Cooperation between humans and robots in fine assembly

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Abstract. The development of ever smaller components in manufacturing processes require handling, assembling and testing of miniature similar components. The human eye meets its optical limits with ongoing miniaturization of parts, due to the fact that it is not able to detect particles with a size smaller than 0.11 mm or register distances below 0.07 mm - like separating gaps. After several hours of labour, workers cannot accurately differentiate colour nuances as well as constant quality of work cannot be guaranteed. Assembly is usually done with tools, such as microscopes, magnifiers or digital measuring devices. Due to the enormous mental concentration, quickly a fatigue process sets in. This requires breaks or change of task and reduces productivity. Dealing with handling devices such as grippers, guide units and actuators for component assembling, requires a time consuming training process. Often productivity increase is first achieved after years of daily training. Miniaturizations are ubiquitously needed, for instance in the surgery. Very small add-on instruments must be provided. In measurement, e.g. it is a technological must and a competitive advantage, to determine required data with a small-as-possible, highest-possible-resolution sensor. Solution: The realization of a flexible universal workstation, using standard robotic systems and image processing devices in cooperation with humans, where workers are largely freed up from highly strenuous physical and fine motoric work, so that they can do productive work monitoring and adjusting the machine assisted production process.

1. Handling small components
The development of ever smaller components during the manufacturing process requires the handling, assembling and testing of similar miniature components. The human eye meets its limits with actual miniaturization of optical sizes and as well as handling becomes difficult limits, because the human eye is not able to detect particles with a size of less than 0.11 mm or register distances below 0.07 mm.

Figure 1. Detection ability limit of the human eye without aids
Employees can not differentiate after several hours color differences accurately and also ensure consistent quality.

Figure 2. Precision assembly at Endress + Hauser

Figure 3. High precision resistor assembly at Endress + Hauser [1]

Assembly is usually made with tools, such as microscopes, magnifiers or digital measuring devices.

Figure 4. Enlarged micro welds [2]
Due to the enormous concentration during work, employees quickly get tired. This requires breaks or change of job and reduces productivity. Dealing with handling devices such as grippers, guide units and actuators for assembling the components requires a time consuming training process. Often succeed not until years of working with the miniature components to increase productivity.

Miniaturizations are needed for example in the surgery, because it must be often provided with additional very small instruments.

![Small gripper used in the surgery produced by Bacher, Germany](image1)

**Figure 5.** Small gripper used in the surgery produced by Bacher, Germany [3]

In measurement it is imperative and a competitive advantage, if the required data can be determined with a sensor as small as possible, with highest possible resolution.

![Measurement, Sensor in the flow technology, pressure, temperature](image2)

**Figure 6.** Measurement, Sensor in the flow technology, pressure, temperature [1]

2. Solution

To solve these types of problems we thought the realization of a flexible universal workstation through the use of standard robotics systems and image processing devices in cooperation with humans, where workers are largely free from the highly strenuous physical and fine motoric work, so that they can monitor and adjust the production process.

For the assembly of such small components we made contact with companies in southern Germany, namely: Endress + Hauser AG (sensor technology) [1], Bacher Medizintechnik GmbH [3]
and Johann Deufel Chirurgische Instrumente GmbH [2] (both manufacturer and supplier of medical technology).

All these companies had the same problems: assembly of very small components, precision processes, long training of employees and cost pressure from low-wage countries.

They had, together with our University, the goal to realize a flexible human-robot workplace for assembly of small components, but with low cost standard devices.

The first objective was to establish a universal experimental workstation, expandable for series production. In this workstation the operator can respond quickly to changes, the robot can work quick and accurately, the image processing system can deliver high resolution pictures for object detection, exact positioning and process documentation.

**Figure 7.** Workstation: Cooperation humans and robots

The next step was to find out which kind of technology was available in our technical university and then to decide what components we needed additionally to our devices.

We knew that robots have to work behind safety fences and other protective devices.

**Figure 8.** Robot cells at the University of applied sciences, Ulm
Figure 9. Robot cell in an exhibition [4]

3. Safety Eye
But because of the cells humans cannot work in direct cooperation with industrial robots. When for example a cell door is opened the robot will stop immediately.

A solution for this inconvenience is to implement a virtual safety system. For this aim we used the Safety Eye from the German company Pilz GmbH [5], developed in cooperation with Daimler AG.

Figure 10. Safety Eye System from Pilz, Germany [5]
In this case operators, can walk up to the vicinity of the robots. The Safety Eye can detect every movement in the neighborhood of the robots. In front of a distance where robots can be dangerous for humans the robots reduce their working speed and an attention signal is switched on. If the operator ignores the signal and moves further towards the robot, the system stops immediately and a red light and an acoustical signal are switched on.

The safety system is designed as a redundant system, in the case if one of the operating systems has a dysfunction.

4. NeuroCheck

Other components of the work station are industrial camera systems. With them we were able to visualize objects, so that robots were able to search and detect the objects they needed for the assembly process.

![Figure 11. Robots operating with cameras, University of applied sciences, Ulm [6]](image)

The most used camera system in our experiments was NeuroCheck from Neurocheck GmbH, in Stuttgart, Germany. NeuroCheck [7] is used in many industrial applications in companies like: Daimler, BMW, Robert BOSCH, ZF, Philips, Federal Money Printing House, etc.

With NeuroCheck it is possible to identify barcodes, check object positions, to compare and recognize patterns, measure components, inspect surfaces, process colours, or to control and guide robots.
Other advantage of NeuroCheck is the ability to use it for quality inspection, because it can inspect and record the whole automated production with a customized documentation.

5. Robots
In the workstations we used as well industrial robots from KUKA [8] as robots from Stäubli [9] for fine positioning.
Figure 14. Industrial Robots from KUKA, Germany [8]

Figure 15. Robots from Stäubli, Germany/Switzerland/France [9]
6. x-y Fine Positioning
To reach precisions under 0.1 mm we used x-y-tables as they are used for micromachining, besides cameras and precise robots to position in the x-y direction.

![Figure 16. Positioning device in X-Y direction](image)

7. Conclusion
With this kind of device it was possible to get precisions under 10 µm. The precision was enough to place the objects in the desired position.

The project showed that companies can use common robots and technical devices for high precision applications and can realise workstations where robots can work together with operators.

References
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