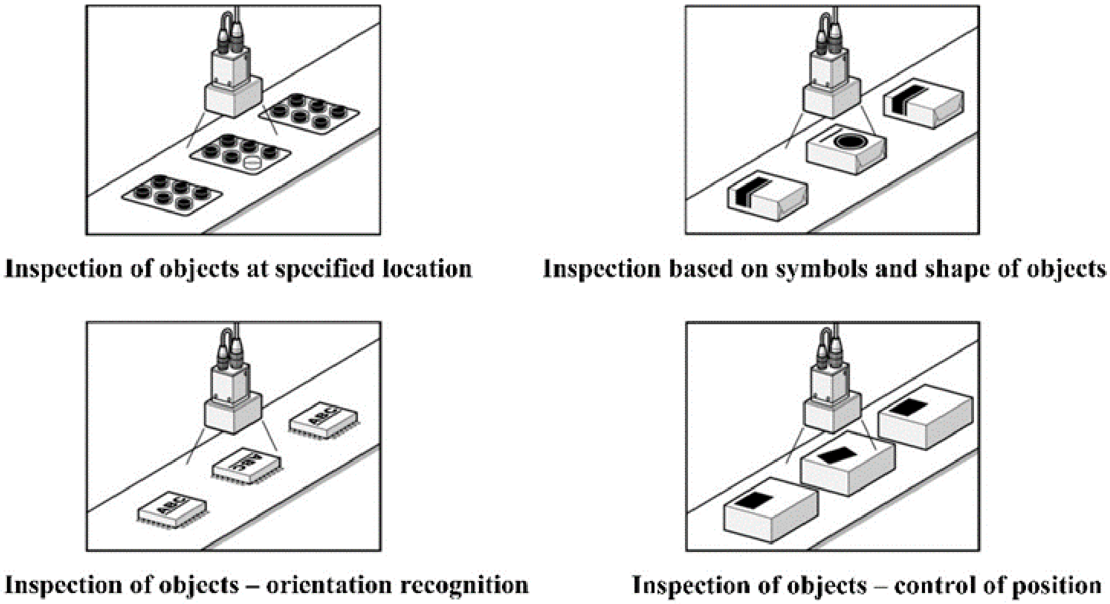

Fig. 1. Examples of vision system usage

Approaches of the image processing. In general, current approaches for solving of the image processing at vision systems are focused on the positions determination for the individual object parameters followed by the pairing of obtained results [5]. Subsequently, based on this information we can determine a geometric imagination about sensing object together with its parameters [6]. Next step suppose a reference plane translation at any distance in the horizontal direction „*x*“ and simultaneously realizing of a measurement at this place with the determination of relevant value for the translation (in pixels). By further calculations can be determine a precise distance from the CCD sensor and the sensing object. One condition for this process is the immobilization of both coordinate axis „*x* and „*z*“. Basic geometrical principle of 3D vision systems leads at least on two CCD camera sensors that are mounted side by side. Object that is under the these cameras will be scanned and digitizing, together with the fulfilling of the requirement that suppose intersection of object capture directions, while its axes are parallel [7]. CCD camera sensor distance from the target (object) is later possible determine as a ratio between the distance of these sensors „*b*” and distance from its reference plane „*r*” to the absolute value between the measured translation „*a* and „*c*”, so:

$$Z = \frac{(b \times r)}{|a-c|}, \tag{1}$$

where b – Distance between the camera1 and camera 2; r – Distance between the reference and visual plane; a – Measured displacement of camera1; c – Measured displacement of camera2.

We also take into the account a following properties that are relevant during the image processing:

- Resolution of the obtained picture.
- Number of the pictures per second.
- Information stability about the picture intensity and colour.

2D camera system usage approach. With this type of visioning is needed the initial calibration of both camera systems in such way that were successfully obtain a necessary information about the sensing objects. It is possible to reach by the setting of CCD camera internal parameters (calibration matrix, distortion coefficient) together with the external parameters (mutual position and orientation of the CCD cameras). Epipolar geometry (geometry that are focused at the relationships of the sensing pictures of both CCD cameras) helping for evaluation of 3D points that can are estimated from the information about the points position at both CCD cameras [8]. So, we can say that during our determination of searched point m = [*x´, y´, 1*] from obtained picture followed equation is applied:

$$m = P \times M. \tag{2}$$

While point „*m*" can be considered as picture of point „*M*" in the plane of projection (therefore, in the plane of sensing area in a way that can be captured by the camera system). Projection matrix dimension „*P*" has value 3x4 and describe an relationship between the real point and the captured are point:

$$P = K \times [I, 0]. \tag{3}$$

While, dimension calibration matrix „*K*" has value 3x3 and describe the environment coordinates to the camera system coordinates, squared unit matrix is „*I*", 3x3 is dimension and „*0*" is zero column.

$$K = \begin{bmatrix} a_x & c & t_x \\ 0 & a_y & t_y \\ 0 & 0 & 1 \end{bmatrix}, \tag{4}$$

where *a* – Direction scaling in axes „*x*" and „*y*" with relationship to vision system; *t* – Intersection of vision plane and optical axis; *c* – Distortion parameter (usually = *0*).

