

# Optical Gripper

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**Abstract.** With increasing automation, many work processes become more and more complex. Most technical products can no longer be developed and manufactured by a single department. They are often the product of different divisions and require cooperation from different specialist areas. For example, in the Western world, a simple coffee maker is no longer so much in demand. If the buyer has the possibility to choose between a simple coffee maker and a coffee machine with very complex functions, the choice will probably fall to the more complex variant. Technical progress also applies to other technical products, such as grippers and manipulators. In this paper, it is shown how grasping processes can be redefined and developed with interdisciplinary technical approaches. Both conventional and latest developments in mechanical engineering, production technology, mechatronics and sensor technology will be considered.

## 1. Introduction

Automation processes are used to transfer work from people to machines. As a result of technical progress, with the increasing use of computers and microchips, the applications become more complex, more intelligent and safer for the user. Automation, however, requires more and more peripheral devices, especially in the technical processes. These devices are again becoming more intelligent when they communicate with the environment via sensors or "perceive" the environment.

Also, the application areas become by automation more complex, so today in many technological processes not only machines but systems are used. For example, the highly complex production lines, where the heavy and monotonous human work is largely taken over by robots. The industrial robots are integrated in production in such a way that they communicate with other robots via sensors and control computers.

The control in the automated production processes, where industrial robots are used, is done in most cases via PLC, industrial control computers, camera systems and built-in sensors. An important component of robotics is the gripper technology. The industrial robots in particular need special grippers and gripper systems depending on the application and application area.

### 1.1. Applications

With the aid of industrial robots (IR), for example, assembly work is carried out or workplaces are machined. It is used in the production as a montage robot, for gluing and sealing, roller folding, for



loading machines, for palletizing, stacking, packaging, varnishing, milling, sawing, welding, grinding or the IR is used for measurement tasks (Figure 1, 2, 3, 4, 5).

Robots with special grippers in the automotive industry: [1]



