Vision-based Monitoring of Manual Assembly Processes

I. Kastanis, M. Höchemer, S. Widmer, P. Schmid

A system was implemented for monitoring manual assembly processes using specially developed visual markers in conjunction with machine learning methods that recognize the actions of the assembly worker. The system learns by instruction and provides online information to the user about the assembly tasks within the process. In line with Industry 4.0 concepts, this monitoring system is highly configurable offering a great degree of flexibility that makes it is an excellent tool for customized small-batch production runs.

Manual assembly processes are still very common in many industrial shop floors. The repetitive nature of these tasks makes them error prone, effectively reducing the overall quality of the manufactured parts. Current methods for quality control typically combine a human supervisor and an automated test station. The proposed system offers an automated solution for quality assurance, which is especially important for medical devices as well as other sensitive areas where manufacturing quality must be 100 %.

The goal of this project was to develop a machine vision and learning system that monitors the manual production of parts and offers assistance to the worker in order to recognize their gestures and avoid errors. This reduces the costs and the resources and guarantees consistency in production. The developed solution is based on a PC system with a connected camera that overlooks the work area.

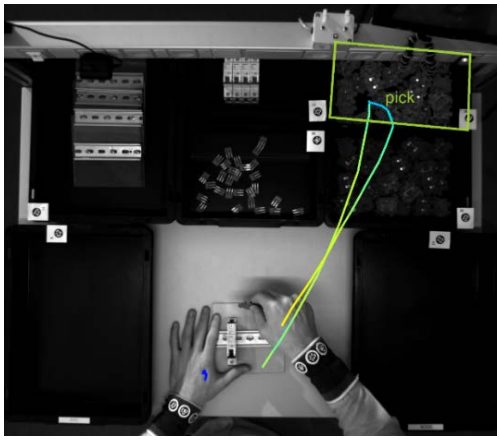

Figure 1: System-camera view. A picking action is recognized.

Tools, component boxes and both hands of the worker can be continuously detected and tracked by using visual markers developed specifically for this project. The system learns with the use of machine vision how the correct execution of the assembly is performed. This is achieved in the learning phase where the process steps from a human worker are observed, analyzed and recorded as "correct" steps. For the robustness of the training, the system must be capable of tolerating variations from different individuals, it is often the case that the positions of component boxes is not fixed. In most cases, a test device is used at the end of the assembly to verify different aspects of the finished product, for e.g. weighting, electrical tests, visual measurements. During these monotonous assembly tasks, it is frequent that after hundreds of correctly assembled products, the test device detects a defect but the worker places it out of habit in the box of "good" parts. The developed solution offers for this case an additional level of quality assurance by having test and measurement devices connected to the system. In the learning phase, the system learns that a defective product goes in the reject box, and a non-defective goes in the "good" parts box.

Another important aspect for error reduction is the ability of the system to display live information to the worker during assembly. Since the system is aware at all times which steps of the process have been completed and which should follow, it can inform the worker about the next steps that need to be executed. Using past information, the system can dynamically assess which variation of the process the worker is currently performing, if a valid one exists. In the case of an error, the system notifies the user and can allow error correction and continuation of the process.

Figure 2: 6D-pose visual markers used for tracking (developed by CSEM).

The tracking of the visual markers was a challenging task due to the many markers that need to be detected and tracked simultaneously in high-resolution images. The required tracking speed for a trained worker makes standard marker technology ineffective. Further, complete pose is desired for analyzing the assembly motions. Appropriate markers were developed in conjunction with detection and tracking algorithms that are capable of complete 6D-pose detection with 60 fps in high-resolution images in a robust manner where short occlusions do not cause problems.

A complete solution for monitoring manual assembly processes was developed offering visual assistance to the worker. A short video can be found on the CSEM YouTube channel [1]. By using machine learning, the processes can be learned by instruction in an efficient manner without requiring expert personnel reducing therefore the ramp up time and the initial setup costs. The developed markers offer robust detection and tracking in high-frame rates, capable of capturing human-hand motion. The dynamic and configurable nature of the system has the potential to reduce the amount of errors in manual assembly lines and offer an automated tool for quality assurance.

The work has been supported by the Swiss Commission for Technology and Innovation CTI (project Nr. 16025.1 PFIW-IW) as a part of the Approbate project in collaboration with Credimex AG [2] and Maxon Motor AG [3].

[1] youtu.be/zBao3QunnGY

[2] Credimex AG, Switzerland

[3] Maxon Motor AG, Switzerland