Projection matrix „*P*" can be in general different from the higher written representation about the value of translation and orientation to the coordinate system. Based on this assume is added a transformation matrix for the camera system coordinate to the environment system:

$$P = K \times [I, 0] \times \begin{bmatrix} R & RC' \\ 0 & 1 \end{bmatrix} \tag{5}$$

While,

R – Matrix with the dimension 3x3 that describes the rotation.

C´ - Vector of translation regarding to the environment system.

In a such way is needed to determine the relationship that for point „*m*" from first captured picture allocate point „*m´*" from the second captured picture. For both these points we assume a followed fundamental matrix „*F*" with dimension 3x3, while:

$$m'^T \times F \times m = 0. \tag{6}$$

Also, we suppose that one of projection matrix will be situated directly at the beginning of coordinate system, so any translation and rotation cannot be created – the sufficient solution consists of determination for the second projection matrix from the second CCD camera system in the following form:

$$W = \begin{bmatrix} 0 & -1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix}. \tag{7}$$

Projection matrices must be tested in the any point and select the correct one, it means – the point must lay before both CCD camera systems. Subsequently, by the linear method for the triangulation is possible to realize coordinate of points - and that way can be determined the linear equations:

$$\begin{bmatrix} xp^{3T} & -p^{1T} \\ yp^{3T} & -p^{2T} \\ x'p'^{3T} & -p'^{1T} \\ y'p'^{3T} & -p'^{2T} \end{bmatrix} \tag{8}$$

Basically, for the 3D position of sensing object lay key factor in the captured picture transformation in a way of each individual paired points has the same „y“ coordinate. After that is just to locate the corresponding point in the corresponding row for the second CCD camera. Obviously, it is recommended that the pre - processing followed by standard processing of captured picture is needed (negative properties removing) [9].

3D camera system usage approach. This type of the visioning with single 3D camera system consists of captured picture transformation and decomposition in a way that can be stated an individual parameters and properties of the sensing object. [10]. Information which were captured by this principle serves for the determination and calculation of the 3D points. Based on this can be evaluated the dimensions, thickness, position and orientation of the sensing object. Any distortions that may occurred from the CCD camera system lens together with the picture deformation can be removed by correction and measurement of the distorted pictures followed by its repairing. Correction are evaluated with the help of calibration. Thanks to the geometric dependence between the sensing object, CCD camera system and by the comparison with CAD model is possible determine sensing object position and orientation [11].

Setup of the vision system. Setup of vision system are focused to the interconnection with help of the available communication protocols and interfaces so that will ensure a reliable communication between the control system of robotic arm and the vision system. Existing communication interfaces are created based on the connectivity and the topology as *Ethernet*, *RS232, RS485, RS422, CAN-bus*, and *PROFIBUS*. From the software point of view, is for robotic arm necessary libraries presence together with the reliable functions for the communication (*with the vision system*) inside their control system.