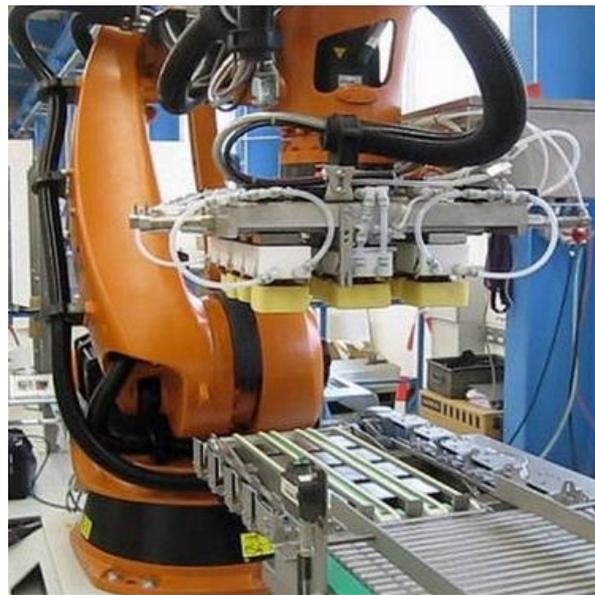
**Figure 1.** Switching pins



**Figure 2.** A smaller type of an intercept pendulum



**Figure 3.** Palletizing robots in the food industry



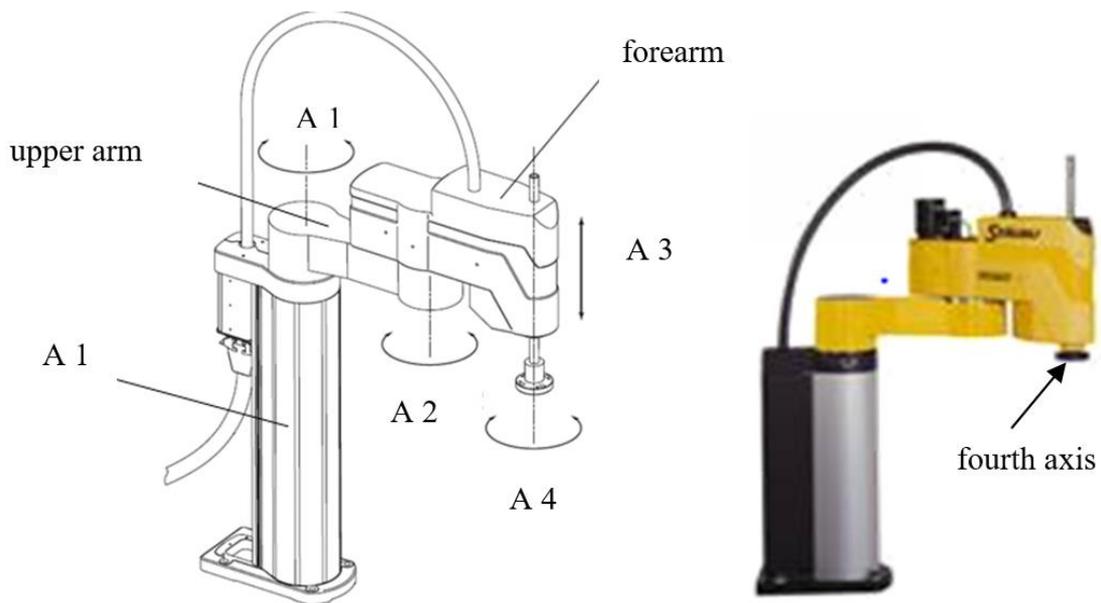
**Figure 4.** Special gripper of a robot in the pharmaceutical industry



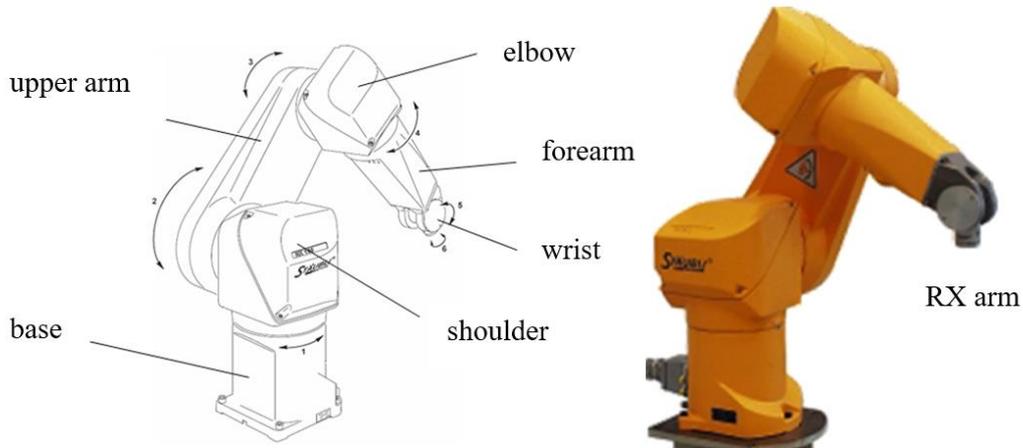
**Figure 5.** Material handling with hydraulic gripper system

**2. Robot grippers**

In order for the robot arm to be able to lift objects, it needs at least one gripper, or a gripper system. The gripper is therefore an important component of the robot system and is usually mounted on the 4th axis (Figure 6) on the SCARA robot and on the 6th axis on the industrial robot (Figure 7).



**Figure 6.** SCARA robot with 4 axis [2]



**Figure 7.** Industrial robot with 6 axes [2]

*2.1. Gripper types*

Depending on the application and the type of drive, the grippers are divided according to different criteria. Mechanical grippers may, for example, be pneumatically, electrically, hydraulically or in combination, e.g. pneumatically and electrically.

A further division of the grippers takes place via the gripping technique: parallel grippers, two-point grippers, three-point grippers, angle grippers, radial grippers, swivel grippers (Figure 8, 9, 10, 11, 12) or special grippers (e.g. FESTO trunk gripper) [3].



