# RECOGNITION OF OBJECT PROPERTIES BASED ON PASSIVE TRIANGULATION AND 2D CAMERA SYSTEM

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Every advanced knowledge about the process, object, or workplace is fundamental. It concerns current trends (digitalization, automation, intelligent industry) and the need to fill the missing technological gaps. Their goal is to increase quality and competitiveness. Therefore, this article aims to present a framework of the systematic approach as an affordable way to obtain relevant information about the object in the field of view of the captured scene. In addition, by using known triangulation methods, the article wants to build a relevant knowledge base that can be used as a suitable basis for solving similarly focused application tasks. Regardless, concerning the sensitive integration of image recognition and a methodological point of view, the article wants to summarize and verify the knowledge of epipolar geometry on a practical example of a selected object.

**KEYWORDS**

2D camera system, triangulation, detection of the picture

## 1 INTRODUCTION

The digitization of processes, services, and the visualization of the objects themselves is currently a challenge not only for standard solutions of application engineers but also for the process and measurement industries. The development of new technologies is presently dizzying. In addition, the advanced deployment of ICT technology and electronics significantly contributes to intelligent recognition processes. However, obtaining an adequate and high-quality representation of the actual image of the object is influenced by several factors, which include, e.g., poor lighting. It causes the appearance of shadows and glosses. Thus, the measured objects are deformed, creating irregular shapes significantly different from the natural ones on the measured workplace scene [Vasilko 2019, Karrach 2020, Cervenanska 2021].

The resulting defect is the disruption of calculations and algorithms that cannot accurately evaluate the sensed objects. If we consider the recognition of differently oriented ones on the measured scene, we can say that one camera system is insufficient. For this type of application solution, designing the so-called 3D camera system is necessary. However, there are several options. One of the direct approaches is procuring a standard industrial 3D camera, which is also equipped with evaluation software. The disadvantage is the unfavourable price and complexity. An alternative seems to be a combination of (several, but at least two) 2D camera systems, which will ensure 3D measurement [Zidek 2018].

Subsequently, with the help of geometric relations, we can obtain the necessary information about the object in space (e.g., the coordinates of the centre of gravity of the object and so on). Methods of 3D representation in the work scene are divided into passive and active techniques. Actives mean 3D image processing based on a two-combination of tools (receiver and transmitter), e.g., laser and sensor. From the phase shift of the modulated laser light between the transmitted and reflected beam, we can subsequently calculate the time from sending the signal to its reception - and from that, the distance to the object. Passive methods primarily include stereo vision, the core of which is triangulation. Its essence is the relationship between the investigated point and the foci of the camera systems, creating a kind of triangle. Suppose we know the distance between the principles and the angle that the rays form with the common plane of the camera systems. In that case, we can use trigonometric relations to calculate the point length from the plane of the camera systems [Janota 2016].

## 2 METHODOLOGY AND MATHEMATICAL BACKGROUND

From a methodological point of view, obtaining information about the object in the measurement scene can be explained in the following steps. The first (and essential) prerequisite is the initial sensing of the object, followed by its preprocessing. This term refers to preparing the image so that it is possible to apply suitable algorithms (for further processing). It often involves converting a colour image to a grayscale image or using filters to remove noise suppression [Holubek 2013, Tatickova 2022]. The process continues with segmentation, extracting properties (points, pixels, etc.) that are of interest in the given application. What happens is that we separate the essential from the unessential. Subsequently, all objects (modified in this way) will be described with characteristic signs representing them. Image analysis algorithms usually solve this part. The last activity is classification, which identifies the collected objects and thus determines which could be objects of interest. The sequence of steps presented in this way is general, which means that all actions may not always be followed, their order may be changed, or some may be entirely replaced by other procedures or combined [Dudak 2020]. Both passive and active techniques can be used [Beniak 2020]. In active techniques, light radiation is projected onto the measurement scene, and its reflection is obtained to calculate the position of the sensed object further. The passive approach is also called passive stereo vision and uses photogrammetric algorithms. This technique is based on processing two stereo images obtained from two camera systems, whose respective positions and angles are known Figure 1.

