ROBUST AUTONOMOUS ASSEMBLY IN ENVIRONMENT WITH RELATIVELY HIGH LEVEL OF UNCERTAINTY

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Abstract:

This paper deals with issues of robustness and adaptivity in a real-world automated assembly system. The focus of research is set on robustness achieving for constantly changing environmental conditions, especially light conditions and changing orientation, position and distribution of the parts for assembly. An increase in the level of information/knowledge used by the robotic system means a relative increase in the level of control. Combination of different types of sensors (vision – mobile camera, laser, optical, etc.) is used as a main perception for exploration of the robots' work space. Developed application shows that proper combination of sensors ensures consistent information flow. In this manner stochastic information variation is minimized and robustness of the system increased.

Keywords:

assembly, robustness, recovery, sensors, control

1. INTRODUCTION

Every environment is naturally unstructured, what can be revealed if it is observed under fine enough scale. In other words, it is not possible to completely determine any environment, no matter how tight tolerance ranges may be applied. Unconstrained environment is though usually introduced to the system through application of tolerances. This is connected with issues of sensitivity and instability and may result with malfunctioning systems for small environmental changes [1].

To ensure robustness, other approaches have to be utilized. The system has to be able to perceive the environment it deals with. In human psychology, it is determined that the level of intelligence (IQ) positively correlates with the sensory capability i.e. quality of eye-sight, hearing, etc [2]. Prerequisite for intelligent behaviour of any artificial system is thus ability to perceive its environment. In the work presented here, environmental perception is achieved by combining different types of sensors, machine vision systems in the first line. Using the camera, additional information is extracted from the environment and can be used for broader set of action of the system. Positive correlation between the amount of the information and possible level of autonomy and intelligence is obvious. The system that can not perceive the environment has to be programmed for a limited range of actions foreseen in advance from the programmer. Such a system can not, by default, act in any unpredicted situation, in the best scenario it could send a signal that an unpredicted situation has occurred.

On the contrary, the system that perceives the environment can be programmed in another manner. The programmer of the system has to decide only how to use information the system gathers autonomously. Apparently – the information obtained are expected to change constantly. The change in information is the consequence of different environmental conditions, for example – change of position of the part for assembly will result in different coordinates the robot receives from the camera. This can be called expected informational change. Yet, another, inconvenient change can occur as a result of changed light conditions or vibrations for example and introduce change in quality of information extracted from environment This can be called stochastic informational change and is problem difficult to solve due to its stochastic nature. One way of solving this problem may be in applying light isolated chamber around the work space of the camera, or by applying sophisticated and expensive light etc. In the work presented here, the issue was how to extract information which determines the part, coordinates of the centre of gravity and the angle in a convenient way for working place that has not isolated light chamber or special light, but conventional neon tubes.

2. CONCEPT OF AUTOMATIC ASSEMBLY SYSTEM

In an automatic assembly the control of a system is usually connected to the control of the working environment. Uncontrolled situation is any situation where any object or subject is not completely defined from the aspects of position, orientation, action and/or process. In order to get an automatic system controlled, the corresponding knowledge about the system and process must exist. The handling operations denote the operations that move objects from-to required positions and orientations. The transition from the free to the controlled/known spatial state is one of the most demanding tasks in automatic processes [3].

By using machine vision in an automatic system, the information about the position and orientation of the work objects can be acquired dynamically during the process. In this way, the state of each object is determined, even if the objects are freely located, and consequently, the assembly system becomes controlled.

The assembly system used for experiments was initially developed as virtual CAD model in CATIA V5, see *Figure 1*.

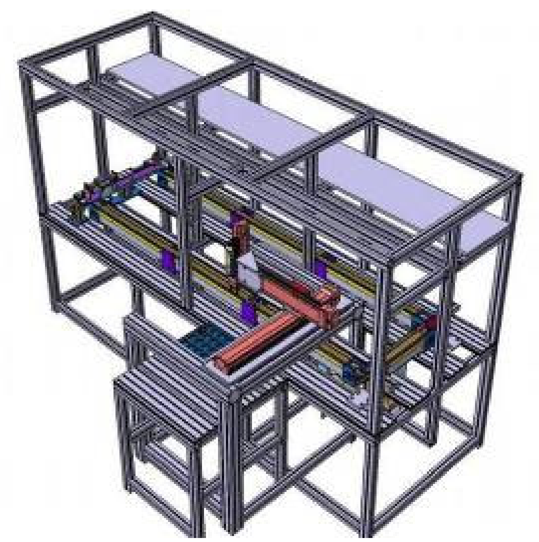

Figure 1: Initial concept of the assembly line

Because of limited field of view, camera was mounted directly to the vertical axis of manipulator, *Figure 2*.