**Figure 8.** Parallel gripper



**Figure 9.** Three-point gripper



**Figure 10.** Angle grippers



**Figure 11.** Radial gripper



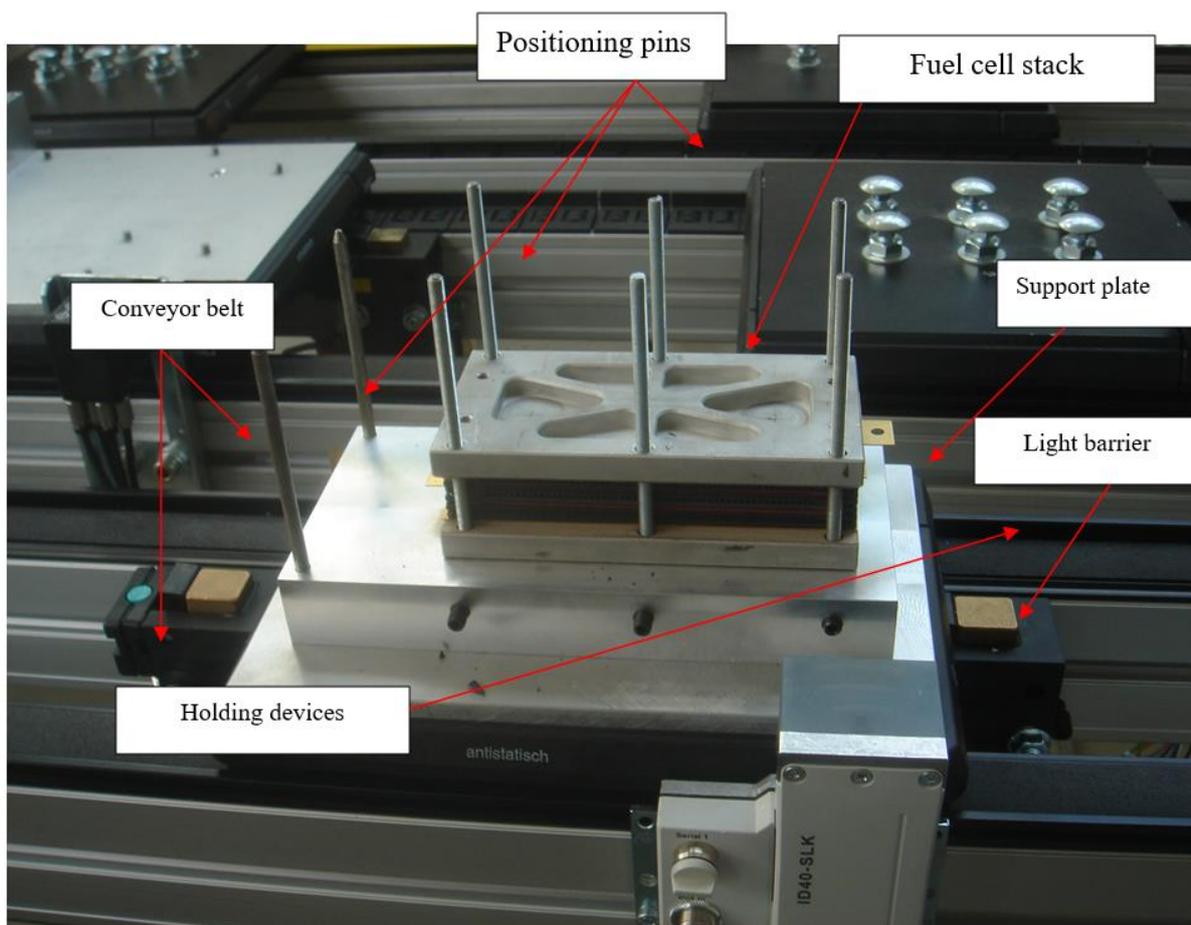
**Figure 12.** Swing gripping unit

Mechanical grippers are used most for mass production with standardized objects. Since the handling operations take place in the same manner, the objects are recorded in a standardized manner: they are programmed and optimized for the production flow, are adapted for gripping processes, they need gripping devices or gripper changing systems, devices for object acquisition and object storage, and they must work in protected working areas [4].

A robotized production line must be checked and tested before production begins. Only when all prerequisites and requirements are fulfilled, the system is released and production can begin. All of this is bound with a lot of time and costs.

We also came to the same conclusion in various experiments in the robot laboratory at the University of Applied Sciences in Ulm, Germany. Many applications could only be carried out with great time and financial effort [5].

For example, we had to develop a system to assemble fuel cells. For this aim we used two different small grippers, each costing around € 1,000 per unit. For the positioning of the guide pins in the mounting plates we used a parallel gripper. For the assembly of the fuel cell plates we needed a suction gripper. During the fuel cell assembly, these two grippers had to be changed again and again. In addition to the grippers we needed a gripper changing system that had to be purchased for around € 2,000, and an assembly line. The entire investment cost about € 10,000 (Figure 13).



