

## VISION GUIDED PARALLEL ROBOT AND ITS APPLICATION FOR AUTOMATED ASSEMBLY TASK

Vladimír Bulej<sup>1</sup>, Ján Stanček<sup>1</sup>, Ivan Kuric<sup>1</sup>

<sup>1</sup> University of Žilina, Faculty of Mechanical Engineering, Department of Automation and Production Systems, Univerzitna 1, 010 26 Žilina, Slovak Republic, e-mail: vladimir.bulej@fstroj.uniza.sk

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### ABSTRACT

The article deals with the application of vision guided parallel robot FANUC M-1iA for automated assembly process. Vision system is used for object identification and filtering the data about its position and orientation. Control system based on iR Vision system can process data collected from camera Sony XC-56 fixed to the frame and navigate the end-effector to grasp and move selected objects. Integration of vision guided robot control into the high speed parallel robot can be highly productive. The functionality of vision guided robot system is demonstrated at automated assembly process of USB memory stick with variable positioning of its components.

**Keywords:** Vision guided robot, delta robot, vision system, FANUC M-1iA.

### INTRODUCTION

Engineers and designers of automated assembly systems around the world are constantly forced to ensure high productivity and low manufacturing costs of their solutions. Because of the ever-increasing requirements on flexibility, complexity and variability of the assembly robotic cells, it is more difficult to provide the sufficiently robust solution. There are several options to fulfil these requirements, such as optimization through the suitable CAx systems [10], simulation of robot motion (for example in ROS platform), application of the so-called collaborative robots [8, 13] and application of different type of advanced and intelligent sensors or other advanced mechatronic units [16].

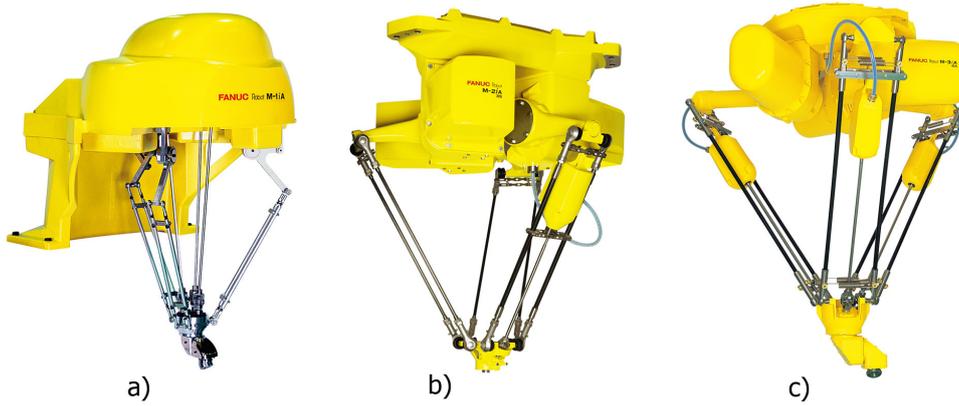
Nowadays, it is going to be very advantageous to integrate the fast vision systems on high speed robots, especially with parallel kinematic structure, to maximize productivity of the whole system. It seems to be the best alternative to apply their commercially very successful type, called delta robots, for this kind of tasks.

A Vision Guided Robot (VGR) system is basically any robot system equipped with one or more

cameras [1]. They can be used as auxiliary sensors to provide a feedback signals for robot control unit. As the result can be obtained very precise motion to a variable target position. VGR systems enable robots to be highly adaptable and more easily implemented on this kind of tasks, whether for material handling, automated assembly, food industry applications, etc. They can reduce the costs and complexity of robotic cells at the same time.

On the other hand, the robots with parallel kinematic structure are interesting mainly due to their high dynamics, suitable stiffness as well as positioning accuracy compared to the serial robots [7]. The basic idea behind the delta robot design is the useage of parallelograms and base-mounted actuators with low-mass and low inertia. It allows to achieve large acceleration of robots and its end-effector. It is well known that this type of robots can reach the acceleration up to 15 times gravity in industrial applications [3, 6].