Figure 2: Position of the camera mounted on the vertical axis of the robot

The result of mounting the camera to the vertical axis was increase in efficiency due to the ability of the robot to receive the part's image in higher resolution and to explore large work space at the same time, limited only by the physical size of the robot. The robot implements following behaviors: inspect the line if product carrier is present, search for parts, and inspect inserted part respectively. The robot consists of two linear IAI axis, 600 and 400 mm, for horizontal plane and 250 mm axis for the vertical movement. Fourth axis is rotational IAI robot-cylinder with gripper for picking the parts.

Machine vision application contains 2D machine vision system which is connected to the PC computer and controller. Smart camera is placed direct on the arm of four-axis manipulator. Manipulator with camera on it scans the working area to find parts to assembly. When the smart camera detects the part, it sends the data to robot controller via Ethernet. Controller receives the data, processes them and with respect to processed information sends the manipulator to pick and place detected part. In this case vision system provides robots to work conveniently in an environment with high level of uncertainty. First, smart camera on manipulator checks the assembly line for product carrier presence. Product carriers are used for part nesting and transporting to next assembly place.

After the camera detects empty product carrier on assembly line, controller will send manipulator with camera on it to scan area to find the part, collect them and put them into the product carrier. If camera detects non empty product carrier on the assembly line, controller will receive acknowledge and skip this product carrier further to the next assembly place without sending the manipulator to find the part.

Assembly parts have to be placed in product carriers with very tight clearance (approximately 0.1 mm) directly on the assembly line what is relatively difficult to achieve because of constantly changing environmental conditions. Despite it is rare, it is also possible and predicted for manipulator to occasionally make a fault. Regarding to developed application fault ratio is about 1 of 30 (3.3%). In order for system to correct the fault, combination of optical and laser sensors has been used. As it is shown at *Figure 3*, there are four possible ways for manipulator to put the part into the part carrier incorrectly.

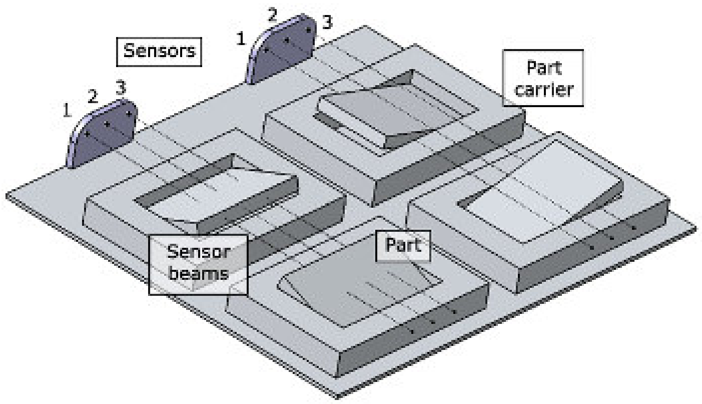

Figure 3: Four possibilities for putting part incorrectly

It is important to know which case of misplacement has occurred. Manipulator is programmed for grasping the part for two different positions – from the head and from the side. *Table 1* shows "Table of action" where it is determined for manipulator to make an action depending on sensors outputs.

	Output	Output	Output	Output	Output	Output
Sensor 1	0	1	1	0	0	1
Sensor 2	0	1	0	0	1	1
Sensor 3	0	1	0	1	1	0
Action: part removing approach	don't remove the part	wide side	narrow side	narrow side	narrow side	narrow side

Table 1: Table of action

With respect to information collected from sensors, manipulator will exclude part from the product carrier and put it back to initial point of the first assembly line which is used for feeding the station with parts to be assembled.

Prior to DVT Smart Camera communication setup procedure it was needed to setup cameras software overall. The DVT has a simple, easy to use PC interface software package called Intellect (Intellect version 1.2.2 was used for this application).

It was very demanding to find the efficient way to provide the communication between DVT 540 Smart Camera, IAI Controller and PC via Ethernet. To establish a communication it was necessary to setup communication parameters. The X-SEL controller acts as a server with the PC and/or DVT as clients. To set up such hierarchy it was necessary to enter the IP addresses of both devices (DVT camera and PC) in the X-SEL parameter file.

The first step after connecting a DVT Smart Camera with PC via Intellect is to make a coordinate transformation. Coordinate transformation establishes relationship between the vision sensor, image pixels and the plane of the real world that the vision sensor is imaging. For our application this allows position and orientation of detected part to be reported in the manipulator space.

