Control of an industrial robot by vision system

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7§Abstract— This document presents a 2-D vision system based on artificial intelligence and image recognition to control a manipulator robot arm Fanuc LR Mate 200 id. The iRVision tool was considered to perform the task of multi-object detection, two different localization techniques are used depending on the task complexity of the and the object to be detected. Filtering techniques are added to the system to overcome image saturation problems, thus combining these techniques with localization techniques helped to ensure the reliability of this system. Finally, LED-based red lighting was used to improve the detection speed and accuracy.

***Mots-clés*— 2D Vision System, iRVision, Fanuc LR Mate, Artificial Intelligence, Image Recognition, Lighting.**

I. INTRODUCTION

In view of the challenges of the Fourth Industrial Revolution (Industry 4.0) and the growing global rivalry, companies are facing many difficulties in gaining market share [1]. Robotisation and the use of modern technological tools will undoubtfully make it possible to overcome these problems. Industrial robot arms are machines capable of carrying out a wide variety of complex tasks, which makes it possible to improve the flexibility of industrial processes and to adapt it to the intensive production rhythm [2], and in order to increase the autonomy and the reliability of industrial processes, the implemented solution is the combination of manipulator arms with a vision system.

Vision systems are used in a variety of applications, they are integrated in industrial environments, medicine, machining and welding applications [3]. In agriculture, they are used during fruit picking and sorting also to avoid damaging the plans [2]. In recent decades, the evolution of collaborating robots has pushed researchers to rely on visual control to develop security algorithms [4, 5], such as trajectory planning according to the constraints of the working environment [6].

The visual control of the robots is effectively used to let the robot the recognize the object and locate it in the scene [2]. In general, 2D vision techniques are used in the manipulation of regular objects at the level of shape, color and position [3]. In the case of complex applications, the objects are of different colors and shapes and they are randomly placed, the work is more oriented towards the combination of 2D vision and image recognition algorithms [8].

3D vision also presents a powerful tool for the detection, it allows to solve the constraints related to the flexibility and the shape variation of the objects, by their capacity to follow the change in real time [2]. Laser-based vision systems are gradually evolving from day to day thanks to their wide detection zone, and their ability to ensure stable detection in critical environmental conditions (steam, dust ...).

Several researchers are currently working on the development of computer vision solutions as less expensive alternatives [11], but these techniques are less reliable due to their sensitivity to conditions in industrial environments [9].

In this work, we considered the 2D vision system iRVIS which is integrated into the controller of an industrial FANUC robot. iRVision offers several processing options and image recognition techniques by learning. First and foremost, it allows us to develop a multi-object detection application with an interesting precision and reliability. In order to evaluate the effect of the environment on the detecting process, a lighting solution has been implemented. The time of detection and the precision have been measured and the results will be presented.

II. SOFTWARE AND METHODS

In this section, the software, tools and method used to implement a multi-object detection application will be described.

A. The robot

The robotic company, Fanuc offers several types of robots for a multitude of uses and applications, The model considered in this application is the Fanuc LR Mate 200 iD with 6 axes, which can lift up to 7 kg with a range of 911 mm. His controller is the R-30iB equipped with a standard ethernet interface for the communication and general transfer of data. A 2D camera is connected to the robot through the standard protocols managed by the software packaged iRVision.

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Fig. 1 FANUC LR Mate 200id

B. The programming language, KAREL

KAREL is the programming language of Fanuc robots specifically developed for such manipulator arms. It is a derivation of the PASCAL programming language and allows the support of different techniques of logical and mathematical operations, allowing flexibility in the program structure.

```
1:  UFRAME_NUM=1 ;
2:  UTOOL_NUM=1 ;
3:  R[1:Notfound]=0 ;
4:L P[1] 2000mm/sec FINE ;
5:  ;
6:  VISION RUN_FIND 'A' ;
7:  VISION GET_OFFSET 'A' VR[1] JMP LBL[100] ;
8:  ;
9:  !Handling ;
10:L P[2] 2000mm/sec CNT100 VOFFSET,VR[1] Tool_Offset,PR[1] ;
11:L P[2] 500mm/sec FINE VOFFSET,VR[1] ;
12: CALL HAND_CLOSE ;
13:L P[2] 2000mm/sec CNT100 VOFFSET,VR[1] Tool_Offset,PR[3] ;
14: !Handling ;
15: JMP_LBL[900] ;
16: ;
17: LBL[100] ;
18: R[1:Notfound]=1 ;
19: ;
20: LBL[900] ;
```

Fig. 2 Program in KAREL[6].