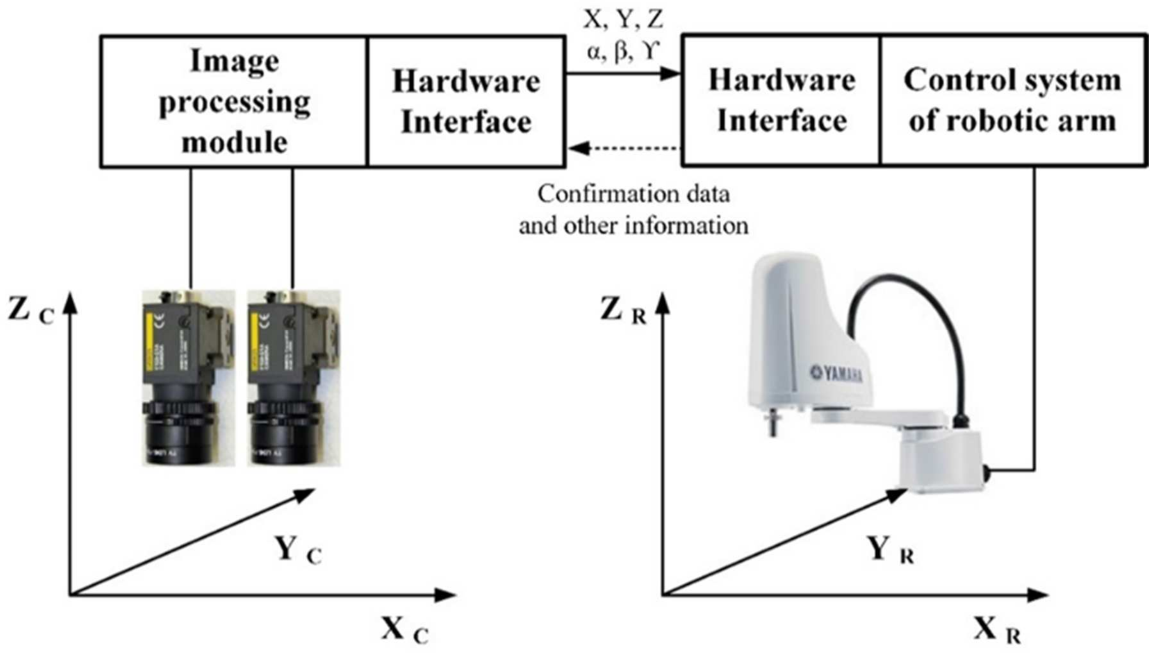

Fig. 2. Setup of the vision system

Interconnection between the control system of robotic arm and the vision system can be seen at Fig. 2. Next logical step consists of vision system calibration. Their purpose is the determination of internal, external parameters together with the values of mathematical model for the lens distortion (due to their impact). By the calibration process we determine the precise position selection of the entities from the pictures. This process is followed by the transformation between relationships of robotic arm coordinate system and the vision system [12].

Conclusions. Trends in the area of nonconventional technology and their implementation at the multidisciplinary manufacturing processes are mainly oriented into the advanced sensing and evaluating of the object parameters that are participating inside of these applications. Nowadays, precision manufacturing machines are usually equipped by the special-purposed sensing devices with the high quality based on vision systems, because the current standard technologies are not satisfied by customer requirements. Standard sensing devices are often implemented directly at the robotic arm, but recent research focus in this area is more oriented to the newly recent sensorial object processing which the classic devices cannot met, so far. In particular, also material engineering is just the relevant touched area, where the advanced 3D vision systems allows the complex embedded chains usage during characteristic recognition of objects parameters.

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ПІДХОДИ ДО ОБРОБКИ ЗОБРАЖЕНЬ СИСТЕМИ 3D КАМЕР НА АВТОМАТИЗОВАНИХ РОБОЧИХ МІСЦЯХ

Актуальність теми дослідження. *Важливим є розгляд можливостей застосування системи 3D-камер на автоматизованих робочих місцях. У той же час ми хочемо описати принципи обробки 2D і 3D зображень.*

Постановка проблеми*. Мета статті - розробити інструкції щодо правильних підходів до системи обробки зображень, яка може бути застосована на автоматизованих робочих місцях.*

Аналіз останніх досліджень і публікацій. *В даний час вже існує безліч інноваційних і зручних рішень для 3D- і 2D-камер. Проте, через їх високі ціни, існує необхідність реалізувати вигідне рішення, яке може бути доступним для маленьких компаній.*

Виділення недосліджених частин загальної проблеми. *Виробник, який займається системою обробки зображень і машинного зору, зазвичай, надає дороге та (очевидно) закрите рішення для обробки зображень без будь-яких коригувань. Тому вважаємо за необхідне дослідити це питання.*

Постановка завдання. *Мета статті - запропонувати доступне за ціною рішення на базі двох ПЗЗ-камер, яке буде впроваджено на автоматизованому робочому місці.*

Виклад основного матеріалу. *Для реалізації більш дешевого рішення доцільно мати відповідний приклад рішення обробки зображень і збору даних на основі регулювання процесу.*

Висновки. *В опублікованій статті представлено доступне за ціною рішення, яке можна застосувати на автоматизованому робочому місці. У представленій статті більш детально розглядаються деякі рішення для обробки зображень, що стосуються захоплення цільового об'єкта, які не часто і не достатньо описані виробниками.*

Ключові слова: *машинний зір; фотоапарат; автоматизоване робоче місце.*

Рис.: 2. Бібл.: 12.

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