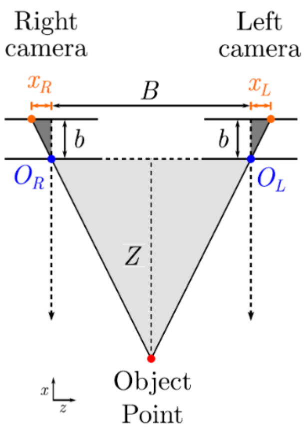



**Figure 1.** Stereo triangulation scheme with parallel camera systems [Hahne 2018]

A point is projected through the optical centers $O_L$ and $O_R$, yielding two image points (orange) in each camera system. The relative displacement of these points returns the horizontal disparity $\Delta x = x_R - x_L$. The baseline $B$, object distance $Z$, and image distance $b$ affect the measured difference. The depicted setup may be parameterized by the spacing of the cameras' axes, denoted as $B$ for baseline, the cameras' image distance $b$, and the optical centers $O_L$ and $O_R$ for each camera system, respectively.

An object point is projected onto both camera systems, indicated by orange dots. To measure displacement (parallax), the horizontal disparity $\Delta x$ is introduced by $\Delta x = x_R - x_L$, where $x_R$ and $x_L$ denote horizontal distances from each projected image point to the optical image center. Relationship (*1*) relies on the method of similar triangles and can be written as an equality of ratios:

$$z = \frac{b}{\Delta x} \tag{1}$$

To infer the depth distance $Z$, we can modify (*1*) to:

$$z = \frac{b \times B}{\Delta x} \tag{2}$$

As seen by these equations, it is feasible to retrieve information about the depth location $Z$. Likewise, if $\Delta x$ is constant, it may be obvious that by decreasing the baseline $B$, the object distance $Z$ shrinks. The coordinates of the point ($x, y, z$) can be determined from the following relations:

For $x$ axis:

$$x = x_L \frac{B}{x_L - x_R} \tag{3}$$

For $y$ axis:

$$y = y_L \frac{B}{y_L - y_R} \tag{4}$$

For $z$ axis:

$$z = z_L \frac{B}{z_L - z_R} \tag{5}$$

Image capture is described in more detail by epipolar geometry, which calculates the 3D coordinates of an object or scene composed of two 2D images. Internal parameters of camera systems and their relative position are used to determine 3D coordinates successfully. Internal parameters include focal length, position of control points, deformation, curvature, etc. Among the external parameters, we have mutual displacement or rotation of images relative to each other [Vagas 2019].

## 3 EXPERIMENTS AND TESTING

Of course, the application of advanced camera systems today is no exception. However, the challenge is using sensor miniaturization principles and software integration for control and evaluation processes.

With a cost-effective inspection camera system, it is possible to reliably detect objects in the field of view (measurement scene). Therefore, the article aims to point out the possibilities of the selected camera system, as well as the ongoing activities (image processing, sending the obtained data, detection of the object's centre of gravity, etc.). As mentioned, one camera sensor cannot manipulate an object in the field of view of the captured scene (e.g., using a robotic arm). This proposed solution offers the construction of a quasi-3D system based on two 2D cameras with an external evaluation unit, Figure 2.

Specifically, the tested (and deployed) system is an assembly from the OMRON company. It contains several input-output devices, peripheral devices, communication interfaces, a control console, an LCD monitor, and the appropriate cabling with a power source. It has the following parameters: resolution (512x484), field of view (in our case = 0 because we do not use an additional source of light), and focal length (focus, 35mm). Possible lens distortions (resulting in image distortion) can be removed by measuring defective images.

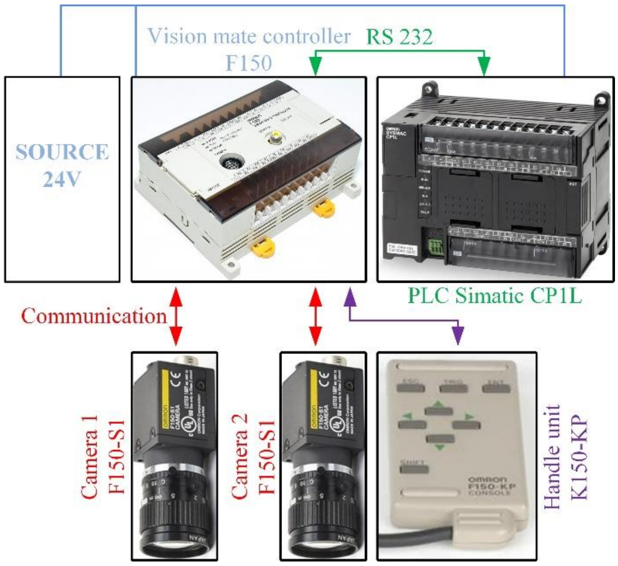
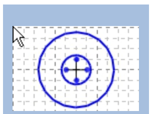
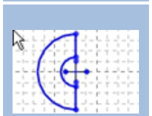
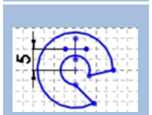



**Figure 2.** Deployed 2D camera system – architecture

Based on the existing geometric dependence of the scanned object and the selected camera system, we can then determine (also with the help of a CAD model) its desired properties (e.g., position, orientation, centre of gravity, etc.). The sequence of data acquisition (and thus capturing the image of the object in the field of view) depends primarily on the implementation of the calibration of both camera sensors. The monitored step is their appropriate location (concerning height) or the use of built-in or additional lighting. The properties of the measured object are in Table 1.

