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Requirements for Industrial Augmented Reality Tracking Systems - an Evaluation

K. Pentenrieder[1], P. Meier[1], F. Doil[2], S. Nölle[2]

[1]metaio GmbH, Germany
[2]Volkswagen AG, Wolfsburg

Abstract

Industrial environments often have special requirements for AR systems and features are prioritized different than in scientific applications. The Volkswagen group (VW) wants to apply an AR-guided stud welding system for small-series and prototype production. To find the optimal tracking system for this application, an evaluation of different tracking systems was undertaken, whose results and consequences are outlined here.

1. Introduction

Figure 1: *Tracking systems: (a) metris iGPS, (b) metris Krypton series, (c) FARO measurement arm*

1.1. Motivation

In industrial applications, Augmented Reality (AR) is today an established technology for supporting industrial processes in areas like design, planning and production, training and maintenance. One AR-based industrial application in production is AR-guided stud welding [ESK*03]. At the Volkswagen group this application shall be used for small-series and prototype production. The goal is to ease and fasten the welding process by providing workers with a guidance corridor leading them to the next welding position. And to save time and costs especially through avoiding the usually needed manual marking process for the welding spots. In addition the system can be used to document the processed welding spots.
To find the optimal tracking solution, an evaluation of tracking systems was undertaken. Tracking systems already known at VW, especially from the measuring department were evaluated for their applicability and suitability for the stud welding application and AR applications in general.
Comprehensive tracking system evaluations have been done in the past [RDB00]. Different from these approaches, our analysis aims to integrate information from data sheets with personal experience in real applications. In addition the list of evaluation criteria goes beyond the common parameters like accuracy and range, to include unique requirements for industrial environments.

1.2. Tracking systems

For the evaluation four tracking systems were chosen (see figure 1). All of these systems are already used at the Volkswagen group for different kinds of measuring purposes. They were selected due to their availability in the company and their high accuracy in measuring.
The three optical tracking systems are manufactured by metris [Z H07b]. Their Krypton series tracking systems K600 and K610 are for instance used for high accuracy measurements in car assembly on medium-sized objects. The metris iGPS is the indoor GPS solution of metris based on infrared light. It is applied for large industrial measurement scenarios for instance in aircraft construction.
The fourth tracking system is the FARO measurement arm [Z H07a], a mechanical tracking system. Here the largest available arm with 7 axes is evaluated. Measurement arms like that are also used for high accuracy measurements, mainly for small volume objects.

2. Evaluation

The Volkswagen group is interested in evaluating these tracking system alternatives both for their performance with respect to the stud welding application, as well as for usage in general AR applications. For a comprehensive analysis, a set of evaluation criteria was defined to rate the quality and usability of the tracking systems according to VW's needs.

2.1. Evaluation Criteria

The evaluation criteria consist of criteria which are especially important for the stud welding application and criteria which are of interest for industrial AR-applications in general:
The overall **accuracy** for the stud welding application is calculated, meaning the pose accuracy for the guidance tunnel from the welding gun to the welding spot. The threshold for acceptance is $\pm$1mm.
Range is evaluated to check the possibility to track a whole car body. In case one system does not reach the necessary range, several ones could be combined. The **costs** for a complete system setup and the necessary welding gun modifications for tracking are considered.
In addition the **link ability of the measurement engineering SW with an AR application** is regarded. Here the interface of the tracking software is considered to check the possibility to connect the system with an AR application.
As measuring and verification equipment at the Volkswagen group needs to be certified according to code VDI/VDE 2617 [vdi97], the **feasibility of certification** for the different alternatives is verified.
Another important aspect is the **robustness** of the system. This is analyzed in terms of general robustness (against shock or dust), error rate and recalibration intervals of the system as well as interference through temperature, light, occlusion and current.
For the **real-time capability** of the system, the frame rate is taken as indicator and the general configurability of the software is analyzed.
As the tracking system should be applicable for general AR-applications, **camera tracking** must be possible. Therefore a 6D pose must be available and a rigid connection of camera and tracking system.
Finally **usability** and **ergonomics** of the systems are evaluated. The overall time consumption and the personal effort for the major configuration and calibration tasks is summed up as a usability measure. Ergonomics is rated by easiness of system setup, its flexibility and constraints on working space and user know-how.

2.2. Evaluation Results

The following table briefly summarizes the results of the evaluation process. Only the main indicators for the different criteria are shown, as a complete description of the evaluation cannot be presented here.

Criterion	K600	K610	iGPS	FARO
Robustness	medium	medium	low	high
Frames/s	50-100	50-100	10	40-100
Acc. (mm)	≈ 0.8	≈ 0.6	≈ 3	≈ 0.3
Range (m^2)	8	8	100	11
Costs (€)	150000	170000	200000	50000
Interface	TCP	TCP	SDK	SDK
Certified	yes	yes	possible	yes
Setup (min)	≈ 60	≈ 60	≈ 30	≈ 30
Usability	complex	complex	easy	easy

3. Conclusions

The system evaluation allows several conclusions:
For very accurate tracking only the Krypton systems and the FARO arm can be used. Concerning robustness, the FARO arm as the mechanical system gets the best rates. In case costs are of greater importance the metris systems should be excluded. But for large ranges (iGPS) or very high accuracy and frame rates (Krypton) they are most suitable. As an overall result, we can say that all the systems require some time for breaking-in.
For our stud welding application the FARO arm is the best choice because of its robustness and usability combined with a good accuracy and low costs. Breaking-in time will be reduced through workers, which are taught in measurement engineering.
For general AR applications the choice in tracking system depends on the importance of the different criteria. Our study is a valuable basis for decision-making.

References

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