The article deals with the application of vision guided parallel robot FANUC M-1iA with integrated iR Vision system for automated assembly process of USB memory stick. There are described the steps of solution of defined problem.



**Fig. 1.** Three different sizes of FANUC delta robots – from smallest (left) to biggest one (right): a) M1-iA, b) M2-iA, c) M3-iA [7]

### TESTING WORKPLACE WITH DELTA ROBOT AND VISION SYSTEM

Laboratory of parallel mechanisms were developed at the Faculty of Mechanical Engineering at the University of Zilina during the last years. One of the key elements is a special robot workcell for testing such system functionality composed of:

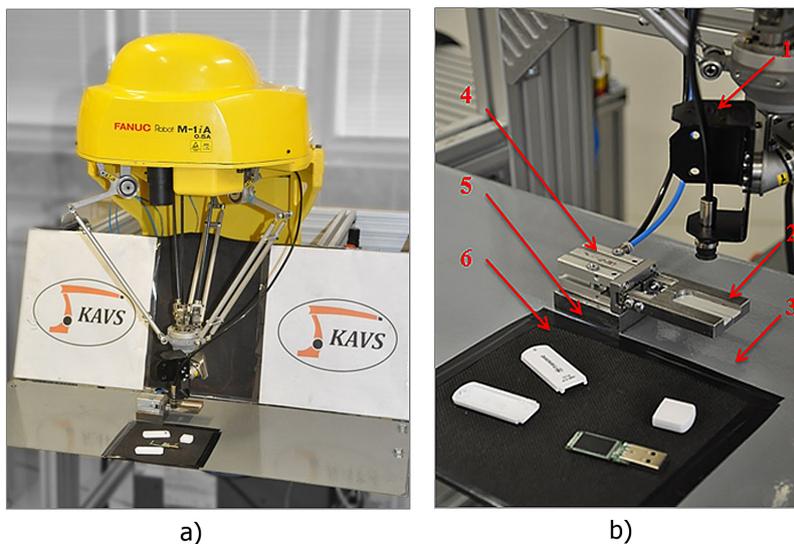
- delta robot FANUC M-1iA/0.5A with control unit R-30iB and Teach pendant
- and iR Vision system.

### DELTA ROBOT FANUC M-1IA

There are currently three different sizes of FANUC delta robots available on the market, from

smallest to the biggest one: M-1iA, M-2iA and M-3iA. All can be delivered in some modifications, like with 4 or 6 DOFs (degrees of freedom), with increased operational range or payload capacity (Fig. 1). These robots are ideal to automate tasks which so far were too fast and too complex for standard serial robots. In addition, this new family of robot series offers the motion flexibility of a human wrist, fast cycle times, ultra-compact arm and precision. It is also possible to support intelligent functions using iR Vision [6].

For our application we decided for the smallest delta robot called M-1iA/0.5A with 6 DOFs. This robot has a cylindrical workspace with maximum diameter 280 mm and height 100 mm. The maximum payload is limited to 0.5 kg included



**Fig. 2.** Workplace with delta robot FANUC M-1iA (a) and decomposed USB stick – the object of automated assembly process (b): 1- holder with suction gripper, 2- fingers of assembly jig, 3- table, 4- two-fingers gripper, 5- support pad, 6- contrast material inside the range of camera

the end-effector. The testing workcell as well as the individual components used for assembly process is shown in Figure 2.

## COMPUTER VISION SYSTEM

A general vision system comprises a camera and microprocessor or computer, with associated software. This is a very wide definition that can be used to cover many different types of systems which aim to solve a large variety of different tasks [2, 4]. Vision system equipped by suitable algorithms can be used for quality control to check dimensions, angles, colour or surface structure or for the recognition of an object as used in VGR systems [15, 12].

The vision system provides the data distribution about shape and location coordinates of components spread out randomly beneath the camera's field of view to the robot controller. It enables to navigate the robot arm with attached end-effector (in our case suction gripper) to the selected component and grasp it from static pick-up position or belt conveyor. In case of picking-up parts from conveyor there are two options - with or without stopping of conveyor [9]. Suitable conveyor tracking system are used for synchronization of both, the robot and conveyor in the second case.