After coordinate system determination it is necessary to setup appropriate vision tools to achieve coordinate and orientation information of detected part. For this application particularly combination of two Area Positioning Vision Tools was used: Blob Locate and Object Locate. Our research shows that combination of these two tools is optimal choice because it is insensitive to non-uniform lighting and low illumination. The Area Positioning

Vision Tools searches in the FOV for the location of a single object or feature that is trained. This type of vision tools were used in combination with a coordinate transformation to give the coordinates of a part to external device. To determine part orientation Object Locate Positioning Vision Tool was used, which uses advanced edge extraction and analysis [4]. To find the position of the part we used the Blob Locate Positioning Vision Tool. This tool uses standard and advanced thresholding and advanced parameter setting to find the location of an object based on connected areas of similar intensity pixel.

After part position and orientation is acquired, the particular information is sent to the external device via Ethernet. Here, Data Link which is build-in tool used to send different data out of the system was used. Data Link was used to receive the string to the system for triggering the inspection as well. Data Link consists of a number of ASCII strings that are created based on information from the vision tool. To simplify string manipulation as much as possible, it is good practice to write one string definition for one data to send that data out from the system. After the camera sends data via Ethernet to the network, X-SEL controller receives data and places them to the register. Placing of the data to the controller register and later data manipulation is enabled with custom application written for this purpose. *Figure 4* presents the flowchart of the process logic.

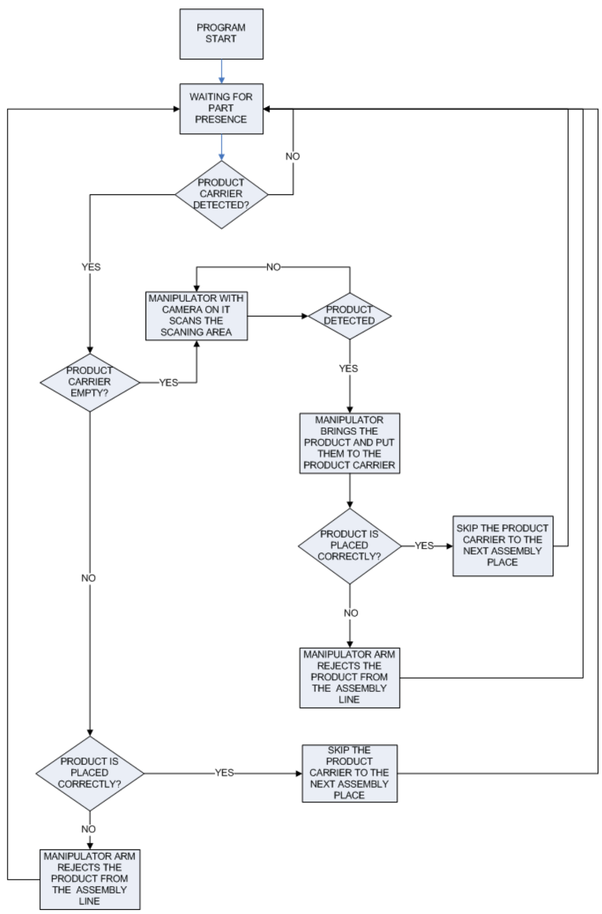

Figure 4: Process flowchart

All further data manipulation is done within the controller of the manipulator, which results with appropriate actions of the manipulator with respect to provided process flow chart.

3. CONCLUSIONS

In robotic/automatic assembly, the information about the position and orientation of work pieces and all other in-process relevant objects represents the essential data for control programs. Location data directly influence handling operations, which are usually the most difficult automation tasks. Automatic handling operations generally presume a deterministic environment, where all spatial configurations are precisely anticipated. However, deterministic chaos inevitably obstructs absolute expectations, always producing slightly changed situations. Despite that, the conventional automation methods tend to create technical systems as almost perfect constructions. It seems that such efforts are definitely hopeless and result in expensive and inefficient systems. The deterministic chaos should be accepted as a natural phenomenon and the development philosophy changes toward the development of intelligent machines capable of adapting their behavior according to the natural imperfect world where nothing is absolutely ideal or accurate.

The mobile camera is used in combination with optical and laser sensors for exploration of the work space of the robot. The vision application developed in this work showed that proper combination of the tools for extraction of data from the images ensures consistent information flow for changing environmental conditions. In this manner stochastic information variation is minimized and robustness of the system increased.

4. REFERENCES

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