C. iRVision

The robot company Fanuc has developed its own vision system called iRVision. It is a system comprised of cameras and laser sensors managed by a connexion software package with the controller. This system offers a lot of image processing and object recognition options that allows for high precision in applications.

Before starting up, the vision system requires several configuration tasks such as the calibration and the definition of the parameters of the workspace. The following figure shows the configuration of our vision system.

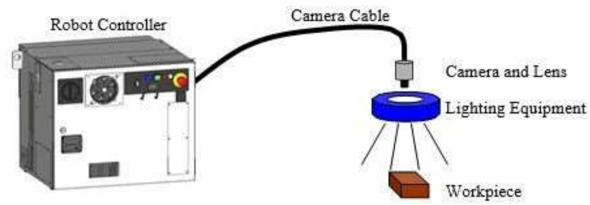

Fig.3 Basic iRVision[10]

D. Lighting system

The type of lighting chosen has a lot of impact on the image processing. In the case of this project, access to the lights was limited to the red LED light and the white LED light that comes from the ambient lighting. The difference between these two types of lights is that the white light contains all electromagnetic radiations of the visible spectrum that have a wavelength between 380 nm and 720 nm and the red light has a wavelength between 622 nm and 700 nm. The following figure shows the same image taken three times with different types of lighting. The image with the most details is the one that just has red light and the one that just has white follows it very closely. The one that has less contrast in the background is the one that has both types of lighting which will happen most often in a factory setting. This contrast can be considered a good thing, because it allows the device to ignore the details that are superfluous and focus on the desired object. Making the object stand out more in comparison with the other cases.

Fig. 4 Impact of different lightings

III. APPLICATIONS

In this section, the tools and methods used to implement the multi-object detection application will be described.

A. Calibration of the camera

The calibration of the camera is a necessary step for the correct function of a detection operation. In this application, the choice of a fixed camera makes it possible to detect the parts during the operation of the robot and to reduce the processing time. The location of the camera is very important for determining the focal length and the distance between the object and the camera.

If these parameters are well defined, the vision system is able to calculate the offset between the position of the part in the learning phase and the actual position during the detection phase. The angle in which the camera is placed is also important. If the angle is too large, there will be a distortion in the image in the extremities of the field of vision. Figure 5

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shows the location of the camera fixed in a 90-degree angle that allows for good vision zoning included in the lighting area. The calibration of the camera depends mainly on the nature of the application. For this, we find several calibration grids (Figure 6) that provide the ability to adapt to the specifications of each operation.

