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STUDY OF AN IMAGE RECOGNITION SYSTEM: IDENTIFICATION OF PART THREAD QUALITY BY CHANGING THE ANGLE OF THE PART WITH THE BASE OR THE ILLUMINATION OF THE PART

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Abstract. Industrial image processing is mostly based on the use of special cameras or imaging systems installed within the production line (SmartRay 2023). Image recognition is a computer vision program that uses machines to identify and classify specific objects, texts, and digital images and videos. Basically, it's the ability of computer software to "see" and interpret things in a visual medium the way a human can (GLOVER et al., 2023). To find out the influence of the lighting and/or viewing angle of the examined part on its quality, the image recognition camera used in the study was the "SICK Inspector PIM60" image recognition camera, the "YONGNUO" LED YN-160S" light source and the camera dome and filters of various colors: red, blue, green, transparent, and variable ND filter. The results obtained show that using isolated lighting and clear, red, blue, green, and ND2 - ND64 filters, the recognition accuracy reaches only 3 recognitions out of 10 attempts, which is still only 30 % accuracy. The recognition of a defects with settings at the angle (10, 20, 30, 40 degrees) using clear filter and the external lighting from one side of the part is high-quality when the surfaces of the parts are completely clean without any mechanical damage (scratches, knocks).Only 3 out of 10 parts threads features were correctly recognized, as the camera captures additional reflections from the part surface because of additional damage on the parts surface (Gasiūnas et al.,2022). The obtained results show that using a green camera filter and external illumination of the part from one side is the best way to identify the thread quality of the part. The results obtained show that using a green filter and external illumination of the test piece, it is possible to obtain ~ 100 % recognition of the part and its holes dimensions quality if the part is always placed in the same place and the same lighting conditions are used (Gasiūnas et al., 2022).

Keywords: angle; image recognition; below; filter; camera; quality; defect

INTRODUCTION

Object recognition is an amazing human feat. An attempt to develop a machine to mimic human capability is the starting point of object recognition. The term “recognition” has been used to refer to many different visual abilities, including identification, categorization, and discrimination (Jain et al, 2022). According to 2012 data, the Image Recognition error rate has been high (about 26 %), By 2018, deep learning models reduced this error rate to 2.2 %, surpassing human performance (average error rate of 5 %) (Xiaohong, et al., 2020, Kruger 2018). Currently, devices are increasingly used to ensure the quality of product parts or other products. To clarify the different capabilities of a standard industrial camera with image recognition software, a study was conducted comparing the quality of detail recognition by changing camera filters, lighting conditions and part angle to surface. The study used 3 different lighting methods (internal - in camera integrated light source, external – led light source from object of interest side, external with outside lighting elimination), 5 different filters (blue, red, clear, ND and green filter) plus camera dome. The obtained results show that ~100 percent part quality and hole dimensions can be recognized using a green filter and external illumination, provided the part is always in the same location and under the same lighting conditions. Quality control is the most important function of manufacturers because the product produced by the company is in demand only if it is of high quality and meets the requirements of accuracy, safety and reliability set by the standards. Quality control can be manual (an employee checks the quality of a product or its part with a special device to detect and identify defects) or automatic (a product defect is determined automatically, without human intervention). Automated inspection can use an image recognition system to compare the physical characteristics (dimensions, surface engraving, holes, etc.) of a quality product. New image processing techniques as well digital image capture equipment provide an opportunity for fast detection and diagnosis of quality problems in manufacturing environments compared with traditional dimensional measurement techniques. The focus of the proposed methodology is on computational efficiency to ensure that the algorithm runs in real time in high volume manufacturing environments. The algorithm is trained with previously classified images. New images are then classified into two groups, quality and defective (Megahed et al., 2012).

THE RESEARCH METHOD

Physical equipment includes YONGNUO LED YN-160S external light source, computer (must have 1 GB RAM or more, CPU Pentium 1GHz or better) with LAN connection, and Inspector PIM60 image recognition sensor manufactured by SICK samples (see Figure 1) (SOPAS 2016). The layout of the physical equipment during the study is

presented in Figures 2 and 4. The free camera software "SOPAS" was used in the study's, which allows you to detect the object based on its size, shape, and identification mark (inscription, scratch, drawing, sticker). etc.) (Gasiūnas et al., 2022, SICK 2018, YONGNUO 2021).

