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Utilization of a Vision System to Automate Mobile Machine Tools

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Abstract

In an attempt to be more flexible and cost effective, Aerospace Manufacturers have increasingly chosen to adapt a manufacturing style which borrows heavily from the Automotive industry. To facilitate this change in methodologies a system for locating robots has been developed which utilizes cameras for both locating and guidance of a mobile platform for a robot with drilling and fastening end effector.

Introduction

The Automotive industry extensively uses AGV's in conjunction with robots and moving line technologies to efficiently manufacture automobiles with high quality and low defect rates. Applying this technology to the Aerospace industry requires some adaptations. Although it is possible to manufacture an airframe utilizing a continuously moving line, pulse line style manufacturing is easier to adapt and when integrated with a flat factory floor, a system that is easier to reconfigure is produced. Future adaptation to a larger or longer airframe is realized with little effort and infrastructure change.

Mobile Robotic System

System Architecture

The robot based system is comprised of a KUKA industrial robot placed on top of a mobility platform. The robot incorporates a drilling and fastening end effector which is used for assembly and integration of Aircraft structures. In this integrated system, the cameras that are used for guidance of the mobility platform are also used by the robot to determine is position on the open factory floor as well as guidance between stations. The platform moves from station to station using lines placed on the floor. It then finds valued targets on the floor calculating its location in the world coordinate system. The proper part programs are then loaded and executed. When complete the system is moved to the next station or removed from the cell for part extraction.

Figure 1 Robotic Automation System

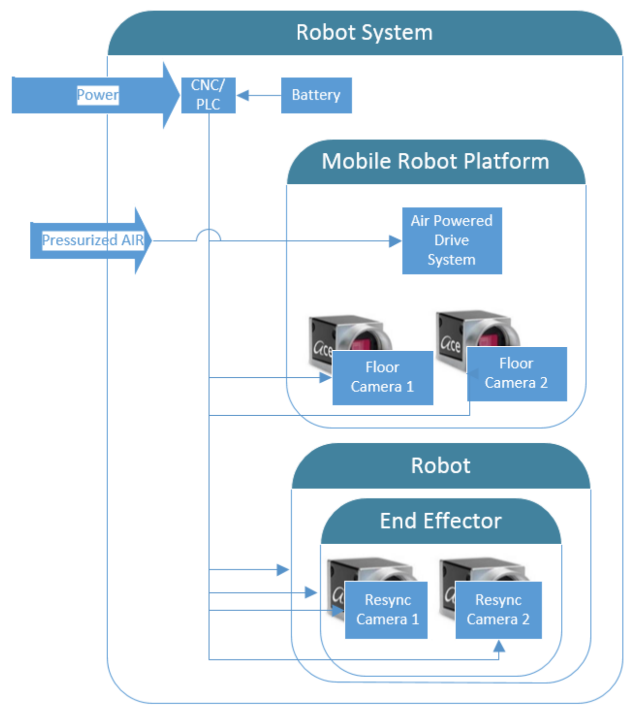

Figure 2 System Architecture

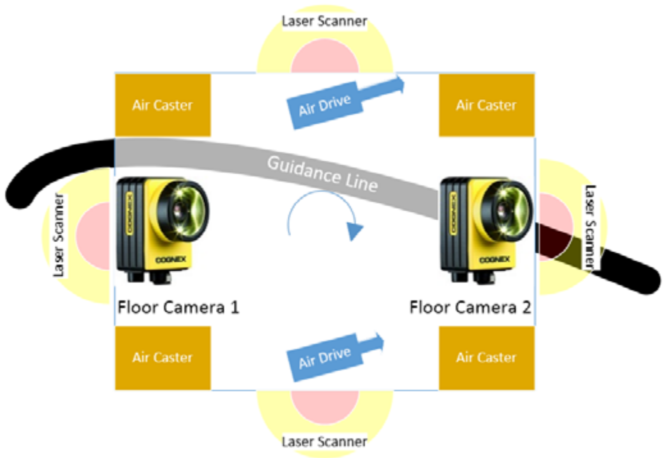

Figure 3 Mobility System Layout

Guidance While Moving

The mobility platform is comprised of 4 air bearings, 4 laser scanners, 2 air drives systems, 2 cameras and a PLC for controls. The platform is driven using a pendant or control panel with the cameras activated for guidance along a line placed on the floor using tape or paint. The path is easily reconfigurable if using tape. When in position the cameras datum on a precision fiducial which informs the machine which station it is in, which part program to load and which transforms to use to align the robot coordinates with airplane coordinates.

