Throwing and Capturing of Workpieces by Robots

New Transport Services for the Internet-Of-Things in Production Systems

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Abstract: In the first part of the paper for the transportation of workpieces within production systems an approach in which robots are throwing and capturing the workpieces is presented. This concept also can be applied for elevating, turn-over and commissioning of workpieces. The main advantages of this method are high speeds, high flexibility and the need of few resources. In the second part of the paper it is described how throwing and capturing of workpieces can be applied in production systems which are realized according to the internet-of-things concept.

1 INTRODUCTION

In the past years throwing and capturing by robots was investigated as a new technology for the handling and transportation of workpieces in production systems. It was shown that it is possible, to throw objects from one robot to another over distances of several meters. In this paper different examples for the application of this new method will be proposed. Further it will be discussed, how such robots can provide new services for the IOT-concept (IOT – internet-Of–things) in production systems.

2 STATE OF THE ART

Many research works have been performed in the past at first to investigate throwing and capturing of ball shaped objects by robots (Frese et al., 2001); (Senoo et al., 2008); (Barteit, 2009). During the last years also throwing and capturing of axial-symmetric objects was developed (Frank et al., 2012); (Frank, 2013). Figure 1 shows a 2-DOF parallel kinematic robot which is capable to throw and capture such objects over distances of 3 m. It consists of an arm-axis which has a length of 50 cm and a gripper-axis which can be turned in its tool center point (TCP). Both axes are driven each by a servo motor.

The concept for throwing and capturing of axial-symmetric objects in their axial direction is shown in Figure 2. For launching the objects, the robot accelerates its arm in a rotary movement until the object achieves in the launching point L its throwing angle α_L and its throwing-speed v_L. At this point the object is released from the gripper. The parameters α_L and v_L must be controlled very accurate, so that the thrown object meets on its trajectory the predefined capturing point C with a high precision.

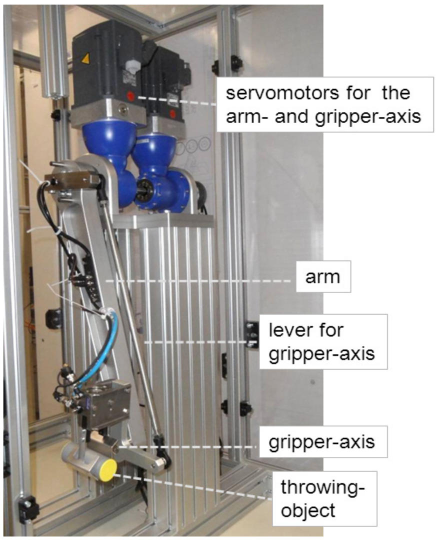

Figure 1: 2-DOF parallel kinematic robot for throwing and capturing of axial-symmetric objects.

During the flight the pose of the object is measure on its trajectory at a point M. With this measurement

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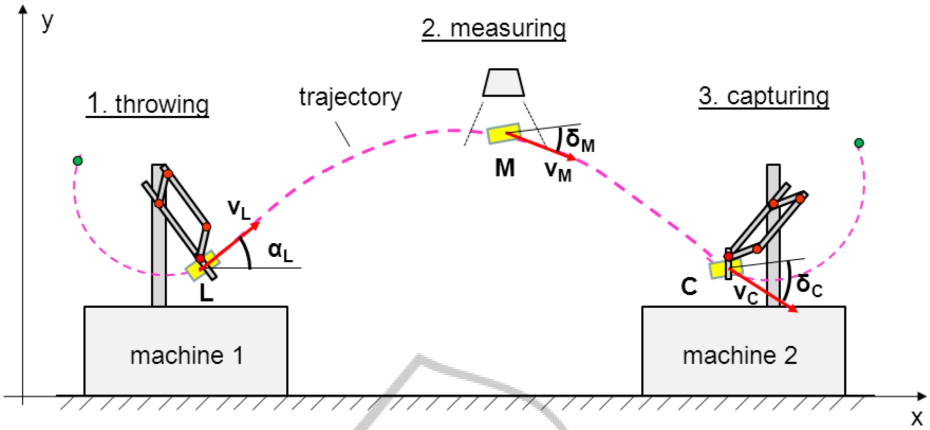

Figure 2: Concept for throwing and capturing of axial-symmetric objects.

the pose of the object at the capturing point C can be predicted.

