Integration of disabled people in an automated work process

C K Jalba¹, A Muminovic¹, S Epple², C Barz³ and V Nasui³
¹Ulm University of Applied Sciences, Production Engineering and Production Economics, Prittwitzstraße 10, 89075, Ulm, Germany
²Kempten University of Applied Sciences, Faculty of Electrical Engineering, Bahnhofstraße 61, 87435 Kempten, Germany
³Technical University of Cluj-Napoca, North University Centre of Baia Mare, Victor Babes str., no. 62A, 430083 Baia Mare, Romania

E-mail: klausjalba@t-online.de

Abstract. Automation processes enter more and more into all areas of life and production. Especially people with disabilities can hardly keep step with this change. In sheltered workshops in Germany people with physical and mental disabilities get help with much dedication, to be integrated into the work processes. This work shows that cooperation between disabled people and industrial robots by means of industrial image processing can successfully result in the production of highly complex products. Here is described how high-pressure hydraulic pumps are assembled by people with disabilities in cooperation with industrial robots in a sheltered workshop. After the assembly process, the pumps are checked for leaks at very high pressures in a completely automated process.

1. Introduction
A Lebenshilfe Donau-Iller e. V. is a private welfare organization from Ulm, in Germany with about 1300 members. The organization takes care of more than 1200 handicapped people from the Ulm area.

Figure 1. Wood products made by the life support [1]
The main objectives of the Lebenshilfe are: life coaching for people with disabilities, the welfare of people with disabilities and their families, human dignity, protection of personality, integration into society [1].

The organization employs around 1000 people at several locations in Ulm and around Ulm, namely Neu-Ulm, Senden, Illertissen, Günzburg, Blaustein and Amstetten.

The life support is financed by donations and membership fees. Another source of income is the production of various products for the free economy. They produce, for example, from simple products such as wood objects (Figure 1), or garden articles to highly complex products for dental technology or industry. Among them are well-known customers such as LIEBHERR (Figure 2 and 3) or BOSCH-REXROTH [1].

Figure 2. Liebherr excavator

Figure 3. Liebherr Hydraulic System

The association needs these financial resources, because on the one hand the care of people with disabilities needs a lot of time and is labor intensive. On the other hand, people with disabilities should be integrated as well as possible into the social life. If necessary, they are provided with accommodation, they are transported between their homes and the workplaces with company-owned vehicles, and they receive food during the working hours. They are also compensated for their work financially.

The workplaces have to be also adapted to the needs of disabled people [2].

Figure 4. Workplaces for handicapped workers
Here are some examples of the conversion of a workplace into a workplace for disabled people (Figure 4) one-hand operation for an amputated worker, for blind people the equipment of a computer workplace with a Braille line, in the case of visually impaired employees, a large-screen monitor or an extra-large keyboard, in the case of deaf people, picture and writing telephones or light signal systems on machines [2].

Each work process must be meticulously planned and is prepared in detail by the supervisors. Disabled people are also not allowed to be used anywhere in the production facilities and their rest periods are regulated differently than normal workers. For example, they may not work for more than 6 hours a day, and after about half an hour they have to take short breaks.

This way of working requires a great deal of commitment and understanding on the part of the supervisors. Above all, the production technicians have to continually reinvent special tools and ergonomic working equipment in order to prevent accidents, during the products must be produced with normal industrial standards.

2. Production of hydraulic pumps

In this context, the University of Applied Sciences Ulm (Hochschule Ulm) was asked whether it would not be possible to automate some workflows at a production site in the field of life support. It was specifically the production of hydraulic pumps for the company BOSCH – REXROTH AG.

BOSCH-REXROTH AG from Unterelchingen by Neu-Ulm, formerly known as HYDROMATIK, is one of the market-leading manufacturers for high-pressure hydraulic pumps for the construction industry, agriculture and conveyor technology (Figure 5) [3].

