Robotic Vision for Bin-Picking Applications of Various Objects

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Abstract

In this paper we present a new experimental work and results regarding the bin-picking problem that has been still a challenging topic in robotic so far. Although the number of potential applications for bin-picking is growing in industry representing a huge market potential, in many situations it is done manually.
We present a functional solution for the bin-picking problem that has been verified on a variety of objects. Initially, there is presented a pilot project concerned with a picking of standard nuts from a bin. Further, based on interests from automotive industry, we dealt with objects complex in shape (sheet-metal parts). However, the solution is not universal; the whole bin-picking system has to be adjusted according to various object specifications.
The bin-picking system, presented in this work, for objects manipulation (grasping and placement) is mainly concerned with an industrial robot, 3D vision system mounted on a movable linear axis frame and a proper end effector – standard gripper or vacuum gripper depending on the variety of objects to manipulate.

1 Introduction

The bin-picking problem is mainly concerned with a robotic vision system for grasping of various objects randomly organized in a bin. In other words, the objects to be recognized by the vision system are placed in a bin non-oriented, interlocked, jumbled and often heavily occluding each other. This field belongs to the actual worldwide research topic in robotics and there has been done a significant progress in this area so far. However, concerning mainly the industrial applications where a system robustness and high reliability is required, the problem seems to be rather unresolved completely. On one hand, requests from industry for a functional, reliable, fast and robust system are raising but on the other hand, systems already available on the market have still its respective limitations and drawbacks regarding an effective application. Nevertheless, a fully automated bin-picking system represents a huge market potential since in many situations the bin-picking is done manually.
One can note that there are two main attitudes to approach this problem. First, general approach concerns with a universal system able to cope with objects of various size, shape, form, mass etc. This approach may be characteristic mainly for big companies developing universal vision libraries. However, it is mainly the complexity of such universal systems that leads to a failure in a challenging industry environment. The second approach is focused rather on a single product or a limited number of objects that are similar in its geometric and other properties. This approach can fulfill company requirements faster though the universality is limited.
Although the bin-picking problem in robotics is still a challenging topic, few applicable solutions exist; Reliabot 3D vision package [1], PalletPicker-3D [8] or SCAPE Bin-Picker (Scape Technologies). In addition to that, such solutions are concerned, more or less, with cylindrical, rotational objects (Figure 1) that are relatively easy to handle by the bin-picking system compared to more complex parts; e.g. sheet-metal parts (Figure 1).

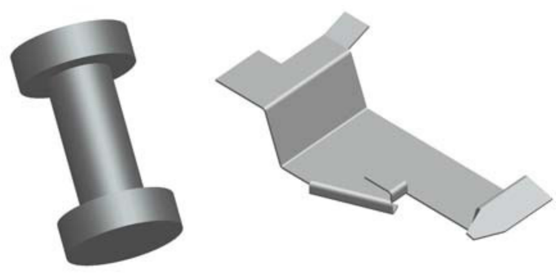

Figure 1 Simple object vs. complex object

The bin-picking problem is concerned with many technical fields such as data acquisition, object localization and pose estimation and collision avoidance [9] that is essential to a successful solution. Concerning the data acquisition, various methods or principles can be used. For example 3D-laser scanners or 3D measurements delivered by a scan-

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ning sensor can be applied [2, 9]. Another approach deals with a laser triangulation [10] using a single camera along with a 2D-laser scanner to compute the 3D data. Further, the sheet of light [5] or stereo vision systems [7] can also be used successfully. The pose estimation of an object can be based, for example, on a 3D model stored in a database [6] or using object cylindrical openings [4] based on elliptic projections from a vision system.
In this work, a single industrial camera (SICK Ranger) along with two linear laser projectors has been used. Based on the algorithm for the whole bin-picking (chapter 3), there has been done an initial pilot project for bin-picking of standard nuts followed by a full solution concerned with complex sheet-metal parts.

2 Technology transfer in practice

Various models for technology transfer in practice have been described in the literature. In general, one approach can start from a researcher doing basic research that might lead to a successful industrial application in the near future. Another approach concerns with specific market needs and a search for a researcher able to cope with the problem. Many models also claim that a successful technology transfer in practice needs to be based on close collaboration between researchers and practitioners.
A successful example is covered for example here [3] where a seven-step technology transfer model based on close cooperation and collaboration between university researchers and practitioners is applied. The model is concerned mainly with identifying industry needs, formulating a research agenda, formulating a solution and comprehensive validation based on small lab experiments, pilot projects leading to release the full solution step by step.