For capturing the object the robot arm is also accelerated in a rotary movement. The gripper must arrive at the capturing point C at the same time and with the same speed v_C as the flying object (Figure 3). Based on the prediction of the pose in the capturing point, the object can be captured within the xy-plane in different angles. After clamping the object during its flight, it will be softly decelerated with the arm-axis of the robot.

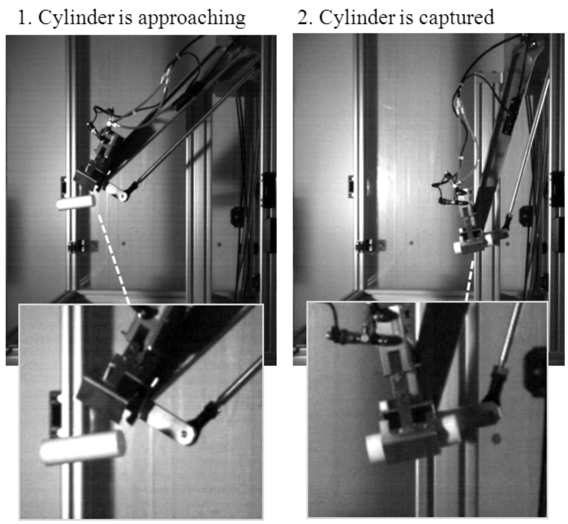

Figure 3: Capturing of a cylinder.

In (Frank, 2013) this concept was validated by throwing of two different types of cylinders. One of them was compliant flying, which means that the orientation of the cylinder was following during its flight always the direction of its trajectory. This cylinder was captured in 98 % of the throws. Another cylinder with a higher mass and a smaller diameter was not compliant flying. It arrived at the capturing point with different angles in the xy-plane. This cylinder could be captured successfully in 85 % of the throws.

3 APPLICATIONS FOR THROWING AND CAPTURING

In this chapter several examples for the application of throwing and capturing by robots in the intra-logistic of production systems are presented.

3.1 Transportation of Workpieces

As already shown in Figure 2, throwing and capturing can be applied for the transportation of workpieces between two machines. For the safety of people the space in which workpieces are thrown must be protected by guards. The following advantages could be achieved with such a concept:

- The workpieces can be thrown with high speeds directly from the handling robot at one machine to the handling robot at another machine. So the transportation times will be very short.
- The workpieces can be thrown from a robot to any random point within a limited space. So the transportation is for the destination points of the workpieces very flexible. This is useful not only for the transportation to different machines within an area but also when machines are relocated from time to time.
- Already today many machines are equipped with handling robots to load and unload workpieces to/from machines. If such handling robots would be extended with the capability for throwing and

capturing, no additional transportation equipment would be required to bring the workpieces from one machine to another.

3.2 Elevation of Workpieces

In production systems workpieces sometimes must be raised from one level to another. Figure 4 shows as an example a study for a continuous flow production, in which vials for pharmaceutical products were thrown onto a band-conveyor. In this approach the throwing parameters were controlled so, that the vials arrived only a few millimeters above the conveyor and with the same speed as the conveyor. The main goal of this approach was to avoid frictions at the vials within an aseptic environment.