**Table 1.** Description of control module functions

| Object | View | 3D model | Correlation factor |
|---|---|---|---|
| Reference state |  |  | 100 % |
| State 1 |  |  | 50 % |
| State 2 |  |  | 40 % |

Correlation values for a "successfully" sensed object we experimentally determine at *84%* to *100%*. The system evaluated all values below these values as errors (unrecognized). Obtaining (searching) an object in the field of view requires steps such as registering camera sensors in the system (a kind of login or their specification), setting process times, and using the built-in functions of the external evaluation unit. In the given lighting conditions of the experiment, the system subsequently identifies the sensed object and determines the exact coordinates ($x, y$), Figure 3.


**Figure 3.** Output from the selected camera system

The object was identified by repeated measurements (20x) in the same lighting conditions regarding the use of known arithmetic functions and database systems, Table 2.

**Table 2.** Measured values of the coordinates of the searched object

| Nr. | x [mm] | Y [mm] | Nr. | X [mm] | Y [mm] |
|---|---|---|---|---|---|
| **1.** | 66.185 | 25.091 | **11.** | 66.180 | 25.095 |
| **2.** | 66.179 | 25.104 | **12.** | 66.185 | 25.102 |
| **3.** | 66.202 | 25.091 | **13.** | 66.197 | 25.097 |
| **4.** | 66.193 | 25.089 | **14.** | 66.214 | *25.085* |
| **5.** | 66.186 | 25.092 | **15.** | 66.213 | 25.092 |
| **6.** | 66.214 | 25.091 | **16.** | 66.176 | 25.105 |
| **7.** | 66.192 | 25.100 | **17.** | 66.193 | 25.092 |
| **8.** | 66.195 | 25.092 | **18.** | 66.176 | 25.100 |
| **9.** | *66.217* | 25.090 | **19.** | 66.206 | 25.095 |
| **10.** | 66.207 | 25.097 | **20.** | *66.160* | *25.111* |

We can further process the obtained data about the object, e.g., send it to the control system of the robotic arm, which can carry out follow-up actions (grasping, moving, etc.). In addition, by connecting to an existing PLC system, coordinates can be sent (via RS232), e.g., to the distributed system of the workplace. Additional statistical data from the measurements are displayed and processed in Table 3.

**Table 3.** Additional statistical data of the searched object

| Data type | X [mm] | Y [mm] |
|---|---|---|
| Max value | 66.217 | 25.111 |
| Min value | 66.16 | 25.085 |
| Arithmetic mean | 66.1935 | 25.0955 |
| Distraction | 0.000238368 | 0.00004120 |
| Standard deviation | 0.0154391709 | 0.0064187226 |

The causes of the measured deviations are since an additional light source did not illuminate the field of view. Another reason was the comparatively greater distance of the camera system from the object. It would be necessary to verify these hypotheses in further research and focus on implementing similarly oriented experiments (e.g., using special lighting). Moreover, by integrating the object data obtained in this way into the structure of the automated workplace (e.g., for another technological operation), we can distribute and transform the coordinates of the external coordinate system into the coordinates of the world CS (e.g., for the robotic arm).

## 4 CONCLUSIONS

The possibilities of the selected camera system with an emphasis on inspection properties go beyond the subject of this article. Therefore, the authors decided to focus only on the framework methodical approach of object detection in the field of view of the measured scene. Of course, someone could object that the article does not deal with obtaining the z-coordinate of the object (that is, the height) or with a more detailed explanation of the functionality of the external evaluation unit. Similar considerations are in order, but some functions are detailed in the manufacturer's manuals and model (demonstration) examples.

However, the article is aimed to point out an affordable automated solution that can be quickly deployed in an accurate standard operation. An essential prerequisite for the experimental solution was finding a suitable communication link (communication protocols) to ensure reliable communication of the components [Bozek 2021]. Technological and non-technological processes require at least two camera systems because, in this way, we can obtain full-value data of the object. The experiments were therefore oriented towards testing a unified (and partially) universal sensing design, assuming hardware and software support of all necessary OMRON devices.

