Interactive Assembly Guide using Augmented Reality

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Introduction

Today many assembly processes are automated, but automation is not optimal in all assembly processes. Automated assembly is only cost-efficient in mass production where a large number of items can be produced with few or no variations in the assembly process. Assembly processes with a high degree of customization require the flexibility of human assemblers. This includes the pump assembly process at Grundfos. In Bjerringbro alone 160,000 CR pumps are produced annually. Of these, only an average of three pumps have the same configuration.

Several studies document that augmented reality compared to traditional paper instructions can make an assembly process faster as well as reduce the number of errors [1] [2]. In [1] test persons that used augmented reality assembled Lego pieces 26 % faster and with 34 % fewer independent errors than test persons not using augmented reality.

The aim of this project is to develop interactive assembly instructions to optimize the assembly process at Grundfos by the use of computer vision. Instructions given as augmented reality in the user interface shall help the user to assemble the pump correctly.

Method

To display augmented 3D graphics correctly, the position and orientation (pose) of the partly assembled pump must be known. The central topic is thus real-time pose estimation.

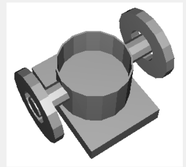
The assembly process is captured using a stationary camera and shown to the assembly personnel along with augmented information on a computer screen. The test setup is shown in Figure 1.

The pose estimation approach is analysis-by-synthesis. 18 hypotheses regarding the pose are tested, and the best 2 are selected for further optimization. In total 28 hypotheses are tested. The best hypothesis is used for displaying the augmented parts.

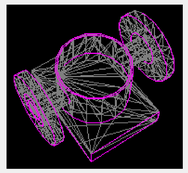
Method

The Region of Interest (RoI) is determined by first subtracting the video frame from a background frame. The pump is then found using BLOB analysis.

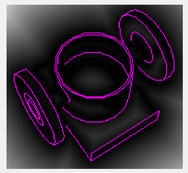
The features used for pose estimation are edges. Edges in the RoI are detected using Canny edge detection [3].



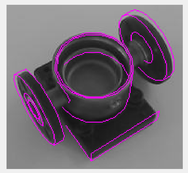
In order to pose estimate in real-time, a low-poly model of the pump has been made. 28 hypothetical poses are generated in two steps to determine the correct pose.



Visible contours and sharp edges are synthesized from the low-poly model in real-time for all hypotheses.



Detected and synthesized edges are compared by chamfer matching. A distance map is generated for detected edges, and thus one distance map allows comparison with many hypothetically posed models.



Superposition of the best matching pose of the model back on the RoI of the video frame.

Results

In the developed prototype, 6 steps of a pump assembly process have been included. Figure 1 shows the test setup, and Figure 2 shows the user interface.

The system has been tested using a 2 GHz dual core computer. The frame rate of the video was identical to the frame rate of the used camera. The rate of pose estimates depended on the model to pose estimate. For the largest model, pose estimation takes approximately 0.4 sec.

In a test, 4 of 6 unexperienced test participants succeded in assembling the pump parts correctly, while the remaining 2 only made minor mistakes.

Figure 1: A user is assembling a pump using IAGuAR.

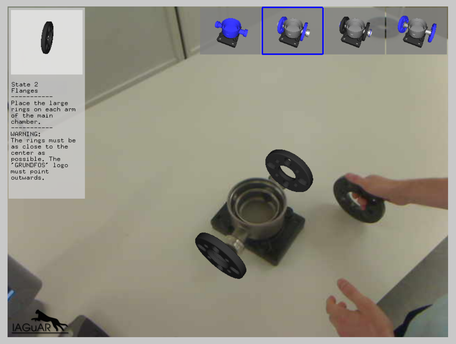


Figure 2: Screenshot of the user interface taken simultaneously with Figure 1.

Discussion

The pose estimation is reasonally robust. However, the user must manually change state by the push of a button when another piece has been mounted. The usability of the system would increase if state switching occured automatically.

A related topic is automatic error detection. It is documented that augmented reality alone can reduce the amount of errors, and error detection might decrease the error rate during assembly even more.

Finally, for the system to be implemented in the industry, it must be possible to automatically generate low-poly models from existing CAD models.

References

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[3] John Canny. A computational approach to edge detection. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, PAMI-8(6):679–698, Nov. 1986.

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