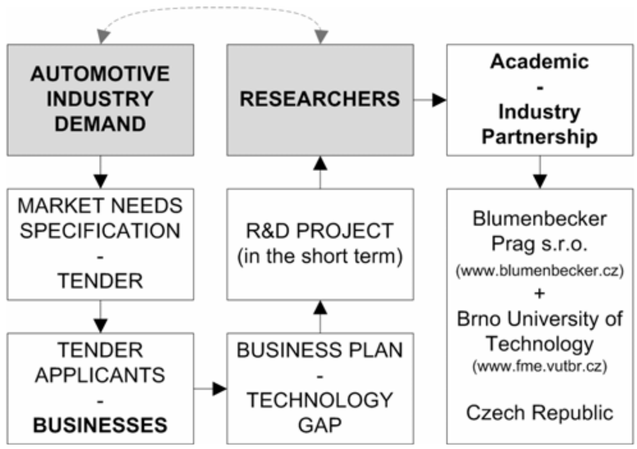

Figure 2 Technology transfer model used for bin-picking problem

In our case, a similar model (as described above) has been applied on the bin-picking problem (Figure 2). Initially, there was a demand for a bin-picking robotic cell able to deal with complex sheet-metal parts (similar model in Figure 1) that came from automotive industry.
In the beginning, there was a pilot project focused on bin-picking of nuts (chapter 4.1) and after that we approached to the more complex sheet-metal parts (chapter 4.2). The result is a functional solution that is currently offered by the company (Blumenbecker Prag s.r.o.) as a **Stand-Alone Bin-Picking System** (Figure 10).
This technology transfer based on academic – industry collaboration was also supported by the ESF project: Knowledge and Skills in Mechatronics - Innovations Transfer to Practice (CZ.1.07/2.3.00/09.0162).

3 Description of the bin-picking system

The bin-picking system for objects manipulation (grasping and placement) is mainly concerned with an industrial robot (6 DOF), 3D vision system mounted on a movable 1 DOF linear axis frame and a proper end effector – standard gripper or vacuum gripper depending on the variety of objects to manipulate.

3.1 Robotic cell design

The 3D vision system is based on an industrial camera (Sick Ranger) and two linear laser projectors mounted on the movable linear frame (Figure 3). Two linear laser projectors have been used to overcome the problem of shadowed areas or shadowing effects.
The linear frame allows 3D data acquisition of objects gradually within the whole space of a bin or over a static table if objects need to be precisely placed and oriented for further processing.
Each object is then picked by the robot gripper to avoid any collisions. There is applied a strategy to avoid mainly the collisions with bin edges and bin corners or with other objects in the bin. To make the process of object grasping (free of collisions) easy, a gripper that is mounted on the robot flange eccentrically is used.

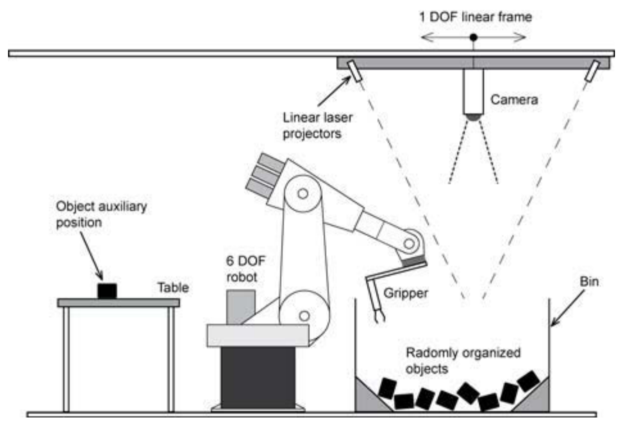

Figure 3 Robotic cell design

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It can be said that the design arrangement described above along with a modified bin (chamfered bin edges) and a proper algorithm for path planning allows 100% of objects to be picked.

3.2 Control system description

The main part of the whole system (Figure 4) is a PLC that controls other devices such as the robot, 3D vision system and industrial PC for image processing.