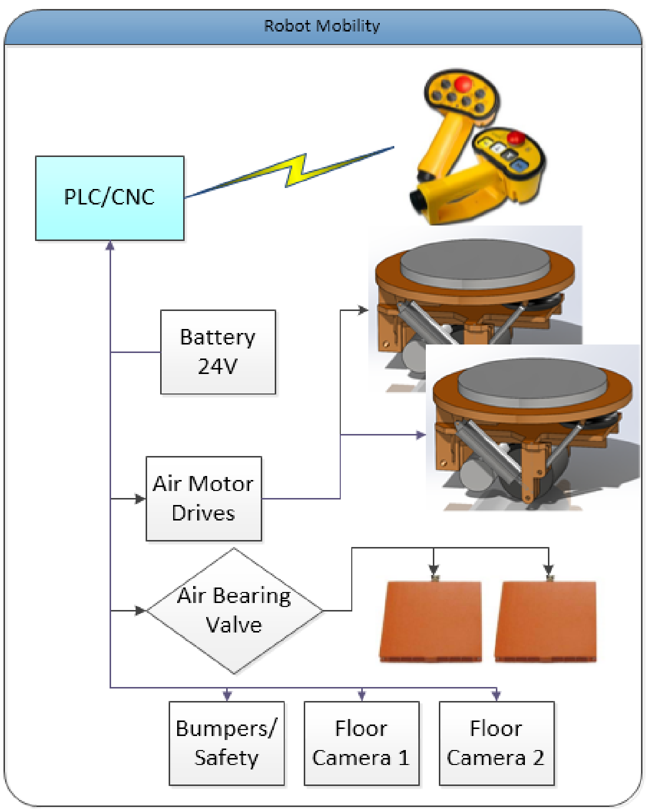

Figure 4 Propulsion

The use of a smart camera allows direct integration into PLC PROFINET infrastructure without having to have a separate PC for processing.

Figure 5 Smart Camera

Kinematics integrate the error reported by each camera into steering and velocity for each drive wheel. Owing to the use of air propulsion PID controls within the PLC are used for velocity and orientation control. Laser scanners provide collision safety and are utilized by the robot during manufacturing operation and during transport operation.

Accurate Datuming to Part

To locate the robot within each station the location of 2 fiducial targets are valued with a laser tracker relative to the world coordinates.

Figure 6 Floor Barcode Fiducial

The transform from robot to camera is calculated using a calibration plate that is seen by the camera and valued by a laser tracker in robot coordinates.

Figure 7 Calibration Plate

The 2 floor cameras then locate the two targets and load the values based on each targets barcode. The transform to world coordinates, ξ_{R}, is then calculated using the 2 target actual values (${}^{C1}\xi_{P}$ and ${}^{C2}\xi_{P}$) and the nominal values. After calculating transform ξ_{R}, the robot is accurate to ±.040" in the World Frame. This calculation takes less than 3 seconds to execute and is only needed once after the system has been moved. Part programs applicable to the current station are then started and normal manufacturing execution begins. Once the Mobile Robot system is located relative to the FAJ, further positional refinement is performed in the part program using resync's directly on the part resulting in accuracies of 0.007"[1] in the World/Aircraft Coordinate Frame.

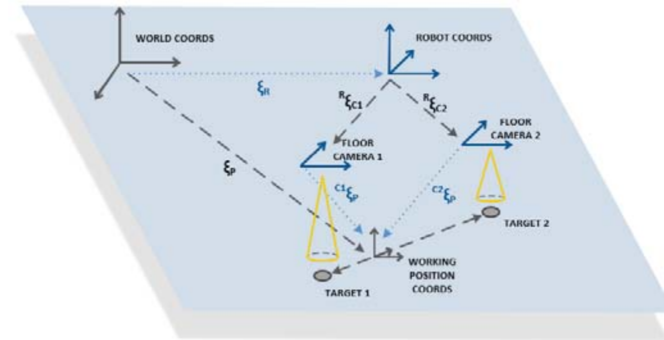

Figure 8 Transform Graph: Grey coordinate axes and grey dashed lines are static. Blue axes and blue dotted lines are dynamic.