The methodology for determining the flaw in threads of parts using an image recognition camera (sensor) is based on the introduction of comparable parameters (by marking the quality characteristics of the part under the conditions in which the characteristics of other parts will be studied). Various filters (clear, green, red, ND, blue) and lighting configurations (internal or external) are used to capture the most suitable conditions, i.e., the best quality recognition conditions are selected for a specific detail on which the object under study is best focused. After the typical (reference) setting is made, the test details are compared to it (see Figure 1 - 4) (Gasiūnas et al., 2022).

The first study used only the camera's factory built-in (integrated) lighting with clear, red, blue, and green filters, and the subject was from ninety to one hundred millimeters away from the sensor. The layout of the equipment used in the studies and the obtained results are presented in Figures 1 - 2 and table 1 (Gasiūnas et al., 2022).

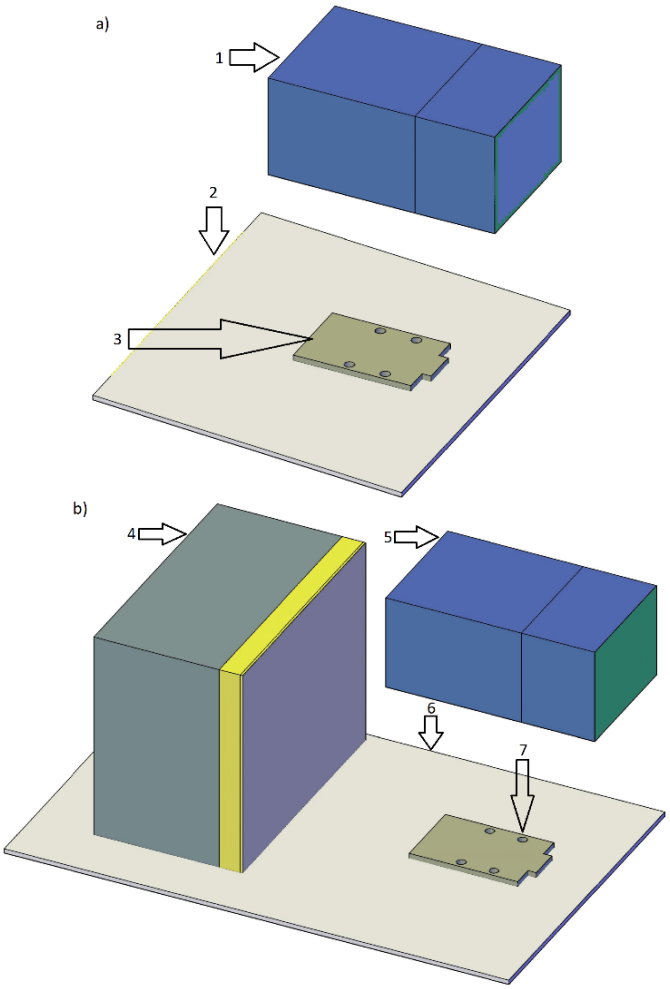

Figure 1. (a) **Layout of the physical equipment used in the study without external lighting (1'st study);** (b) **Layout of the physical equipment used in the study with external lighting (2'nd - 3'rd study) (Gasiūnas et al., 2022).**
1, 5 – image recognition camera / sensor (*SICK INSPECTOR PIM 60*); 2, 6 – interchangeable base; 3, 7 – object under investigation; 4 – lighting.

In the following study used additional external side lighting of the subject with blue, clear, red, and green filters, and the subject was 90 - 100 mm away from the camera. The layout of the equipment used in the experiments and the obtained results are presented in Figures 1 and 2.

RESULTS FROM PREVIOUS STUDIES (1'ST - 3'RD STUDY'S)