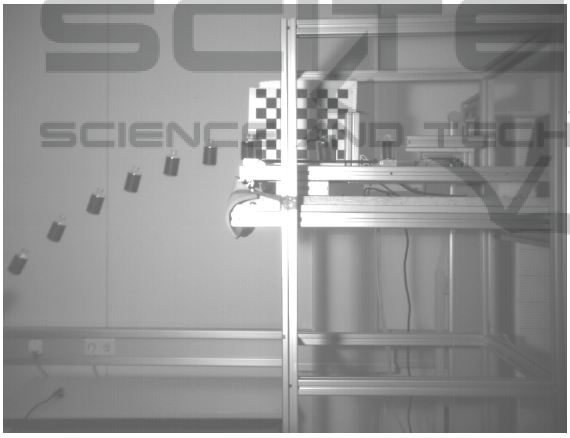

Figure 4: Elevation of vials onto a conveyor.

3.3 Turnover of Workpieces

Workpieces can be turned-over by throwing and capturing from one orientation to another. For such an operation a workpiece can be thrown with the arm of the robot vertical up. At the launching-point the gripper-axis must give the workpiece also a certain turning movement. So the robot can capture the workpiece again like a juggler. Today turn-over operations are performed either by separate turn-over devices or by robots which put the workpieces first on a deposition place, than turn their gripper and finally grap them again. Such an operation is generally very time-consuming.

3.4 Commissioning of Parts from a High-bay Racking

Figure 5 shows a concept for commissioning of parts from a high-bay racking. From the bin locations individual parts can be pushed out so that they are falling down. A robot can capture the parts during their flight, decelerate them smoothly and then put them onto a conveyor belt. So a predefined sequence of parts can be achieved on the conveyor belt. The main advantage of this concept is its high commissioning rate.

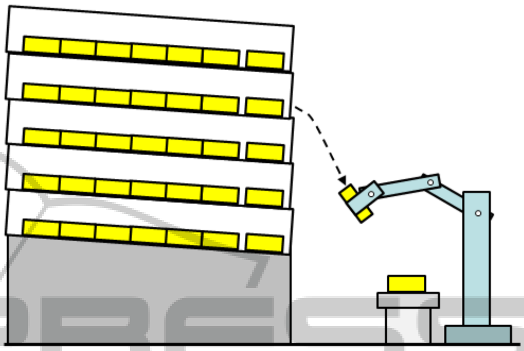

Figure 5: Commissioning of parts from a high back racket.

3.5 Operations which need an All-around Access for Parts

In production some operations need for the parts an all-around access. Examples are inspections by cameras and coating, painting or surface-treatment of workpieces. Such operations could be performed when parts are flying. During the flight time the parts then can be accessed from each side. The flight time however is in general only the fraction of a second.

4 THROWING ROBOTS FOR THE INTERNET-OF-THINGS

4.1 IOT-concept

Since the complexity of many production systems is steadily increasing, today much research work is performed to adapt the principles of the world-wide-web (global interconnected network of computers) for production systems. In such systems production devices are considered as an interconnected network of things (IOT – internet of things). The main features of such systems can be summarized as follows (Hribernik et al., 2010); (Wagner et al., 2010), (Hompel et al., 2008), (Vossiek et al., 2010):

- Individual production devices like machines, robots and transport systems shall be realized as decentralized autonomous units (things) which offer production services and which are able to collaborate with each other. Therefore they must be connected directly to the internet communication network.

- Like subnets in the internet, production systems shall provide redundancies and a high robustness. For an easy adaption to new production requirements it shall be possible to remove and add things very easily („Plug'n'Produce“).
- Objects which have to be moved through the network of things, like individual parts, individual tools or pallets with several parts or tools must be equipped with an identification-tag (e.g. RFID - radio-frequency identifi-cation) which can be read by the transportation devices.
- The basic principles for controlling the information flows in the world-wide-web shall be adapted in the IOT for the control of the material flow. Objects shall move self-determined through the network. According to their desired workflow the objects are asking themselves for their desired transportation and processing services.

4.2 Throwing and Capturing in a Subsystem of an IOT

In the world-wide-web subnets can be realized with different media like fiber optics, twisted pair or WLAN and different topologies like line, mesh and ring. As it can be seen in Figure 6 in subsystems of production systems in an analogy different types of transport systems like automated guided vehicles (AGV), conveyors, pick-and-place robots, and rail guided vehicles (RGV) can be used.