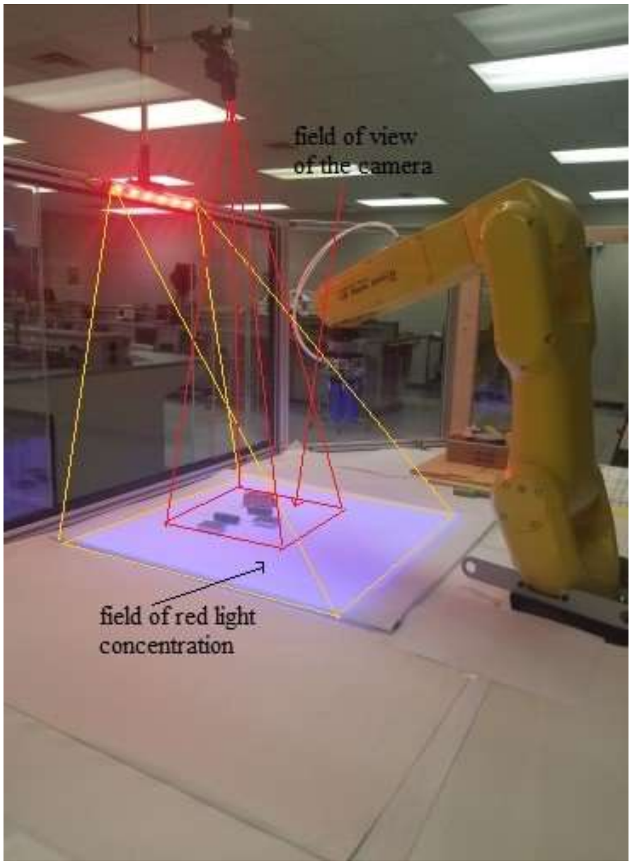

Fig. 5 Zoning of the light and the camera

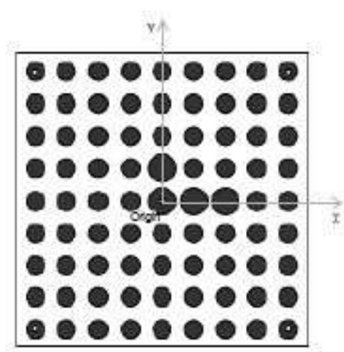

Fig. 6 Camera calibration grid for the Fanuc robot [3].

B. *Calibration of the tool*

The calibration of the tool is a very important step in giving the robot the new point of origin of the coordinate system relative to the center of the robot flange. Here, an emphasis was placed on the calibration of :

- The TCP (Point Center of the tool).
- The alignment of the coordinate system

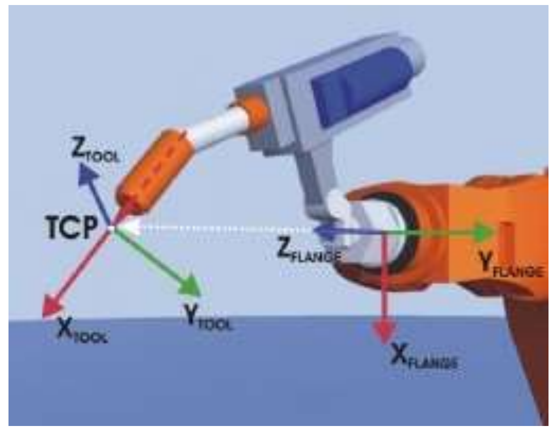

Fig. 7 Example for origin of the coordinate system (TCP) of a device [12].

There exist several methods of calibrating the tool. For this application we will use the Three Point method which is to approach a point with the tip of the tool in three different directions. For the three different paths, it is better to be almost at the same point for better accuracy.

C. *Image processing with iRVision*

The iRVision vision system offers several localization tools, color filtering features and contrast enhancement techniques. In this application two different types of position locator have been used:

- GPM Localization tool: This device looks for the similarity between the models saved in the database and the detected object based on the shape of the contours. This type of tool is reliable for detecting objects with shapes of low complexity. The following figure shows the principle of finding the percentage of compatibility between the two images of the object.GPM Localization tool: This device looks for the similarity between the models saved in the database and the detected object based on the shape of the contours. This type of tool is reliable for detecting objects with shapes of low complexity. The following figure shows the principle of finding the percentage of compatibility between the two images of the object.

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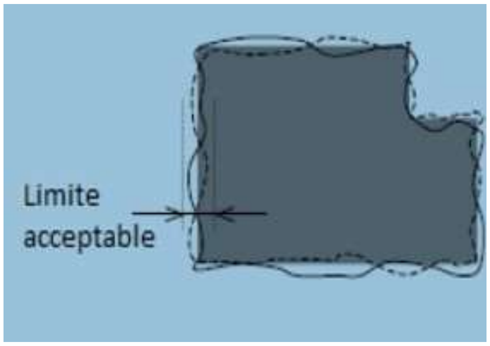

Fig. 8 Operating principle of the GPM Locator [10]

- CSM localization tool: This tool is based on the gradation of light on the surface of the object. It is often used for recognizing objects that have more complex details. Figure 8 shows the operating principle of this tool.