### Hardware

Camera system was installed on our FANUC M-1iA robot, which will serve the robot guidance and creation of programs supported by iR Vision system. This configuration enables the implementation of handling tasks with variable components location on designed workplace. Hardware part of iR Vision system is made up of camera Sony XC-56 (in Fig. 2, left - the black cylinder mounted in the middle of robot frame), the lens and connecting cable. The software tool is based on web server, which is running in personal computer connected to the robot control system with Ethernet cable.

The applied camera Sony XC-56 is connected to the robot control unit by special JRL6A port, which is located on the base panel. Before the first use of the camera in iR Vision system is necessary to configure the hardware. Configuration is carrying out by DIP switches that are located on the back side of the camera. Thanks to the configuration step the camera can be placed in a fixed point (static camera position) or it can be mounted on the robot arm. For our applications with robot M1-iA fixed camera location was chosen.

### Software

Among others, the WEB server is a universal platform for communication with robot control system [5, 14]. It can be used to configure the camera, to create the software tools for part identification, monitor the actual state of robot, actual list of programs, etc. [11]. The initial setting of WEB server contains following steps:

- robot connection to local network (LAN),
- entering of robot IP address into a web browser (Internet Explorer 6 and above) and
- installing of required controls tools.

### VISION SETUP PROCEDURE

After the hardware configuration an application Vision Setup is started in WEB server environment. There can be shown any default setting as well as can be set and change any of system parameters. The iR Vision main menu contained set of basic tools is displayed on the left-hand side of the screen.

The configuration contains following tools or steps:

- Camera Setup Tools – basic settings and camera configuration.
- Camera Calibration Tools - camera calibration for our scene, hardware configuration and conditions.
- Process Vision Tools – preparing of a special testing task.

### Camera Setup Tools

At the beginning port number where the camera is connected was selected. Control system recognizes the type and parameters of all connected cameras and it creates a list of them automatically. Then the user can simply select the one which will be used for the solved task. Already in this configuration step (Camera Setup Tool) the user can see first camera image outputs thanks to the function Live Image or Snap. For any cases when the higher image output quality is needed the optimum exposure settings can be set by parameter Exposure Time with respect to the lightning conditions.

There must be set also the zoom, focus and aperture ring located in lens cylinder with respect to the distance between the robot frame and working table, size of pick-up area as well as to the light conditions. In our case the camera can see the area with dimensions approximately 150×150 mm which is covered with a non-reflecting black material (Fig. 2, right).

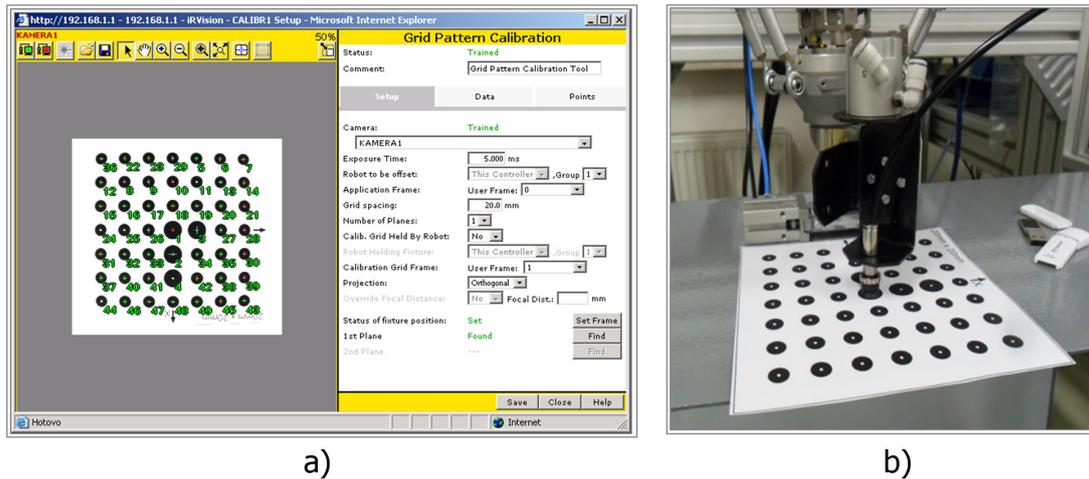


Fig. 3. Screen of Camera Calibration Tool (a) and calibration grid for alignment of camera and robot coordinate system during configuration of iRVision system (b)

### Camera Calibration Tools

The next important configuration step is camera calibration. Calibration process allows vision systems to “understand” relation between camera and robot coordinate system and will return real-world coordinate data. The process usually involves a dot grid or checkerboard pattern, typically called a calibration plate or calibration grid. It is necessary to have it calibrated with high accuracy for vision guided robot system.