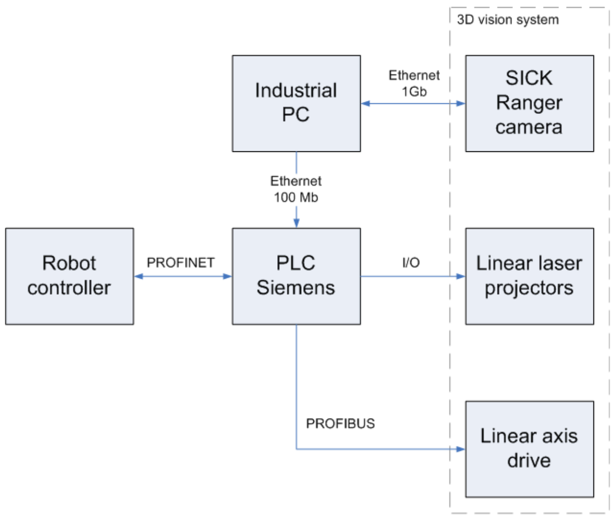

Figure 4 Control system description

The camera is in this case used only for image-data acquisition and it is connected to the industrial PC via the Ethernet bus (1GB). The PC is connected to the PLC via the Ethernet (100 Mb).

The PLC is concurrently used to control the linear lasers and the linear axis frame. The PLC is connected to the robot system controller via the PROFINET bus.

3.3 Methodology for the whole bin-picking problem

The algorithm (Figure 5) for data acquisition and bin-picking is as follows.

The vision system is placed over the bin with randomly organized objects and in mounted on the linear axis frame; the vision system then performs an image acquisition procedure within the whole bin space.

According to the image analysis, there is roughly detected an object that can be grasped from the bin and also the object position is calculated. After that, a path free of collisions is planned and the object is grasped by the robot gripper.

If needed, the object is then placed on the auxiliary position (Figure 3) and the vision system performs a second “scan” in order to specify the object parameters. Further image processing is used to precisely determine the object position and orientation so that the robot can grasp it and precisely placed the object on a place with respect to additional process requirements.

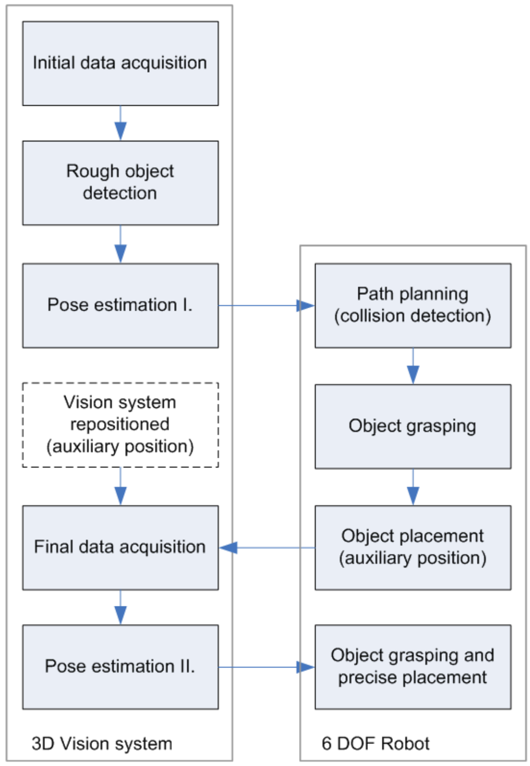

Figure 5 Bin-picking methodology

The auxiliary position is in our case essential since the objects need to be inserted into a process station very precisely and with particular orientation respecting further process flow requirements. However, the auxiliary position can be left out in cases where previous requirements are not essential and objects can be directly picked from the bin and placed on a conveyor belt for example.

4 Results

4.1 Pilot project: bin-picking of nuts

Bin-picking of nuts can be considered as a pilot project to initiate the research in this area though based on own know-how from other robotic vision projects. Standard nuts (Figure 6) of various dimensions are randomly organized in a small container (Figure 7) and are to be picked by the robot gripper and placed on the table.

Despite the variety of nuts, it seemed obvious that we cannot handle all types of objects, or in other words, to develop a universal solution or a vision library able to cope with a general object. Therefore we focused on individual objects separately where the research is far more faster and the solution is functional, reliable and robust enough.

The average cycle time for a nut grasping and placement is about 5 s depending on the object configuration.