**Figure 13.** Fuel cell assembly line

This application should serve as a pilot project for the industrial assembling of fuel cells. For this, assembly cycles had to be optimized. The assembly cycles were between 140 and 63 seconds. The

shorter assembly time in the range of one minute per cycle could only be achieved if the KUKA industrial robot used operated at 100% maximum speed in automatic mode [1].

In industry, longer assembly cycles are associated with additional costs per assembly cycle. Therefore, the assembly cycles of the fuel cell should be reduced to a minimum.

The higher mounting speed for the above - mentioned mounting could be achieved, for example, if path points were programmed with PTP (point to point) instead of with LIN (linear) movements, or when precision points were overlapped. As a result, the repeatability accuracy was lower, which in turn could lead to damage to the mounting plates and the gripper changing system. The time response in the case of gripper exchange systems was also significant in other laboratory tests.

The use of cameras from industrial image processing proved only to a limited extent as a further solution [6], [7]. The problem was, for example, a dynamic illumination of the objects that should be picked up. Especially in the case of metallic parts, reflections had to be taken because they led to the loss of important information. The object contours could become blurred. This resulted in unintended measurement inaccuracies [8-11].

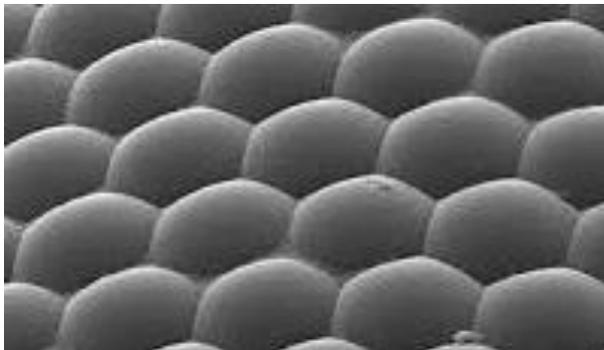
A further disadvantage was the time required for the programming of the gripping process and the provision of application of specific mounting devices.

All this inconveniences led to the idea of developing a universal intelligent gripper, which even recognizes the objects [12] and adapts and controls the gripping process according to the object contours to be gripped [13].

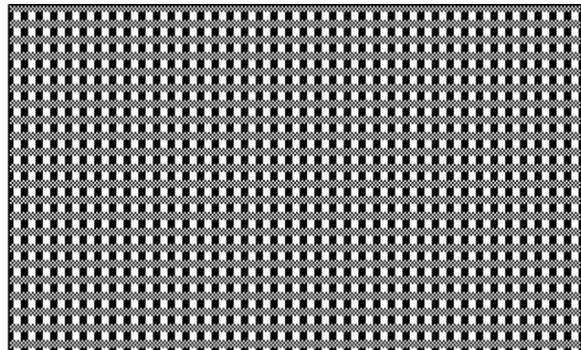
### 3. Ideas for a new design

When the gripper has its own sensor system and artificial intelligence, it can independently access any object of different strength without having to be programmed for it.

As an example, from nature served the insect facet eye (Figure 14, 15) [14].



**Figure 14.** Part of a facet eye

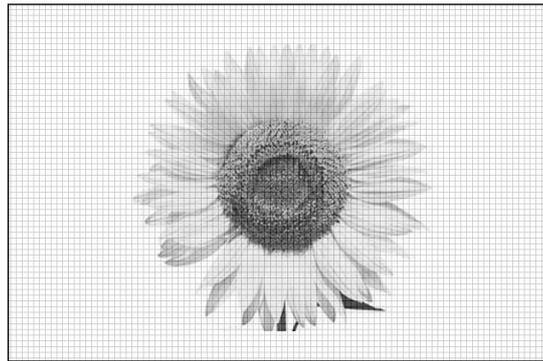


**Figure 15.** Facet eye as a binary model

If, for example, an insect sees a flower (Figure 16), the optical stimuli are not perceived centrally over an eye and processed further in the brain. The images are instead recognized by the individual facets as light and dark surfaces as partial images and then guided to an overall image (Figure 17).