Calibration is performed by using predefined models in a form of two-dimensional grid with different size - from 6.5×6.5 mm up to 30×30 mm in order to sizes of workspace. In our case we use the calibration plate with grid spacing of 20×20 mm (Fig. 3). Calibration is related to a specific User Frame, which can be selected directly in the

calibration window. The properties of used lens and scanned objects can be described by the type of calibration projections. This parameter may be either orthogonal or perspective.

Now we will choose the method for definition of coordination system (FANUC use the name User Frame). User Frame can be set by three point method, four point method or direct entry. We choose the three points method based on definition of one orient origin point and one point for each axis (axis X and axis Y).

When we have finished the calibration procedure, our robot knows the position and orientation of selected coordinate system. It means that the distance between coordinate system plane X-Y and the robot frame (it means the high in Z axis) is defined.

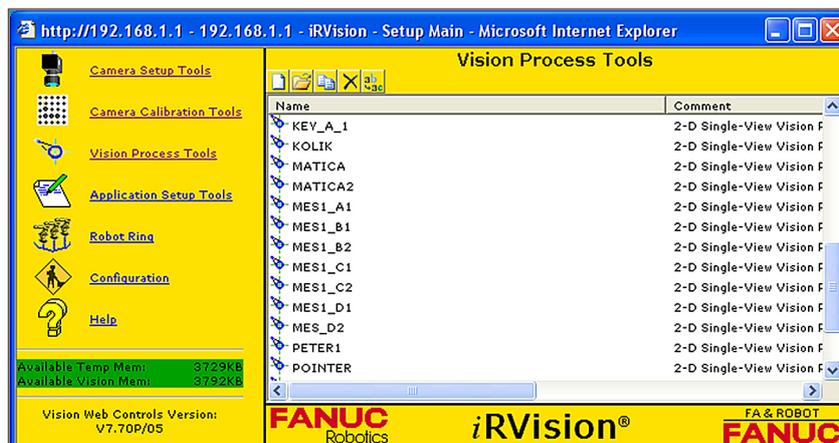


Fig. 4. List of all Vision Process Tools

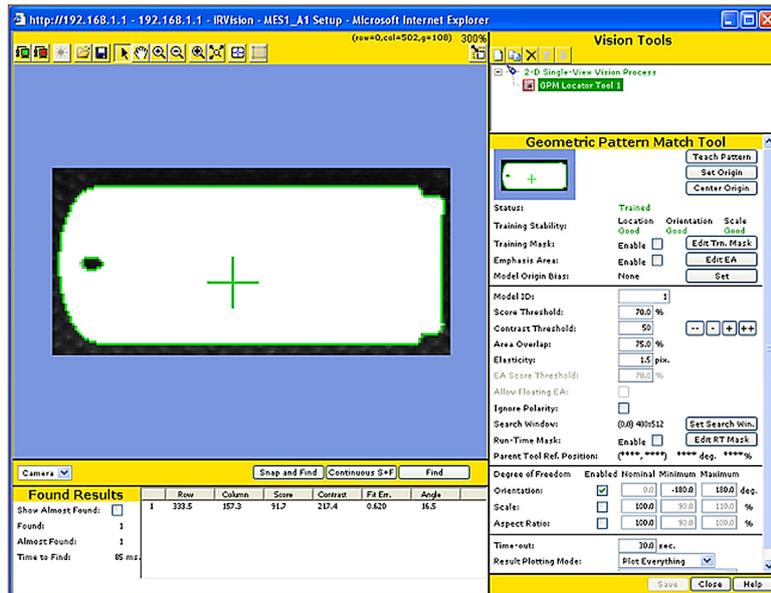


Fig. 5. Main window of Vision Process Tool “MES1\_A1” for identification of the first part

### Vision Process Tools

Designing and configuration of our visualization task by using Vision Process Tools is the last basic step of a preparation phase in the system iR Vision. There it is necessary to create an individual process tool for each object or component of assembly process. There were created 4 unique tools (Fig. 4): MES1\_A1 for the first part (bottom half of body), MES1\_B2 for the second part (electronic board), MES1\_C2 for the third part (upper half of body) and finally the MES\_D2 for the fourth part (cap).

