Rapid Deployment Automation: Technical Challenges

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Abstract

Product life cycles have shortened to 1-2 years in many industries, causing increased interest in flexible automation. However it still often takes 1-2 years to sell and install a robot system. We would like to shorten this time by a factor of ten to 2-3 months. In order to achieve this we must be able to design automation systems in a matter of days, build and install them in a matter of weeks, and train them in a few hours. Adept is pursuing a technical approach to this challenge based on geometric modeling and reasoning, sensor-based part feeding and assembly, and smart application packages. Significant technical challenges remain, including acquiring models or parts quickly and automatically, 3-D machine vision, assembly strategies which reason about geometric uncertainties, error representation and recovery, and simple teaching techniques. Adept's current approach is described and technical challenges are discussed.

1 Introduction

To date, applications for robots have been primarily industrial. Many potential new applications are emerging, however they face many of the same types of barriers that faced industrial applications. This paper will examine one industrial application, assembly, and discuss factors which have limited its rate of acceptance. Readers may wish to examine their own applications with these factors in mind.

Market demand for flexible assembly automation is driven by several factors. These include rapidly shrinking product life cycles, miniaturization, increased demands for quality and cleanliness, and a constantly rising cost of labor. Flexible automation using industrial robots is replacing both conventional automation (which used cams and air cylinders) and manual labor.

It is interesting to note that robotic assembly was accepted more rapidly in Japan than in the U.S. or Europe (International Federation of Robotics, 1996). In Japan assembly robots account for over 40% of the robot market whereas in the U.S. and Europe assembly is 10-15% of the total robot market. Japan initially used assembly robots largely in high-volume production applications, essentially to replace hard automation. The U.S. and Europe looked for assembly robots to replace expensive labor. It was easier to replace hard automation than manual labor resulting in broader proliferation of assembly robots in Japan.

Today, with the continuing demands for shorter product life cycles and more product variety, Japan is beginning to require increasing levels of flexibility from assembly systems. At least one manufacturer (Sony) which has invested extensively in flexible automation, is discussing whether manual labor might be the better solution for their flexible assembly needs.

Adept has identified a number of barriers which have limited the widespread adoption of robotic assembly and has developed a plan to address these barriers.

2 Time and Risk

An informal survey conducted at General Motors several years ago found that the typical implementation time for a "hard" automation assembly system was three years. While this was acceptable when automobiles had product lives of 7-10 years, it is not acceptable as the auto industry compresses its product lives to three years.

Three years ago Adept surveyed a number of its customers and determined that the average
time to sell and install a "flexible" automation assembly system was 1.5 - 2 years. This was not dramatically better than "hard" automation.

This implementation cycle could be divided into two parts: the sales cycle and the system build cycle. The sales cycle is defined as the time from first contacting a prospective customer to the time the purchase order is received. The system build cycle starts with the receipt of a purchase order and ends when the customer accepts the system running production on the factory floor. The sales cycle was taking 9-12 months and the build cycle an additional 9-12 months. This contrasts with installing a manual assembly line in 2-3 months.

The sales cycle includes time for the following activities: determining the feasibility of the application, developing one or more detailed automation system proposals for the application, determining the cost and throughput of the proposed system (justification), and convincing the customer that the system will work (addressing customer perceived risk).

The build cycle includes time for detailed system design and layout, ordering parts, building and installing system components, writing software for the system, and running and debugging the system until it meets acceptable levels of performance.

3 Rapid Deployment Automation

Adept asked the question, "What is required to reduce the sales and build cycle by a factor of ten, from several years to several months?" This magnitude of reduction would make buying and installing a robot assembly line as fast as installing a manual assembly line in 2-3 months.

A technical strategy was developed to address this goal, resulting in a four-layer product hierarchy. We call the top layer in this hierarchy "The Design Layer". It includes 3-D simulation products for the design and off-line programming of robot systems. For example a simulation product called "RAPID" allows virtual workcells to be composed from 3-D CAD models of robots, part feeders, conveyors, etc. and for CAD models of customers parts to be imported into the virtual workcell. The workcell can then be animated, and can provide a 3-D visualization of the proposed system working with the customer's parts, accurate cycle times, a list of workcell components required, a physical layout of the system, a wire list to hook up the system and the software to download to the actual system. The design layer is intended to compress the proposal and sales cycle by allowing 3-D animated system concepts to be developed and verified in a matter of hours or days. The efficiency of this tool allows the customer to easily interact with the design process and results in a video tape which both documents the concept and becomes an internal sales and education tool for the customer.

The second layer in the Rapid Deployment Automation (RDA) hierarchy is called "The Process Knowledge Layer". This layer is composed of an application development environment and a series of application packages which contain process knowledge and allow programming at the "task" level. This environment is called "AIM". Task level application instructions separate "WHAT" is to be done from "HOW" to do it from "DATA" necessary to perform the task. This allows the application developer to embed process knowledge ("HOW") in task-level instructions. The "DATA" necessary for the particular instance can be trained or downloaded from a model, i.e. the RAPID simulation system. The process knowledge layer allows application programs to be quickly developed by less skilled programmers, and eventually to be semi-automatically generated from the system design process.

The third layer in the RDA hierarchy is called "The Real-Time Control Layer". This layer includes the robot programming language, sensors such as machine vision and force, and motion control hardware. We now view this layer as a building block rather than as an end in itself.

The fourth layer is called "The Mechanism Layer". It includes the mechanical devices necessary to construct an assembly system. Adept has recently expanded its product line to include part feeders which use machine vision to enable them to feed a wide variety of parts with no mechanical adjustments. As custom part feeders such as bowl feeders or pallets were dedicated to a specific part, they limited the flexibility of the system. To change from one product to another, any part-specific feeders must be changed. This is expensive and time-consuming. Flexible part feeders may be programmed in a few minutes and as a result shorten both system development time