The application of throwing robots is shown within Figure 6 in subsystem 4. Therefor the robot, as it is shown in Figure1, would require an additional axis to turn the whole robot into different directions. In an IOT-concept the method of throwing and capturing provides the following advantages features:

- The robots are autonomous devices which need for the interconnection to their surrounding only a cable for their power supply. The connection to the internet can be performed by WLAN. The robots don't need any direct mechanical connections to other devices.
- For plug 'n produce a throwing robot at first must be toughed with its own location within the production system. In addition to this it needs the locations of the other throwing robots, which it can retrieve from them via WLAN.
- For the transportation of parts the robots offer services for throwing and capturing as they are described in chapter 3. When e.g. a transport-service is requested from an object, the throwing

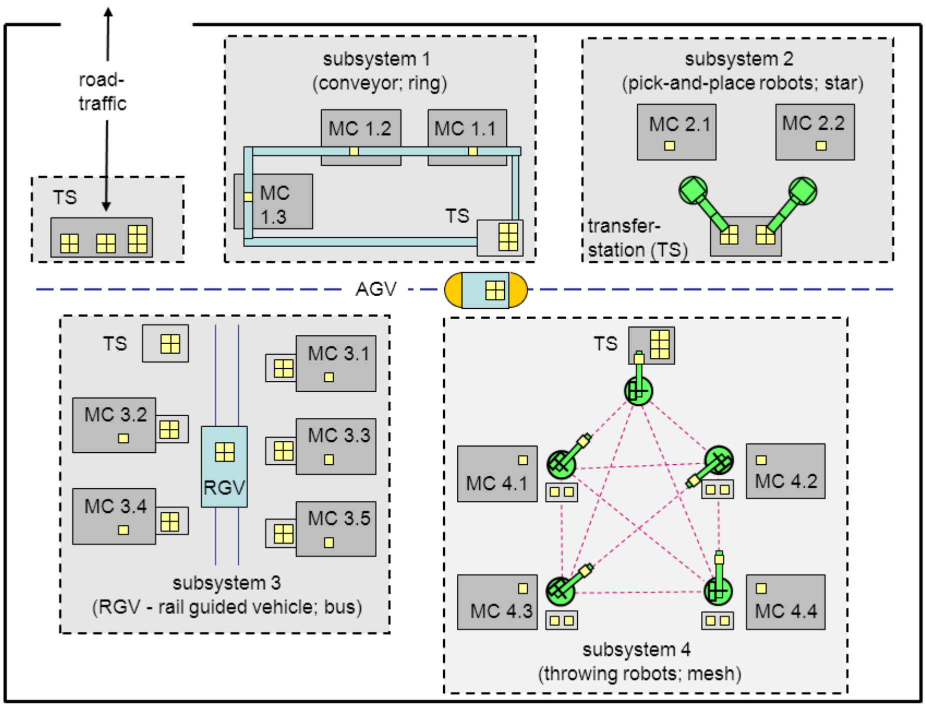

Figure 6: Example for the intra-logistic in a production environment with different types of subsystems.

- robot needs further information like dimensions and the mass. Such information the robot can retrieve from the internet. Then the throwing-robot has to request the capturing-service from another robot. After that the transportation can be performed.
- For the transportation of the objects within the subsystem alternate paths can be used. For that automatically routing tables can be generated within the robots similar to the routing tables within routers in the internet.

5 CONCLUSIONS

In the first part of this paper for the transportation and handling of workpieces within production systems a visionary method for throwing and capturing them by robots was presented. The advantages of this method would be short times, high flexibility and the need of few resources. In several research works it was already proved, that this method is basically working. On the other hand further research work is still required to make this method for practical applications more reliable. In the second part of the paper it was shown, that the features of throwing robots provide good conditions for their integration in IOT-concepts.

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