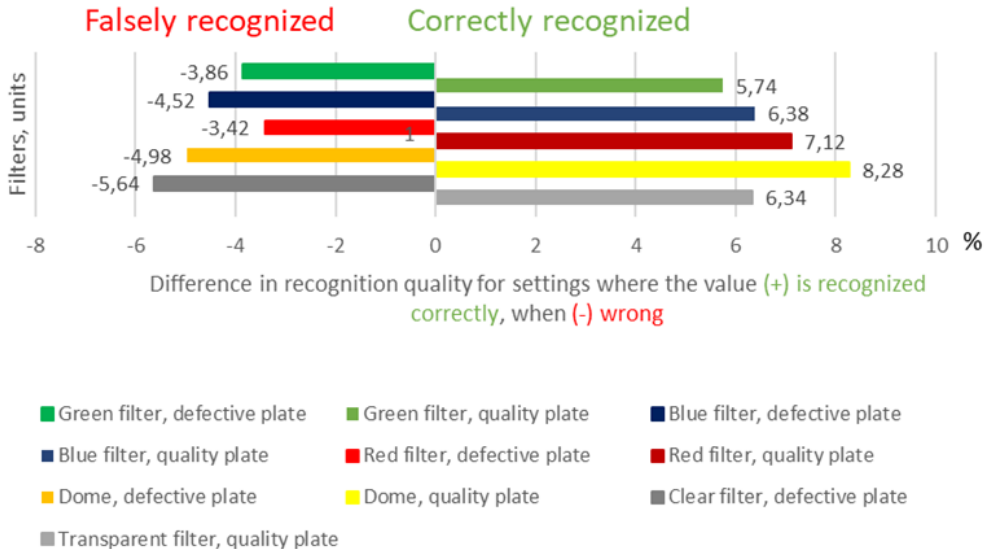

Figure 2. **The first study results**

In the first study, the recognition of a part's dimensional inconsistency with settings using red, clear, blue, and green filters and the internal (integrated) illumination of the camera is null, i.e., the defect in details is not noticeable and all of them are 100 percent cases are identified as high quality (see Figure 2).

Table 1

The first study

Study	Average difference with conformance limit (conformance difference must be ≥ 0 %), %			Comment
	Quality	***Defect***	***Results***	
Green filter	5,74	-3,86	-	Correctly identified 5/10
Blue filter	6,38	-4,52	-	Correctly identified 5/10
Red filter	7,12	-3,42	-	Correctly identified 5/10
Dome	8,28	-4,98	-	Correctly identified 5/10
Clear filer	6,34	-5,64	-	Correctly identified 5/10

According to the results obtained in the second study, the recognition of the quality parts was 20 % with external lighting and the red filter, 0 % with the blue filter, 20 % with the clear filter and both quality and defective parts with the green filter in all tests were correctly identified, i.e., 100 % accuracy (see Figure 2).

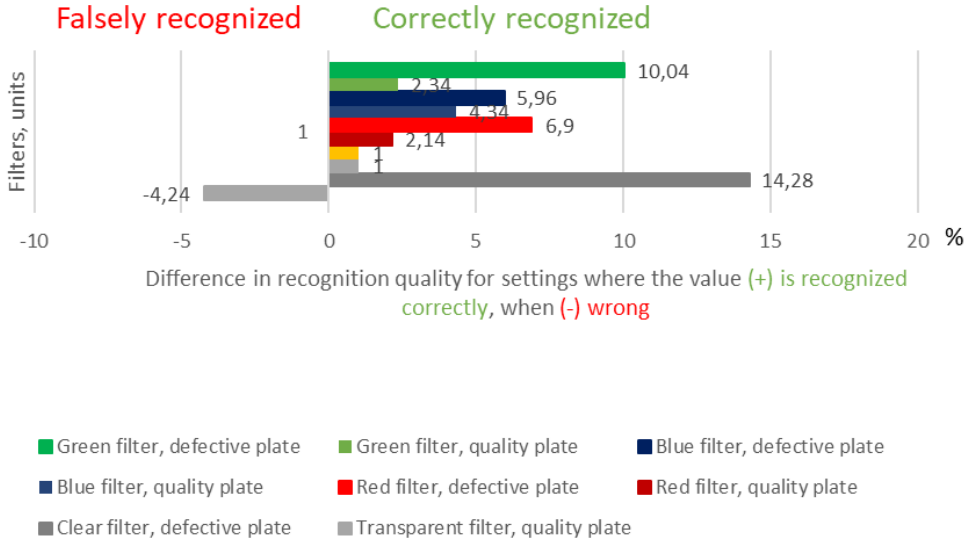

Figure 3. **The second study results**

When using a green filter and illuminating the part under investigation from the side, the features of the part were correctly identified in all cases, and the recognition of a quality part exceeded 0,94 percent. value (≥ 90 %) (see Figure 2) (Gasiūnas et al.,2022).

Table 2

The second study

Study	Average difference with conformance limit (conformance difference must be ≥ 0 %), %			Comment
	Quality	***Defect***	***Results***	
Clear filer	14,28	-4,24	-	Correctly identified 5/10
Blue filter	5,96	4,34	+	Correctly identified 10/10
Green filter	10,04	2,34	+	Correctly identified 10/10
Red filter	6,9	2,14	+	Correctly identified 10/10

The third study used additional external side illumination of the subject with ND filter, and the subject was from ninety to one hundred millimeters away from the camera. The layout of the equipment used in the experiments and the obtained results are presented in Figures 1b), 3 and table 1 (Gasiūnas et al.,2022).