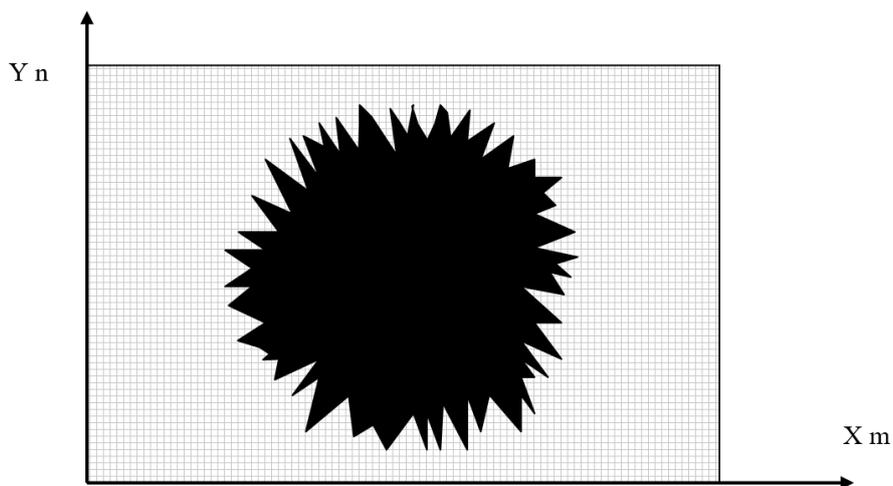
**Figure 16.** Analog image



**Figure 17.** Digitized image

The facet eye can handle up to 300 images per second by fast-flying insects, while the human eye can process approximately 60 to 65 images per second [14], [15].

In this case the light signals can be immediately evaluated by the downstream neurons. In addition, only the change in the light signal can be selectively relayed. This has the advantage that only the most necessary light information is processed (Figure 18), which leads to faster overall processing with less computation effort.

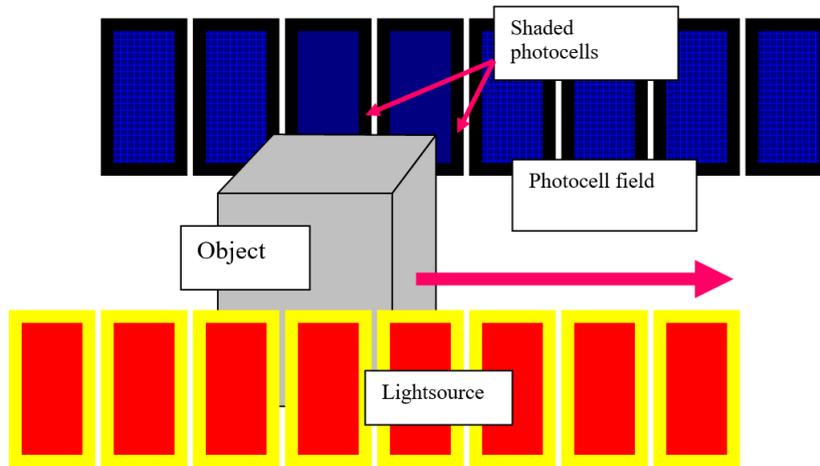


**Figure 18.** Digitized image in a matrix with relevant information like contour and surface

This perception principle can also be used for the recognition of contours in the case of an intelligent optical gripper. The image is segmented into pixels and is transferred to a projection surface.

### 3.1. Test setup

To be able to use the principle of the facet eye by an intelligent optical gripper, the object recognition should still take place directly at the object. For this aim was made a test setup with a light source and photocells (Figure 19).