Every single process tool has attribute as 2D-Single-View Vision Process Tool. Using these

vision process tools the objects can be detected by camera. The basic requirement is that for each object must exist the pattern stored in memory of control system. The first part (Vision Process Tool “MES1\_A1”) is placed on a working table inside the range of camera.

We are taken its photo and then pressing the button Teach Pattern, which activates a selection window for identification of part borders (highlighted by green curve - see Figs. 5 and 6). Consequently we can set parameters collected in right-side panel. Such parameters as Set Origin point (gripping point shown as green cross) which will be aligned with gripping point on real part, Edit Train-

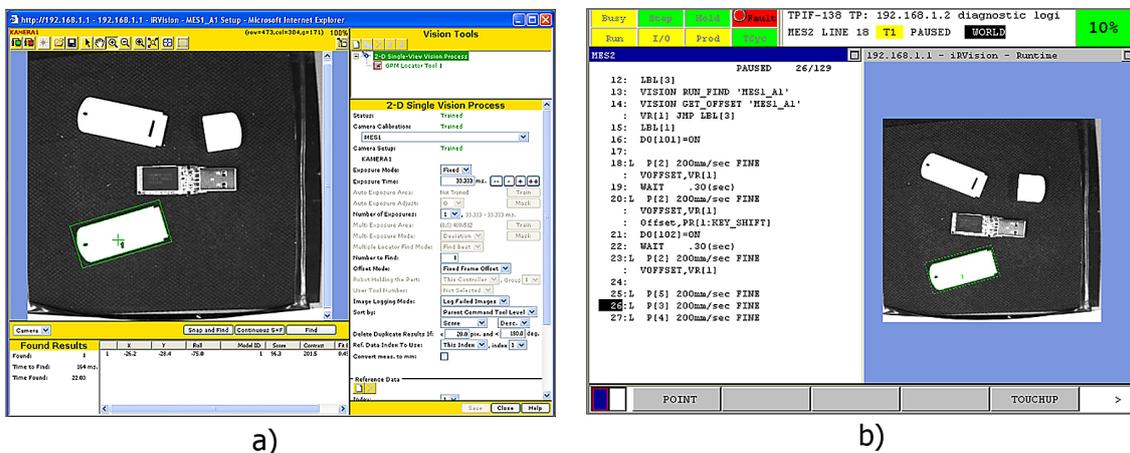


Fig. 6. Vision Process Tool “MES1\_A1” for the first part: the screen of Web Server after Snap and Find process (a) and the screen of Teach Pendant (b)