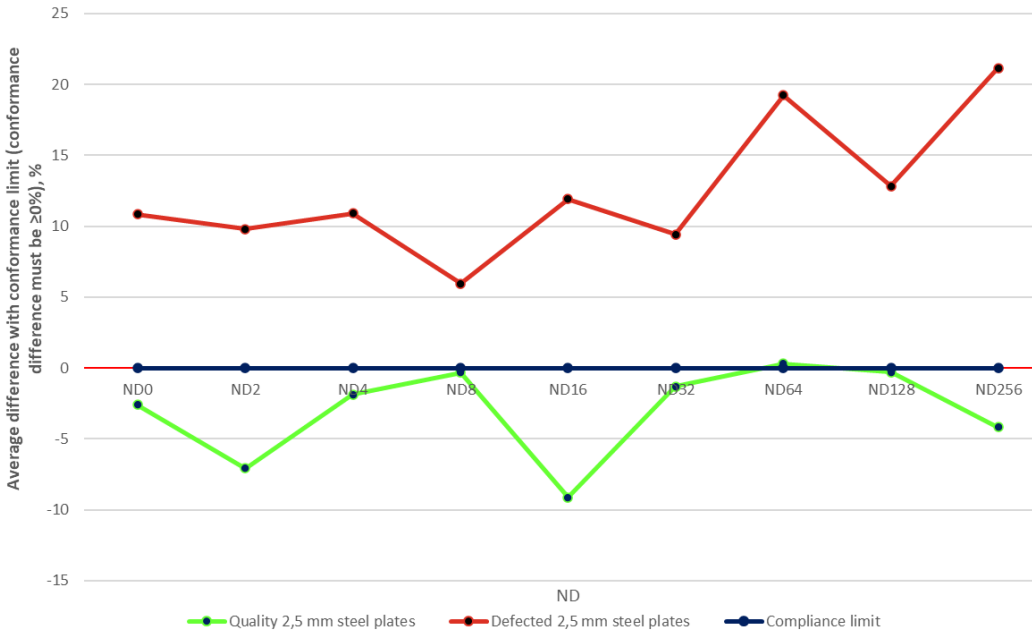

Figure 4. **The third study (with ND filter), results (Gasiūnas et al., 2022).**

In the third study, the recognition of defects with settings using ND (variable) filter and the external lighting of the PIM60 is close to null, i.e., the quality details are not noticeable and 95,56 percent. cases are identified as defective (see Figure 4).

Table 3

The third study (with ND filter)

Study	Average difference with conformance limit (conformance difference must be ≥ 0 %), %			Comment
	Quality	***Defect***	***Results***	
ND0	-2,6	10,86	-	Correctly identified 5/10
ND2	-7,07	9,81	-	Correctly identified 5/10
ND4	-1,88	10,9	-	Correctly identified 5/10
ND8	-0,31	5,96	-	Correctly identified 5/10
ND16	-9,14	11,93	-	Correctly identified 5/10
ND32	-1,31	9,41	-	Correctly identified 5/10
ND64	0,3	19,24	+	Correctly identified 7/10
ND128	-0,29	12,84	-	Correctly identified 5/10
ND256	-4,19	21,17	-	Correctly identified 5/10

Only when the filter is set to ND64, the sensor detects the features of the parts more accurately, the recognition accuracy reaches only 7 recognitions out of 10 attempts, which is 70 percent accuracy (see Figure 3) (Gasiūnas et al., 2022). According to the results obtained in the third study, the recognition of the quality with ND filter was not noticeable and still the best results are obtained with the green filter, i.e., 100 percent accuracy (see Figure 3).

FOURTH AND FIFTH STUDY'S

The fourth study used only isolated lighting and clear, red, blue, green, and ND2 - ND64 filters, the subject was 90 – 100 mm away from the camera. The layout of the equipment used in the experiments and the obtained results are presented in Figures 5 and table 4.