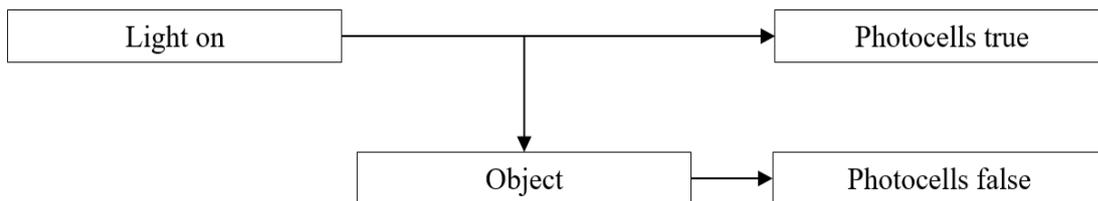


**Figure 19.** Test setup

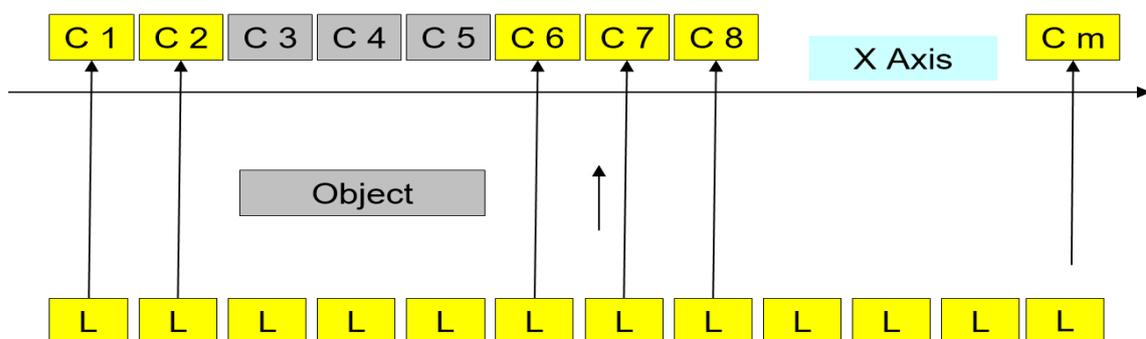
In this case, the photocells serve similarly to the facet eyes of the insects for the object recognition. A light source on the opposite side irradiates a parallel number of photo elements. As objects move relative to the photo elements and the light source, they are captured by shading some photocells. The thus shaded photocells provide a dynamic image of the object, or of the objects that are located between the light source and the photoelectric elements.

In this experimental setup, as in the case of industrial image processing, black and white values can hardly be expected for better contrast and the subsequent digitization. The photo sensors only get a similar value, or an attenuated value, against an irradiated reference value (light source).

In the initial state, the photocells were illuminated with light-emitting diodes. The output current at the photocells was assumed to be a reference value with a reasonable tolerance. This value should correspond to the binary threshold on the gray scale of industrial image processing. Values which corresponded to the reference value were interpreted as TRUE values, those which were under it were assumed to be FALSE values (Figure 20).



**Figure 20.** Principle of the switching logic and object detection



**Figure 21.** Object recognition

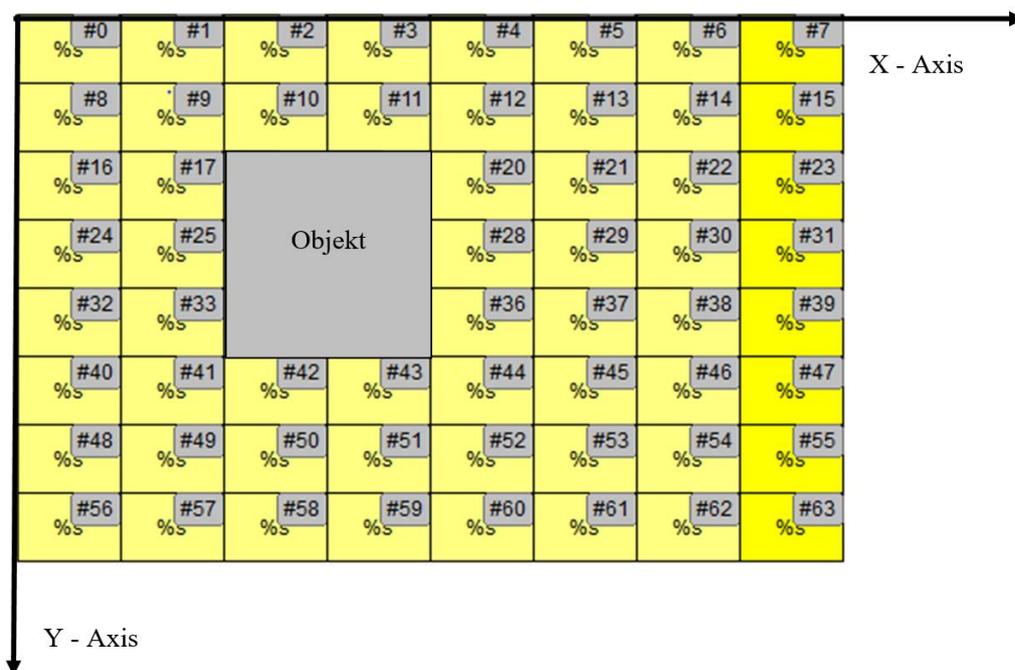
The photocells are represented in a switching logic as a two-dimensional matrix. The rows are numbered from left to right and from top to bottom and are declared as variables (Figure 18, 21).