The resync camera on the end effector uses datum features on the part including DA holes, fasteners, temporary or permanent, and edges.

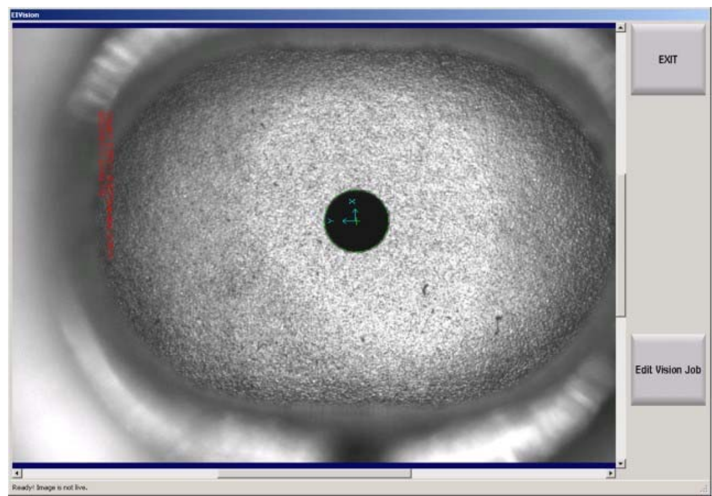

Figure 9 Resync Picture

Additionally vision systems on the end effector can be used to determine the 3D location of features, enabling enhanced automation when there is uncertainty as to the location of fasteners and other structural items. This is accomplished using 2 cameras, arranged at angles to each other and calibrated to a common coordinate frame relative to the end effector coordinate system.

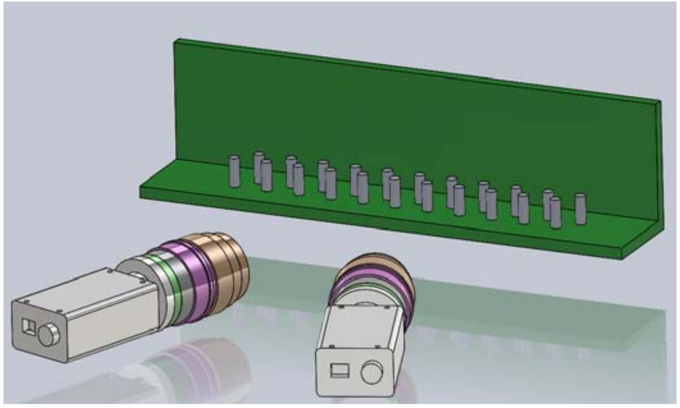

Figure 10 3D Camera Setup

Each camera takes a separate image and calculates the orientation and 3D position of the fastener relative to the end effector. A nut or collar is then placed on the fastener and secured. The need for manual interaction is minimized.

Figure 11 3D Vision of Fastener Tails

Summary/Conclusions

This methodology and system architecture provides for a mobile system which is highly accurate and flexible in its utilization and placement on the part. Leveraging vision systems in Aerospace manufacturing provides for higher productivity, quality and accuracy of finished parts.

References

1. Saund, B. and DeVlieg, R.,"High Accuracy Articulated Robots with CNC Control Systems" SAE Technical Paper 2013-01-2292, 2013, doi:10.4271/2013-01-2292.

Definitions/Abbreviations

CNC	Computer Numerical Control
PLC	Programmable Logic Controller
FAJ	Final Assembly Jig
PID	Proportional, Integral, Derivative
DA	Determinate Assembly
end effector	Tooling at the end of the robot arm which can be comprised of drills, fastener inserters and other measuring devices
PROFINET	a standard for industrial automation using a computer network
smart camera	A camera which integrates vision processing without the need for a PC
fiducial	An object placed in the field of view of an imaging system for use as a point of reference