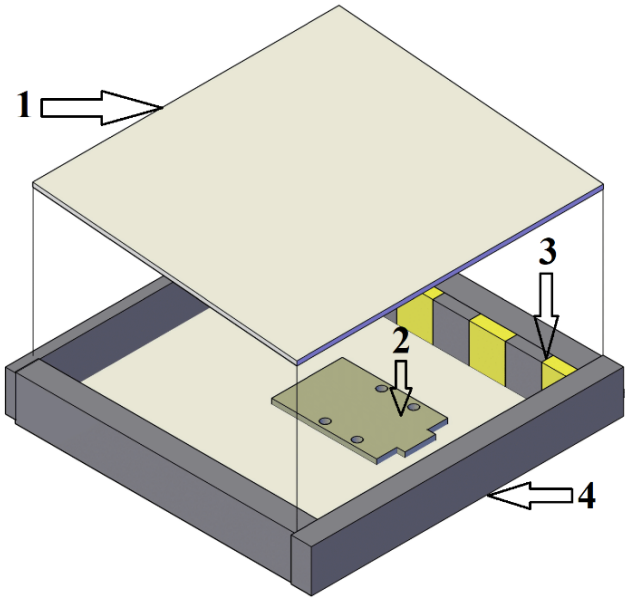

Figure 5. **Layout of the physical equipment used in the study with isolated lighting from 4 sides (4'rt study).** 1 – A box that isolates the part and the camera from external lighting; 2 – Detail under investigation; 3 – The LED strip which illuminates the detail from all 4 sides; 4 – Frame supporting interchangeable base.

Table 4

The fourth study isolated lighting from 4 sides

Part number	Quality	Red filter	Blue filter	Clear filter	Green filter	ND2	ND4	ND8	ND16	ND32	ND64
		Compliance %									
1	-	61,1	51,8	65,0	66,6	73,0	72,7	70,3	66,9	61,3	-
	+	88,2	55,9	85,4	83,4	90,2	90,0	87,9	83,9	79,0	-
2	-	62,8	52,1	66,4	67,2	58,6	59,0	55,7	52,4	52,0	64,3
	+	87,5	45,1	87,6	89,9	87,6	86,9	83,5	80,3	74,4	-
3	-	56,5	45,0	70,0	69,2	69,8	68,8	66,7	61,8	56,7	60,0
	+	87,2	58,7	90,1	91,0	87,2	86,8	84,1	80,5	74,2	56,3
4	-	64,3	41,3	69,1	68,6	71,3	72,6	71,0	66,3	63,2	-
	+	91,1	53,9	87,1	90,5	90,2	88,7	87,1	81,6	72,6	57,7
5	-	64,1	47,4	64,7	66,8	69,9	69,4	66,7	61,3	60,9	-
	+	91,8	56,1	87,3	80,8	90,2	91,1	88,8	84,0	76,5	59,0
6	+	48,6	99,8	83,3	83,6	60,7	62,5	52,5	55,6	52,1	-
	+	58,8	44,8	62,4	61,6	63,2	62,1	57,1	56,7	53,0	37,4
7	+	61,2	59,1	55,6	56,4	64,3	63,5	62,0	60,9	57,8	38,4
	+	80,4	61,8	79,3	76,0	81,6	80,5	78,7	74,9	70,2	23,1
8	+	72,3	58,8	81,4	84,5	65,7	65,4	64,1	61,1	59,2	63,0
	+	61,4	57,5	63,0	65,4	80,0	78,2	76,6	77,8	66,6	35,6
9	+	51,0	51,8	82,5	65,5	25,9	25,5	23,2	21,1	21,1	-
	+	62,7	45,8	63,2	84,0	79,1	74,9	75,2	70,3	67,5	14,3
10	+	59,2	57,9	59,3	66,1	67,9	66,5	65,2	60,7	57,9	62,6
	+	79,4	59,9	57,7	56,6	83,9	83,4	82,0	76,7	70,6	-

The fifth study used additional external side illumination of the subject with clear filter, and the subject was 90 - 100 mm away from the camera at 10 to 40-degree angle to interchangeable base. The layout of the equipment used in the experiments and the obtained results are presented in Figures 1b), 3 and table 5.