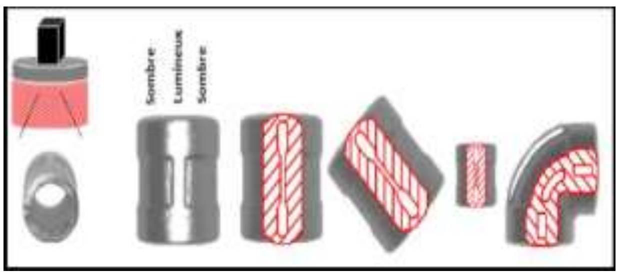

Fig. 9 Operating principle of the CSM tool [10]

To improve the accuracy of the application, we applied filters on the photos of the base model. Unnecessary or non-regular details have been ignored. The application is dedicated to multi-object detection while the two location tools are applied to three different 3D objects in terms of shape and complexity of details as shown in the following figure.

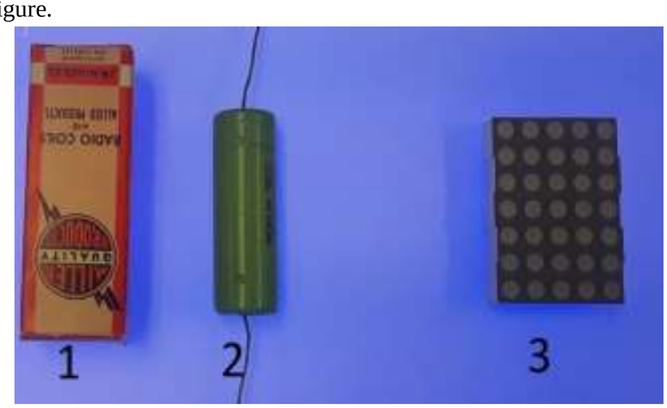

Fig. 10 The detected objects

During the learning phase, it is important to well initialize the three following parameters: location, orientation and scale. A good configuration of these parameters makes it possible to ensure the accuracy of the calculations of the point of origin of the objects which is detected in accordance to their location and orientation.

The number of images recorded in the database greatly influences the success rate of detection. The more the models are dissimilar, the greater the risk of having similitudes for critical cases. The following figures show some models registered in the database for the GPM locator tool.

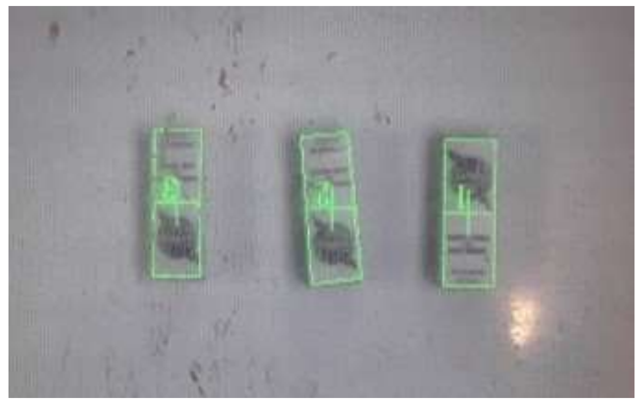

Fig. 11 Model taught for object 1

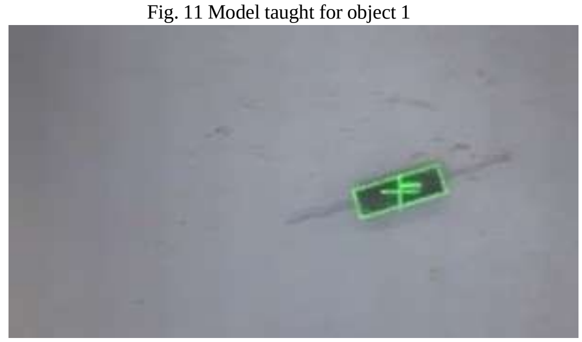

Fig. 12 Model taught for object 2

Fig. 13 Model taught for object 3

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D. Image processing principle with iRVision

The following flowchart explains the principle of the detection application based on the iRVision vision system with 2D camera.