The test results document the usability, applicability, and universality of the proposed approach for the object specification, lighting conditions, and processing time of the obtained image data. Our ongoing research focuses on controlling transmission processes, testing selected entities from the image, and getting external parameters of the mathematical lens distortion model.

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## REFERENCES

[Beniak 2020] Beniak, J., Krizan, P., Matus, M. Conductive material properties for FDM additive manufacturing. In: MM Science Journal. Vol. 2020, March (2020), p. 3846-3851. ISSN 1803-1269

[Bozek 2021] Bozek, P., Nikitin, Y., Krenicky, T. The Basics Characteristics of Elements Reliability. In: Diagnostics of Mechatronic Systems. Series: Studies in Systems, Decision and Control, 2021, Vol. 345, pp. 1-15. ISBN 978-3-030-67055-9.

[Cervenanska 2021] Cervenanska, Z., Vazan, P., Juhas, M. and Juhasova, B. Multi-Criteria Optimization in Operations Scheduling Applying Selected Priority Rules. Applied Sciences, 2021, Vol. 11, No. 6, 2783. https://doi.org/10.3390/app11062783.

[Dudak 2020] Dudak, J., Kebisek, M., Gaspar G. and Fabo, P. Implementation of machine learning algorithm in embedded devices. In: 9th International Conference on Mechatronics - Mechatronika (ME), Prague, Czech Republic, 2020, pp. 1-6, doi: 10.1109/ME49197.2020.9286705.

[Hahne 2018] Hahne, C., Aggoun, A., Velisavljevic, V., Fiebig, S. and M. Pesch. Baseline and triangulation geometry in a standard plenoptic camera. In: Int. J. Comput. Vis., vol. 126, no. 1, pp. 21-35, 2018.

[Holubek 2013] Holubek, R. and Ruzarovsky, R. The Methods for Increasing of the Efficiency in the Intelligent Assembly Cell. Applied Mechanics and Materials, 2013, Vol. 470, pp. 729-732. doi.org/10.4028/www.scientific.net/amm.470.729.

[Janota 2016] Janota, A., Nemec, D., Hrubos, M. and Pirnik, R. Knowledge-Based Approach to Selection of Weight-in-Motion Equipment. Communications in Computer and Information Science, 2016 pp., 1-12. https://doi.org/10.1007/978-3-319-49646-7_1.

[Karrach 2020] Karrach, L., Pivarciova, E., Bozek, P. Recognition of perspective distorted QR codes with a partially damaged finder pattern in real scene images. Applied Sciences, 2020, Vol. 10, issue 21, Art. No. 7814. ISSN 2076-3417.

[Murcinkova 2013] Murcinkova, Z., Krenicky, T. Implementation of virtual instrumentation for multiparametric technical system monitoring. In: SGEM 2013: 13th Int. Multidisciplinary Sci. Geoconf., Vol. 1; 16-22 June 2013, Albena, Bulgaria. Sofia: STEF92 Technology, 2013, pp. 139-144. ISBN 978-954-91818-9-0.

[Tatickova 2022] Tatickova, Z., et al. SMART Interactive Paints - The Effect of Dispergation on Color Characteristics. In: 7th International ScientificTechnical Conference Manufacturing 2022, Poznan, Poland, 16-19 May 2022. Berlin: Springer Science+Business Media, 2022. Lecture Notes in Mechanical Engineering - Advances in Manufacturing, pp. 175-188. ISSN 2195-4356. ISBN 978-3-031-00804-7. DOI 10.1007/978-3-031-00805-4_15.

[Vagas 2015] Vagas, M., Galajdova, A., Simsik, D., Onofrejova, D. Wireless data acquisition from automated workplaces based on RFID technology. In: IFAC-PapersOnLine. 2019;52(27):299–304. doi: 10.1016/j.ifacol.2019.12.677.

[Vasilko 2019] Vasilko, K., Murcinkova, Z. Experimental study of chip shapes in grinding by unique quick stop method and the ground subsurface layers micro-hardness. Journal of Mechanical Science and Technology, 2019, Vol. 33, pp. 1341-1347.

[Zidek 2018] Zidek, K., et al. Auxiliary Device for Accurate Measurement by the Smart vision System. MM Science Journal, 2018, Vol. March, pp. 2136-2139.

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