These pumps (Figure 6) have been produced for Lebenshilfefulfe e.V. in Neu-Ulm for about 20 years, without errors and other complaints. For this purpose was set up by Lebenshilfe in Neu-Ulm a dedicated production line (Figure 7).
Figure 6. Hydraulic pumps produced by Bosch Rexroth AG [3]

Figure 7. Production line for hydraulic pumps
The production line is designed in such a way that it can be adapted to the respective requirements (Figure 8) regarding product and production safety, or any changes.

Most of the work steps can be carried out by disabled people. However, there are some work sequences that cannot be executed by them (Figure 9).

In the upcoming project, the main focus was to find out where automation processes are necessary and how they can be integrated into the production flow. For this reason, the production processes were first studied and then the products were analyzed throughout the entire production process. Finally, it was possible to determine where automation processes could be introduced and could be adapted in the production [4], [5].

At the beginning of the assembly components are provided by employees without disabilities (Figure 10 and 11).

In the next steps the assembly takes place. This includes steps that require a more complex workload. One of these steps is, for example, the pressing-in of the ball bearings. This work step requires very good physical skills. It can be seen in the picture, eyes, hands and feet must be used together. This work step cannot be performed by people with physical disabilities (Figure 12 and 13).
During this operation, the almost finished hydraulic pump is placed on the hydraulic press by the assembly line. Because the hydraulic pumps, depending on their size, can be very heavy, it is very difficult to lift them permanently, even for people without disabilities (Figure 14).

Figure 12. Pressing-in ball bearings

Figure 13. Pressing ball bearings, assembling housing

Figure 14. Final assembly
A further challenge was the test bench (Figure 15, 18), where the pumps were checked (Figure 19) under very high pressures (180 – 300 bar) for tightness (Figure 20). In this work section, employees of BOSCH-REXROTH AG were mostly employed because this work could not be trusted to people with disabilities [3].

Figure 15. Test bench

The workplace requires specialist knowledge, physical fitness and craftsmanship. This workplace is not only physically very stressful, but also loud and dangerous [16]. Here, liquids must be handled at very high pressures. At the same time, the final inspection for each product must be recorded (Figure 16).

Figure 16. Monitoring test results
Figure 17. High pressure test
If the work on the test bench could be solved differently, the entire value added for the assembly of the hydraulic pumps would remain by Lebenshilfe e.V. and thus the product could be handed over from one hand to the order.

**Figure 18.** Handling with all senses

**Figure 19.** Checked hydraulic pumps

**Figure 20.** Checking under high pressure
3. Cooperation project

With the help of these examples and the collected data, the experiments were started at the University of Applied Sciences in Ulm in the laboratory for robotics and industrial image processing [6], [7].

One of the first attempts was to classify the individual components for the construction of the hydraulic pumps. Because different pump types are assembled, the individual parts for the respective series have to be identified [8], [9]. This work step was carried out by coding the individual work pieces with barcodes. The encoded components were identified by industrial image processing and the results were recorded in quality assurance files (Figure 21) [10-12].

Another step in the process was the recognition of the rotational position (Figure 25) of the multi-shafts (Figure 23), which had to be fitted precisely into the pump bearing. For this purpose, was used a Stäubli robot, [13] which recognized the contours of the waves using a camera system [14], [15] and image processing (Figure 22) [16].
The robot had to remove the multi-shafts from a holder and lead to a wing light (Figure 24). A camera took a snapshot and sent a picture to an image recognition program on a connected PC [7], [17], [18].

The image processing had to compare the contours of the wave with a pattern image stored in the working memory. If all features, such as area, number and position of the notches, diameter, etc., coincided with the deposited patterns, the rotational position still had to be detected. Subsequently, the required rotation angle correction was performed on the sixth axis of the robot arm. The shaft could then be guided into the bearing by means of robots.