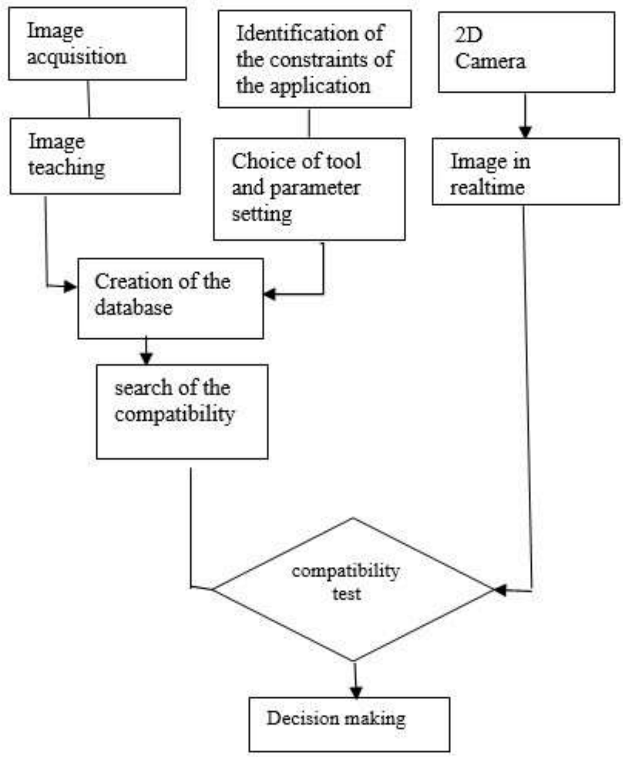

Fig. 14 Principle of the vision application with iRVision

E. Real-time implementation and experimental results

During the implantation, we tried two localization processes for two different conditions. One with red LED-lighting and the other under ambient lighting. The following table shows the detection times for each object in the different experiments.

TABLE I
DETECTION TIME OF DIFFERENT OBJECTS

	GPM Locator		CSM Locator	
	Red lighting	Ambient lighting	Red lighting	Ambient lighting
Objet 1 (t= s)	0.57	0.89	0.49	0.68
Objet 2 (t= s)	0.45	0.61	0.40	0.58
Objet 3 (t= s)	0.39	0.49	0.34	0.46

The results show the effectiveness of red specific illumination in vision applications. The long wavelength limits the saturation of the colors. The CSM locator is more efficient at detecting objects whose details are too complex.

The tests are done in several scenarios. Each time, the objects are oriented at 30 degrees in the field of view. The following table summarizes the accuracy of the application with respect to the center of the object defined earlier in the learning models.

TABLE II
DETECTION TIME OF DIFFERENT OBJECTS

	GPM locator	CSM locator
Objet 1 (Error en mm)	3.57	2.8
Objet 2 (Error en mm)	2.97	2.25
Objet 3 (Error en mm)	2.85	2.6

IV. Conclusions

A 2D vision system implemented on a Fanuc LR Mate 200 id industrial robot was presented with the objective of having a multi-object detection application. The approach combines the vision system with a specific lighting technique using red LEDs to limit color saturation. The models taught with this lighting have more details than those taught under ambient lighting. It has been shown that the processing time has been reduced by more than 30% for the first object, 26% for the second and 20% for the third, which summarizes the impact of industrial lighting in vision applications.

After several tests for both types of location and with a well calibrated and well positioned fixed camera, the experimental results show the effectiveness of the CSM locating technique whose average accuracy error is around 2.55 mm under the various orientations and position of the considered objects.

However, the proposed techniques can be combined with other detection sensors (LIDAR, 3D laser ...) or computer vision algorithms to manage more information on the profile of the objects.

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