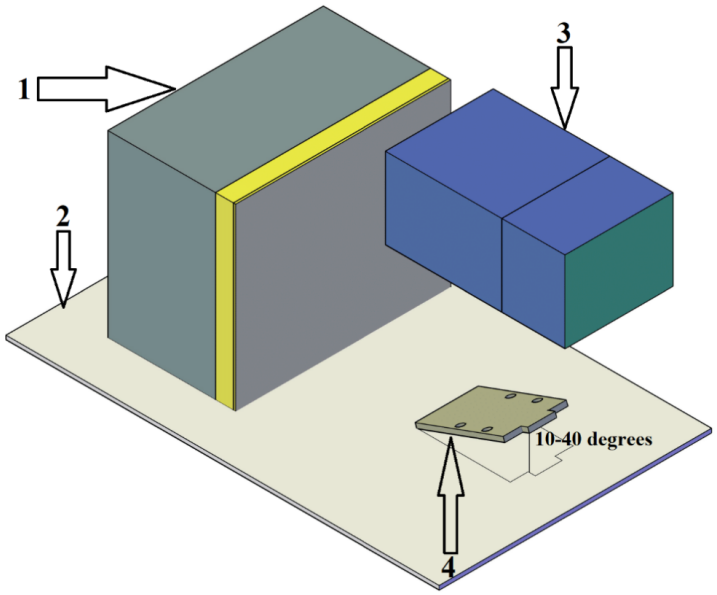

Figure 5. **The fifth study used additional external side illumination of the subject with a clear filter, research subject is at 10 - 40 degrees angle to interchangeable base.**
1 – External lighting; 2 – interchangeable base; 3 – sensor; 4 - detail at angle from 10 to 40 degrees to an interchangeable base.

Table 5

The fifth study

Part number	Quality	Examination at an angle of 10 degrees	Examination at an angle of 20 degrees	Examination at an angle of 30 degrees	Examination at an angle of 40 degrees
		Compliance %	*Compliance %*	*Compliance %*	*Compliance %*
1	-	81,90	76,00	73,90	76,00
	+	92,00	90,20	90,70	92,00
2	-	76,20	74,60	73,70	70,00
	+	94,70	90,70	92,30	95,30
3	-	73,10	72,60	68,80	73,70
	+	93,50	90,70	91,80	91,50
4	-	78,30	77,30	71,50	71,30
	+	91,40	91,60	91,00	91,60
5	-	77,10	76,60	71,50	71,60
	+	92,90	91,40	90,40	91,50
6	+	92,80	69,70	90,50	84,60
	+	65,50	84,00	82,60	75,00
7	+	92,00	65,60	90,10	93,80
	+	78,20	73,90	83,10	78,90
8	+	81,60	67,40	80,70	94,60
	+	91,50	84,70	81,60	86,30
9	+	77,70	69,00	91,60	84,40
	+	77,50	81,00	82,90	90,30
10	+	91,50	69,60	89,10	86,00
	+	79,00	84,40	82,70	93,30
Comparative	+	99,30	99,90	98,20	99,80

It can be seen from Table 5 that the investigation of the quality of the threads of the examined parts after turning the part in relation to the base through an angle of 10 - 40 degrees, when the part is illuminated from the side, is unsuccessful. The success rate is only about 30 percent.

RESULTS

In the fourth study, the recognition of defects with settings using red, clear, green, blue and ND (variable) filters and the isolated lighting from 4 sides of the camera is close to null (8 %), i.e., the quality details are not noticeable and 92 %. cases are identified as defective (see Table 4). Only when the filter is set to ND2, the sensor detects the features of the parts more accurately, the recognition accuracy reaches only 3 recognitions out of 10 attempts, which is still only 30 % accuracy (Gasiūnas et al.,2022).

In the fifth study, the recognition of a defects with settings at the angle (10, 20, 30, 40 degrees) using clear filter and the external lighting from one side of the part is high-quality when the surfaces of the parts are completely clean without any mechanical damage (scratches, knocks) (see Table 5). These are violations in which the part is still of high quality because they do not affect the use of the part. Only 3 out of 10 parts threads features were correctly recognized, as the camera captures additional reflections from the part surface because of additional damage on the parts surface (Gasiūnas et al.,2022). (Gasiūnas et al.,2022).

CONCLUSIONS

1. After the fourth study, the best quality research results with the isolated lighting from 4 sides were obtained when the filter is set to ND2, accuracy reaches only 3 recognitions out of 10 attempts, which is 30 % accuracy. So, the results from the previous 3 studies were better.
2. After the fifth study, the best quality research results with settings at the angle (10, 20, 30, 40 degrees) using clear filter and the external lighting from one side of the part is high - quality when the surfaces of the parts are completely clean without any mechanical damage (knocks, scratches, or other marks).
3. After conducting research, the best quality research results were obtained by observing the part at 90 - 100 mm, using a green sensor filter and external lighting from one side. It was found that, when observing the part in approximately the same position (± 5 mm and ± 5°), 100 percent can be obtained. recognition accuracy (quality details correspond to settings ≥ 90, and defective parts correspond to settings < 90).

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