Another challenge was the hydraulic test. At the beginning, we had only one KUKA industrial robot [19] with a load capacity of 15 kg (Figure 26). This load was not sufficient for all pump types. For this reason, some things had to be improvised until the acquisition of a larger industrial robot. The robot arm by KUKA KRC 15 could e.g. under maximum load, cannot be fully extended, or certain
tilting movements could not be carried out. After the acquisition of a KUKA KRC 30 (Figure 27) the robot could be finally programmed for all the movements required for the pressure test. With the new robot and with a larger gripper, the larger pump types could also be handled without any problems.

Figure 26. KUKA KRC 15/2

Figure 27. KUKA KRC 30/4

4. Conclusions
Laboratory experiments have shown that a division of labor between disabled people and industrial robots is possible. The cost-effectiveness of this type of cooperation has to be examined on a case-by-case basis.

The costs of acquisition for industrial robots and industrial image processing are relatively high. The investment can be worthwhile if the skilled workers are more likely to be used for the preparation of jobs and to supervise disabled workers rather than for monotonous and dangerous tasks.

With intelligent robot protection devices, it is further possible to allow robots to work together with disabled workers.

References
[1] Lebenshilfe Donau - Iller e.V., Eberhard-Finckh-Straße 30, D - 89075 Ulm
   http://www.lebenshilfe-donau-iller.de
[2] Schwerbehindertengesetz (SchwbG) Gesetz zur Sicherung der Eingliederung Schwerbehinderter in Arbeit, Beruf und Gesellschaft,
   http://behinderung.org/gesetze/schwbg.htm
[3] Bosch Rexroth AG, Oberelchingen, Glockeraustraße 2, 89275 Elchingen, Germany,
   http://www.bvs-cnc.de/produkte/rexrothindramat.html?gclid=CLyt76C6x80CFeUV0wodHWMK6A
[4] Deman C, Streicher-Abel B and Waszkewitz P 2011 Industrielle Bildverarbeitung Wie optische Qualitätsskontrolle wirklich funktioniert, Springer Verlag Berlin Heidelberg
[5] Bauer N (Hrsg.) 2008 Handbuch zur Industriellen Bildverarbeitung. Qualitätssicherung in der Praxis. 2, Auflage, Fraunhofer IRB-Verlag, Stuttgart
[6] Hochschule Ulm, Prittwitzstraße 10, 89075 Ulm, Germany, https://studium.hs-ulm.de/de/Seiten/Homepage.aspx
[7] Demant C and Streicher-Abel B 2011 Industrielle Bildverarbeitung, 3, Auflage
[8] NeuroCheck GmbH, Aldingen, Neckarstraße 76/1, 71686 Remseck am Neckar
   http://www.neurocheck.de/
[9] Jähne B 2005 Digitale Bildverarbeitung. 6. überarbeitete und erweiterte Auflage, Springer, Berlin
[10] NeuroCheck GmbH, Engineering Center, Neckarstr. 76/1, D-71686 Remseck, Germany
[11] NEURO CHECK Industrielle Bildverarbeitung, System Schulung, Version 5.1, 2003, NeuroCheck GmbH
[12] NEURO CHECK Industrielle Bildverarbeitung, Einsteller-Handbuch, Version 5.1, 2002, NeuroCheck GmbH
[13] Stäubli Bayreuth GmbH, Theodor-Schmidt-Straße 19, 95448 Bayreuth, Germany,
http://www.staubli.com/index.php?id=22&L=2
[14] Baumer GmbH, Pfingstweide 28, 61169 Friedberg, Deutschland
http://www.baumer.com/index.php?id=22&L=2
[15] Kaiser Fototechnik GmbH & Co.KG, Im Krötenteich 2, 74722 Buchen,
http://www.kaiser-fototechnik.de/de/produkte/2_1_sortiment.asp?w=381
[16] FusionSystems GmbH, Alchemnitz, Annaberger Str. 240, 09125 Chemnitz
http://www.fusion-systems.de/anwendungsberichte.html
[17] NeuroCheck Einführung, Extras Springer
[18] NeuroCheck Getting Started, Extras Springer
[19] KUKA AG, Zugspitzstraße 140, 86165 Augsburg, Germany,
http://www.kuka-robotics.com/germany/de/company/