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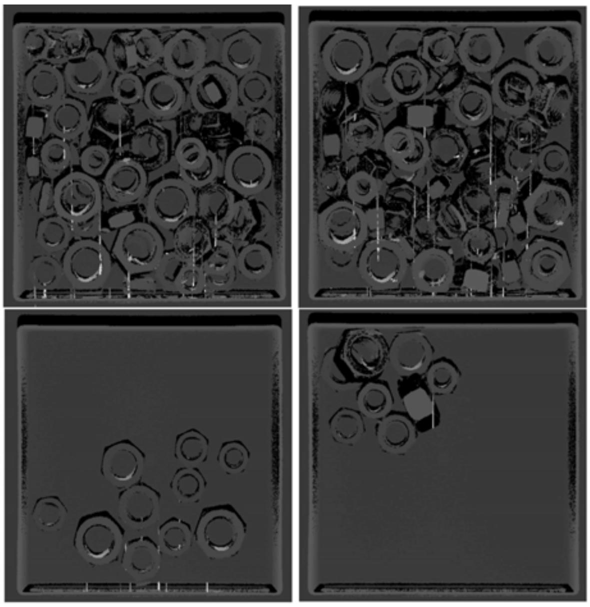

Figure 6 Camera scans for nuts

Figure 7 Experimental set-up for bin-picking of nuts

4.2 Real application: bin-picking of sheet metal parts complex in shape

After the solution for bin-picking of nuts was fully verified

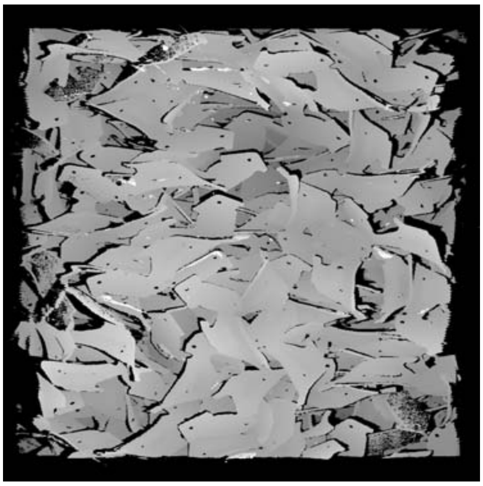

Figure 8 A camera scan for sheet-metal parts

and optimized, we approached directly to more complex parts – specific sheet-metal parts (Figure 8).

For this purpose a vacuum gripper is used to pick and place an object.

The robotic cell in this case is based on the scheme represented by the Figure 3: eccentrically mounted vacuum gripper on the robot flange, vision system on a movable linear frame and a modified container. Such arrangement allows 100% of objects to be successfully picked.

The accuracy for placement is up to ± 1 mm and ± 3°. The cycle time for object placement on the auxiliary position (required in this case) is about 5 s. The total cycle time including additional image processing resulting in precise placement of an oriented object into the process station is about 15s.

Figure 9 Experimental set-up for bin-picking of sheet-metal parts

4.3 Final product: Stand-Alone Bin-Picking System

Based on the previous experience and results, a fully integrated solution (Figure 10) is being offered.

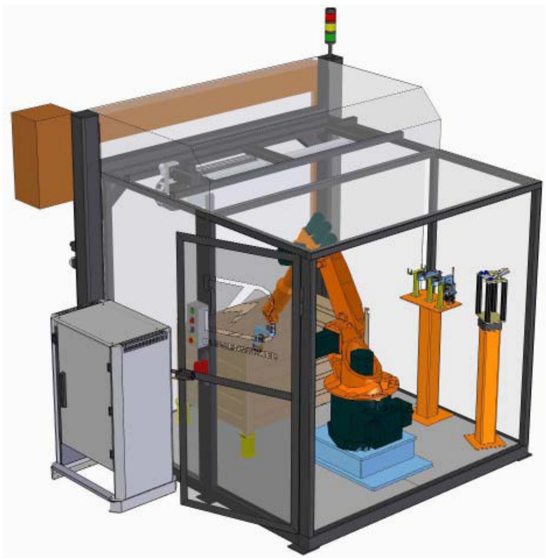

Figure 10 Stand-Alone Bin-Picking System

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The Stand-Alone Bin-Picking System (Blumenbecker Prag s.r.o.) can deal with both rotational "simple" objects and objects complex in shape. More information or specification can be found on www.blumenbecker.cz.

5 Conclusion

The main focus in this work was to develop a functional solution for the bin-picking of such complex objects as the sheet-metal parts presented in this paper. An emphasis has also been put on a short-term research and an easy applicability in automotive industry.

The whole robotic system is concerned mainly with the end effector eccentrically mounted on the robot flange, the vision system mounted on a movable linear frame and a modified container. Based on this arrangement, we managed to pick 100% of sheet-metal parts from the container. The total cycle time is about 5 s without the auxiliary position and about 15 s with the auxiliary position. The auxiliary position is particularly important for a precise placement of an oriented object into a process station within the whole work flow.

We presented a successful solution that is currently being offered as the **Stand-Alone Bin-Picking System** by the Blumenbecker Prag company.

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