# Augmented Reality for Programming Industrial Robots

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## Abstract

*Existing practice for programming robots involves teaching it a sequence of waypoints in addition to process-related events, which defines the complete robot path. The programming process is time consuming, error prone and, in most cases, requires several iterations before the program quality is acceptable. By introducing augmented reality technologies in this programming process, the operator gets instant real-time, visual feedback of a simulated process in relation to the real object, resulting in reduced programming time and increased quality of the resulting robot program. This paper presents a demonstrator of a standalone augmented reality pilot system allowing an operator to program robot waypoints and process specific events related to paint applications. During the programming sequence, the system presents visual feedback of the paint result for the operator, allowing him to inspect the process result before the robot has performed the actual task.*

## 1. Introduction

Traditionally, operators specify a number of waypoints in relation to a target to create programs for industrial robots. In addition to these waypoints, a number of events located on the robot path describe process-related occurrences along the trajectory. For paint applications, these events may describe e.g. paint color changes or changes in fan-width. Computer-animated design (CAD) programs are one type of applications often used to generate such robot programs. These engineering tools, however, are often complex and require skilled operators with a thorough understanding of CAD combined with process knowledge in order to produce good results. Additionally, the CAD-based approach requires a computer model of the target object to be available.

Another common way of performing the programming task is to use a robot teach pendant to sequentially move the robot tool center point to desired positions and then record points. After all points have been recorded, process-related events are added to the path in a second iteration. There are three main issues related to this way of generating a robot program:

1. Specifying points and orientations (six degrees of freedom) using a teach pendant, traditionally a joystick with two degrees of freedom, is cumbersome and time consuming.
2. The operator does not get any visual feedback of the process result before the program has been generated, downloaded to the robot, and executed.
3. Several programming iterations are needed in order to add process-related events to the robot path.

The main purpose of this pilot system is to develop a robot programming system that is easy to use, speeds up the programming process, utilizes the intuitive process knowledge of the operator, and increases the quality of the finished program without the need of a CAD model.

## 2. Demonstration description

Figure 1 illustrates the system configuration with the physical components of the system described in the following sections.

### 2.1. Tracking system

The vision-based tracking system comprises a camera system worn to the operator identifying a set of circular fiducials with unique identities and known 3D positions. The pose estimation algorithm needs at least four of these fiducials to be visible and detected simultaneously [1], [2]. The two purposes of the tracking system are to:

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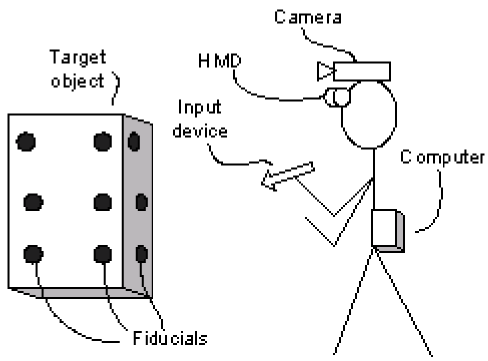


**Figure 1. System configuration**

1. Track the pose of the HMD in relation to the reference frame for accurate registration of the computer generated graphics in relation to the real world
2. Determine the pose of the hand-held input device in relation to the reference coordinate system

### 2.2. Hand-held input device

A hand-held input device, having a number of fiducials attached to it, acts as the main tool for interaction between the operator and the system. The operator places the input device at a desired pose in relation to the target object to be processed to specify points describing the desired robot path and process-related events in a sequential manner.

### 2.3. Wearable computer

All active system components (camera, head-mounted display (HMD), and input device) are directly connected to a wearable computer running algorithms for detection of fiducials, pose estimation, rendering of virtual graphics, image registration, capturing of path waypoints and process events, as well as generation of the robot program code.

### 2.4. Program generation

To start the programming session, the operator places an adequate number of fiducials onto or around the target object. Then, an automatic configuration procedure calculates the positions of the fiducials [3]. Once positions of the fiducials are calculated with sufficient accuracy, the operator starts to teach waypoints and events in a sequential fashion. During programming the operator sees a graphical representation of the simulated paint result visualized by virtual graphics overlaid on the real target. Finally, the system generates the robot code to be downloaded to the robot controller.

The programming results are visualized on the HMDs worn by the operator and projected on a large-screen inside the booth.

## 3. Conclusions

The use of Augmented Reality for robot programming represents a revolutionary concept for industrial applications such as robot programming. This novel robot programming method using augmented reality to visualize the paint result while making a new robot program has proved to be at least five times faster than traditional robot programming methods. Additionally, the operators report that they find the process of programming robots much easier and intuitive.

The submitted video clip illustrates the use of augmented reality for robot programming implemented in ARToolKit. The technical demonstration to be given at the ISMAR conference is not based on ARToolKit but implemented from scratch with other tracking and pose estimation algorithms.

## 4. References

[1] C.P. Lu, G.D. Hager, and E. Mjolsness, "Fast and Globally Convergent Pose Estimation from Video Images", *IEEE Transaction on Pattern Analysis and Machine Intelligence*, 22(6), June 2000, pp. 610-622.

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[3] U. Neuman, J. Park, "Extendible Object-Centric Tracking for Augmented Reality", *Proceeding of Virtual Reality Annual International Symposium 1998*, March 1998, pp. 148 – 155.


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