The light source is represented in the above drawing by individual light emitters (L). The photocells are light receptors (C1 to Cm). In a static view, the object shadows several photocells, namely the photocells: C3, C4 and C5 (Figure 21). When the photocells are irradiated, the logic state TRUE is accepted in an electronic circuit. If they are shadowed, they are assumed to be FALSE and represent the area of the captured image (Figure 18).

### 3.2. Object-oriented programming

For the logical processing, simulation and visualization of the switching logic, was used the development environment CoDeSys (Controller Development System) from 3S-Smart Software Solutions GmbH, DE 87439 Kempten, Germany.

CoDeSys can be configured for a large number of controllers. For example, SIEMENS PLC controls can be easily imported into CoDeSys. Conversely, programs developed in CoDeSys can be exported to SIEMENS controllers. Furthermore, with the simulation and visualization possibilities the programs can be tested for functionality and their functioning can be visualized (Figure 22). A solution to this problem is a customized technical device to significantly increase the lifetime of the clutch. It was accomplished by a precisely controlled activation of the clutch at a point of time when pendulum and motor are at synchronized speed and direction using incremental encoders.



**Figure 22.** Matrix visualization with CoDeSys

The fields were programmed and addressed via arrays like in the following figure (Figure 23).

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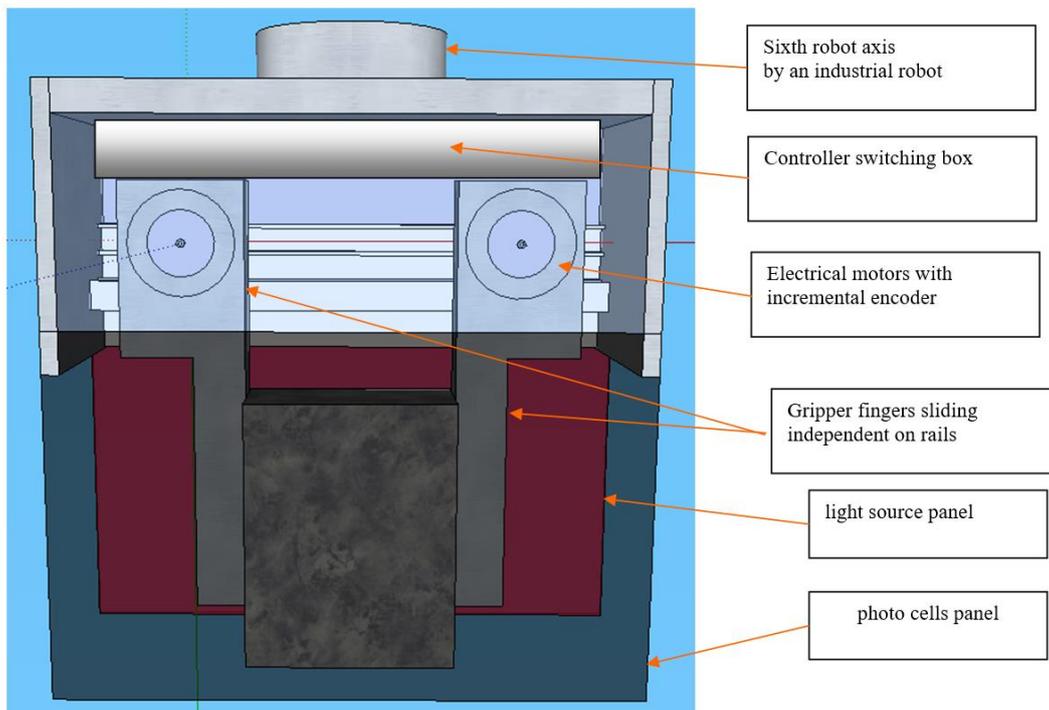
PROGRAM PLC_PRG
VAR
  Lichtfeld: ARRAY [1..8, 1..8] OF BOOL:=64 (TRUE);
  Result: ARRAY [0..63, 0..1] OF INT;
  X_Achse: INT;
  Y_Achse: INT;
  counter: INT:= 0;
END_VAR