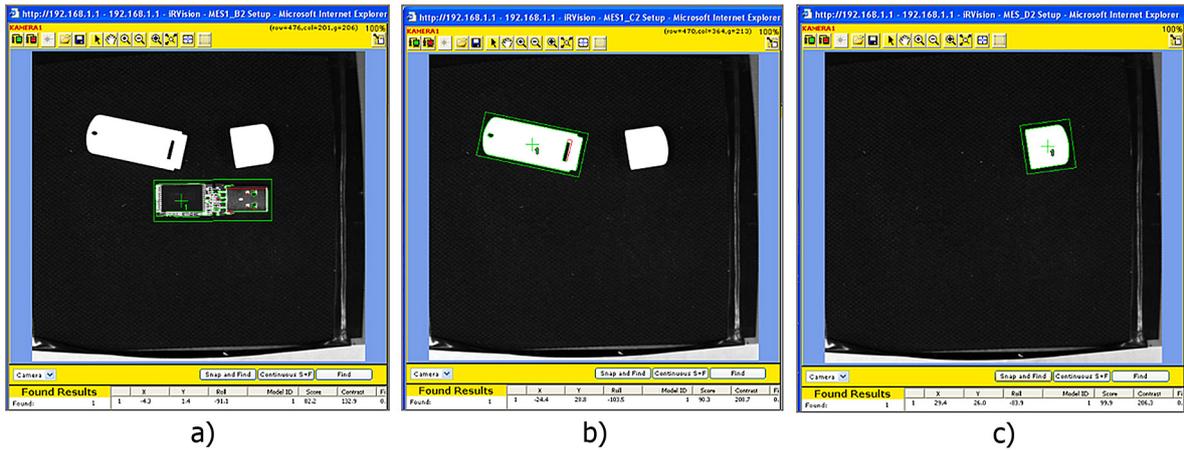


Fig. 7. Vision Process Tool “MES1\_B2” (a) after Snap and Find and identification of the second part (green border line), “MES1\_C2” (b) after identification of the third part and “MES1\_D2” (c) after identification of the fourth part

ing Mask (for filtering of non-important elements of the part), Score Threshold, Contrast Threshold, Overlap, disable or enable and set some range for orientation, etc. can be edited. Gripping point can be freely moved anywhere on the subject.

The same method was applied for all other parts. The screenshots from finding process are

shown in Figure 7. You can adjust the contrast, exposure time, the percentage of compliance, method of sorting as well as the number of exposures and many others.

If parameter Orientation is not selected, iRVision will ignore the angle of object. For assembly tasks where it is necessary to orient objects is

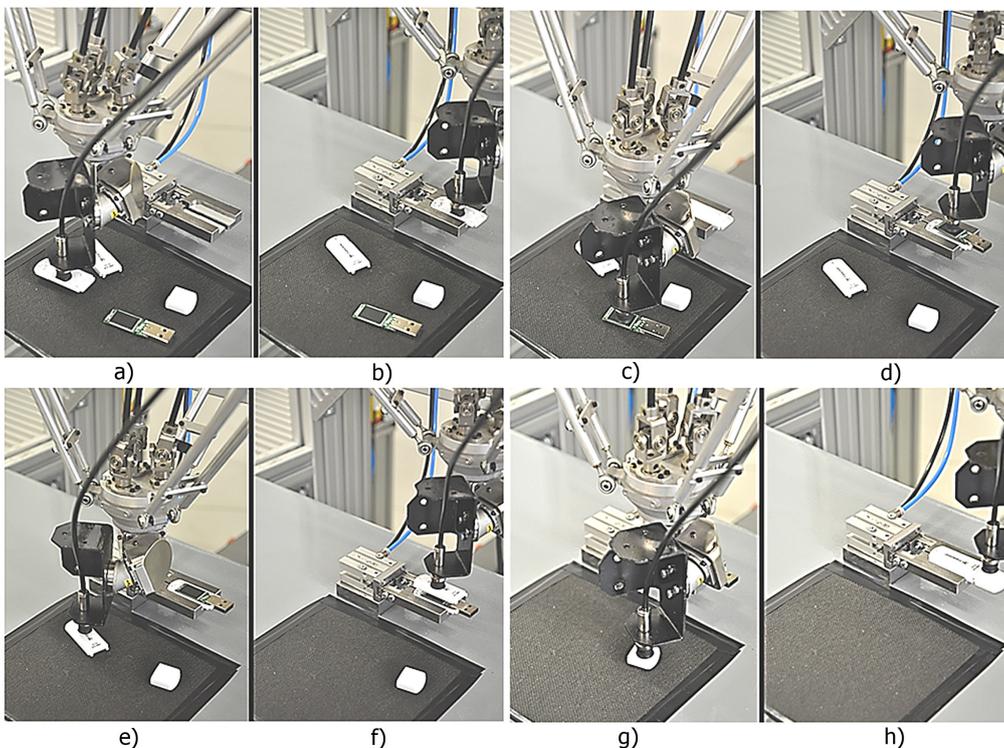


Fig. 8. Assembly process of USB memory stick: base part picking (a) and in assembly position (b); electronic board picking (c) and in assembly position (d); upper part picking (e) and in assembly position (f); cup picking (g) and in assembly position (h)

VISION 1		VISION 2		VISION 3	
1	RUN_FIND	1	VR[] .MODELID	1	RUN_FIND SR[]
2	GET_OFFSET	2	VR[] .MES[]	2	GET_OFFSET SR[]
3	GET_PASSFAIL	3	VR[] .FOUND_POS[]	3	SET_REF SR[]
4	GET_NFOUND	4	VR[] .OFFSET	4	CAMERA_CAL SR[]
5	SET_REFERENCE	5	VR[] .ENC	5	GET_PSSFAIL SR[]
6	OVERRIDE	6	VR[] .STRING_RES	6	GET_READING
7	CAMERA_CALIB	7		7	
8	--next page--	8	--next page--	8	--next page--

Fig. 9. Vision functions available in FANUC iR Vision system

the absence of this setting inadmissible. In Figure 8 the real assembly process controlled by iR Vision system is shown.

### ALGORITHM AND THE MAIN PROGRAM

The definition of start (reference) point requires its physical touching by robot end-effector (the robot must be guided to this point manually). This point is stored the same way as any standard point P[n] by Teach Pendant panel. At this point the function offset by Vision register VR [n] can be applied. Then, any point of interest and any path (linear or joint motion) can be described with respect to the reference point by pure offset coordinates. List of available FANUC Vision func-

tions is shown in Fig. 9. An example of functions Vision Run\_Find and Vision Get\_Offset is shown in the below figure.

The basic vision functions applied in standard program for image processing are:

- VISION RUN\_FIND ‘VisionTool’
- VISION GET\_OFFSET ‘VisionTool’ VR[n] JMP LBL[n]

The function RUN\_FIND opens a specific user-defined Vision Process Tool. GET\_OFFSET function extracts any position data from a particular vision process as well as it saves them into a Vision register VR[n]. In case the vision process was aborted (it doesn’t find the object), make a jump to label LBL [n]. When all Vision Process Tools are prepared, we can start to de-

11: J P[13] 100% FINE	; Home position of the robot
12: LBL[3]	; Label number 3
13: VISION RUN_FIND 'MES1_A1'	; Run finding procedure for the first part 1
14: VISION GET_OFFSET 'MES1_A1'	
VR[1] JMP LBL[3]	; In case you detect part - Get offset data, Else jump LBL[3]
15: LBL[1]	; Label number 1
16: DO[101]=ON	;
17: ;	
18: L P[2] 200mm/sec FINE VOFFSET,VR[1]	; Move linear to point 2, over the part 1
19: WAIT .30(sec)	; Wait 0.3 second
20: L P[2] 200mm/sec FINE VOFFSET,VR[1]	
Offset,PR[1:KEY_SHIFT]	; Move linear to point 2, touch the part 1
21: DO[102]=ON	; Activate suction cup
22: WAIT .30(sec)	; Wait 0.3 second
23: L P[2] 200mm/sec FINE VOFFSET,VR[1]	; Move linear to point 2, over the part 1

Fig. 10. Part of main program for detection of the first part in FANUC iR Vision system

sign the main program (Fig. 10) according developed algorithm.

## CONCLUSIONS

Nowadays, there are some difficulties of integrated vision system to match the camera with the set expectations of the system. In most cases, this is caused by lack of knowledge on behalf of the integrator or machine builder. Many vision systems can be applied successfully to virtualise any production activity, as long as the user knows exactly how to set up system parameters. The performance of such an assembly system is heavily dependent on the placement of the camera and light source, as well as proper algorithms and precise set-up.

This article presents an example of automated assembly system based on application of high speed parallel robot FANUC M-1iA with integrated iR Vision system. The effectiveness of the algorithms and set-up of whole system was illustrated on a typical small-scale mechanical assembly task – assembly of USB memory stick. Nowadays, we can see that the number of applications of robots guided by vision system is still growing. Therefore continuous development and intense improvement process is highly desirable. However, it may be concluded that VGR system can provide a low cost, accurate and efficient solution to the automated assembly problem.

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