FOR X_Achse :=1 TO 8 DO
  FOR Y_Achse :=1 TO 8 DO
    IF ( Lichtfeld [ X_Achse, Y_Achse] = FALSE)
    THEN
      Result [counter, 0] = X_Achse;
      Result [counter, 1] = Y_Achse;
      counter = counter + 1;
    END_IF
  END_FOR
END_FOR
    
```

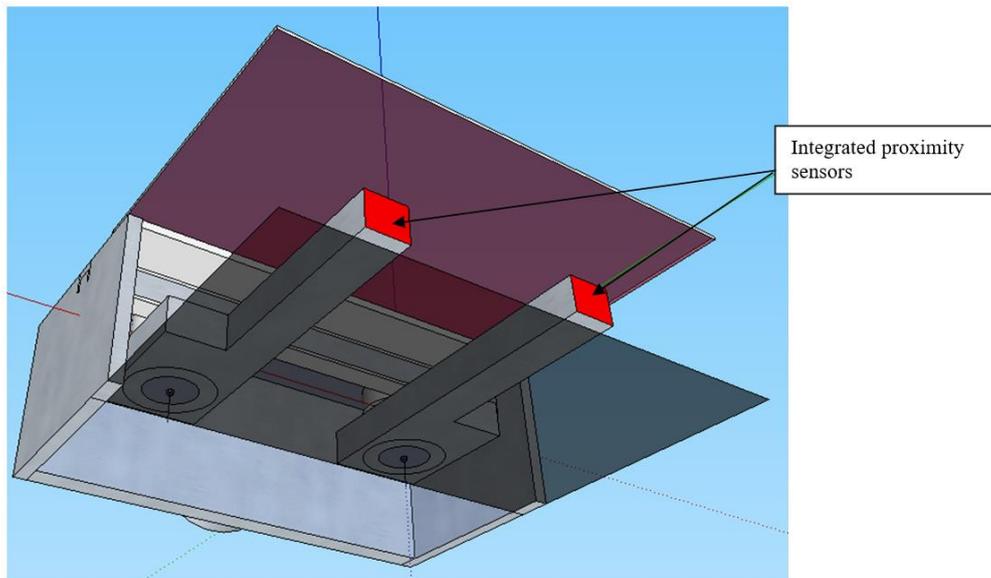
**Figure 23.** Arrays Code with CoDeSys

If the objects are located, the gripping process can be controlled through a routine of queries. The precision of the image detection and the accuracy of the gripping process are determined by the size of the arrays. The more pixels are detected, the more precise the gripping process can be controlled.

One way of implementing this principle was to attach the optics directly to the gripper (Figure 24). In this case, the optics is guided together with the gripper. This has the considerable advantage that the gripper can furthermore be made of metal for mechanical reasons. The optics and the associated electronics remain largely unaffected by the mechanical activities of the gripper.



**Figure 24.** Intelligent optical gripper



**Figure 25.** Optical gripper, bottom view

The object recognition can be captured by the attached optics independently of the IR system in real-time and the gripping process can be controlled directly through the integrated gripper controller.

By movements in the Z direction to the object, the gripper can be controlled by means of proximity sensors integrated in the gripper fingers (Figure 25).

#### 4. Conclusions

A major advantage of this gripper concept is the use of conventional and thus affordable optics together with standard grippers, or with adapted mechanics, which in turn can be produced from conventional materials.

With only one intelligent gripper it is possible to grip objects with different sizes and different shapes. The intelligent gripper automatically regulates the gripping force by means of the optics without having to be programmed. All this leads to cost reductions and production acceleration [16].

#### References

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- [3] \*\*\*Festo AG & Co. KG, Rüter Straße 82, 73734 Esslingen, Germany [https://www.festo.com/cat/de\\_de/products\\_010800](https://www.festo.com/cat/de_de/products_010800)
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