AN INTELLIGENT WORKCELL ROBOT

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Abstract

In batch type production, workcell settings are subjected to changes. The set-up time for changeover and calibration ultimately lead to low machine utilization. To reduce the set-up time, this study aimed to develop an intelligent workcell robot that can on-line adapt to the workcell changes and the associated calibrations automatically. The results showed that this intelligent robot is able to automatically re-organize itself for dynamic workcell changes including mal-functioning machines, newly introduced or removed machines and product changes. A significant amount of time in system installation, re-setup, calibration and re-programming can therefore be saved.

Keywords: Intelligent Robot, On-line Adaptation, Workcell changes

1. Introduction

In recent years, the demand for small-size and high value batch production has surpassed the need for mass production. In small-size batch production, workcell settings are subjected to changes. These changes may be deliberate (as in new product introductions) or forced (as in machine breakdowns or material shortages), but in any case they are inevitable in the factories of the future.

Nowadays, if changes occur, the workcells have to be halted until the set-up, installation, calibration and programming are completed. Obviously, it is not efficient to frequently interrupt production for changeovers. Therefore, for small batches of products to be made economically, the capability of adapting to changes automatically is essential for future intelligent manufacturing systems [1]. Due to the importance, many research projects have been targeting at the development of intelligent manufacturing systems [1-3]. The common goal is to fabricate an intelligent system, or part of it, for future factories.

In line with this, this paper presents the development of an intelligent workcell robot which uses the information generated by off-line simulation and on-line sensors to adapt to the variations in real-time. The proposed system consists of a vision system, a 3D Force/Torque sensor, a 6-axis industrial robot, neural networks, a common database, and software modules.

With this research achievement, a significant amount of time in system installation, re-setup, calibration and programming can be saved for changeovers. This then leads to higher machine utilization efficiency and more effective manufacturing systems, especially for small-size batch production manufacturers.

2. Methodology

2.1. Functional Requirements

The primary purpose of a system needs to be defined before the functional requirements of the system can be determined. For the presented robot system, being able to on-line adapt to the workcell changes and the associated calibrations automatically was the primary purpose. With this in mind, functional requirements were decided. The system must be able to:

1. know what is happening in the workcell, including which machine is malfunctioning; which is the newly introduced machine, where the raw component is to be located in the new machine; and which machine has been removed or disabled?
2. recognize and pick up the right parts randomly presented at a non-fixed feeding position.
3. automatically detect and compensate for robot relative positioning errors caused by any mechanical drift and/or simulation inaccuracy, etc.
4. take appropriate actions for all the items listed above with minimum human intervention.
5. maintain cell production while changeovers occurring.

In addition, programming method was also looked at. It was aimed to be user friendly, offline, hardware-independent, and without the need of visual aids or special care in setting up spatial relationships between workcell components.

2.2 System Component Requirements

<u>To know what is happening in the workcell:</u>
In the workcell, each machine has its own time-dependent expected/unexpected conditions and needs, therefore, a workcell information center (i.e. a common database) is important for the machines and robot to exchange information.
<u>To recognize and pick up randomly located parts:</u>
Machine vision is required for part recognition, and the position and orientation derivation. To avoid time-consuming teaching for part recognition information and robot collision-free moving paths, off-line simulation is also required.
<u>To automatically detect and compensate for robot relative positioning errors:</u>
A sensing module is required to detect and compensate for robot relative positioning errors, and update the system data (i.e. robot moving path) stored in the system memory.
<u>To take appropriate actions and maintain cell production:</u>
With sufficient input sensory information, reasoning, planning, and decision-making capabilities are required for appropriate actions. To maintain production while changes occurring, flexible programming and job-scheduling method are required.

3. System Overview and Components

3.1. System Hardware Overview

The system hardware configuration [4], shown in Figure 1, consists of:

- Six-axis industrial robot - A six-axis robot, ABB IRB 2000 with Model M92 controller.
- 3D Force/Torque sensor [5] - for robot control while interacting with the environment.
- Sensor signal processing circuits - 3D Force/Torque signal was amplified, converted into current for long distance transmission, transmitted and then converted back to voltage.
- Mutlifunction I/O board -The signal from F/T sensor was eventually received by Lab-PC+, installed in PC and then processed by software modules for robot control.

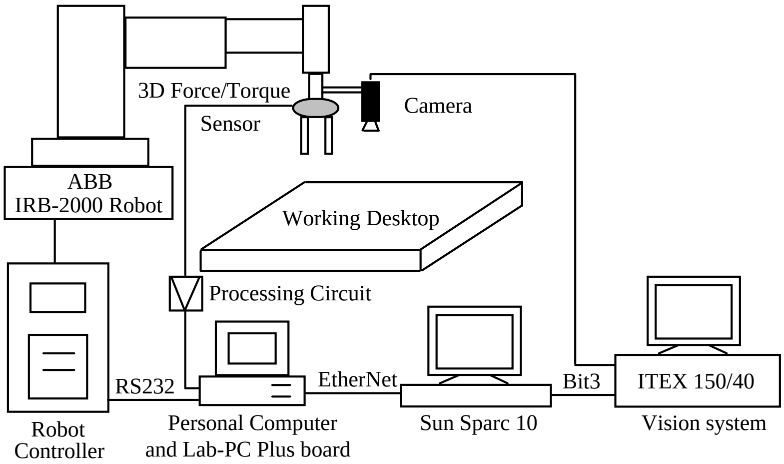

Figure 1: System hardware configuration

- Vision System - ITEX 15040 series was adopted, including a monochrome camera with a monofocal lens, and an image monitor. The camera was attached to the robot final axis.
- 486 Personal Computer
- SUN Sparc 10 platform for workcell simulation, running vision system, simulating machine controllers and coding *C* programs. It also stored simulated robot-moving paths.
- Interface among hardware subsystems: Personal Computer and Sun Sparc 10: Ethernet; Personal Computer and Robot Controller: RS232 serial line; Sun Sparc 10 and Vision System: The BIT 3 Sbus - VME bus adaptor; and 3D F/T sensor and Personal Computer: RS232 and Multifunciton I/O board - Lab-PC+.

3.2. System Functional Modules

The system functional modules, shown in Figure 2, include:

- ASM (Advanced Solid Modeller) - ASM was developed to simulate camera and robot workcell operations [6] and thus able to render 2D perspective gray scale images that are highly similar to those from real cameras. The workcell was also modeled and the robot collision-free moving paths were simulated and stored in the common database.
- Image processing module (machine vision) - This module processed both the images from ASM and the real camera to generate image codes in order to recognize the right part randomly located and derive its position and orientation.
- Communication among subsystems:
    - CommTools: between the personal computer and ABB Robot Controller.
    - PC-NFS: It allows PC to access files on any NFS server on the network.
    - Image processing system and robot control system: A data file was employed.

  - 3D F/T sensor and robot control system: Neural networks and *C* programs.
- Common database: It contained the following sub-directories:
  - CADPATH: keeps robot moving path files generated by ASM simulation.
  - IMGCDE: keeps image codes. Workpart might be presented under camera in upside down, right side up, or other poses. Therefore, it was possible to associate several codes with one workpart.
  - JQC: Job Queue Centre keeps all job requests.
  - FRC: Fault Report Centre keeps machine status.

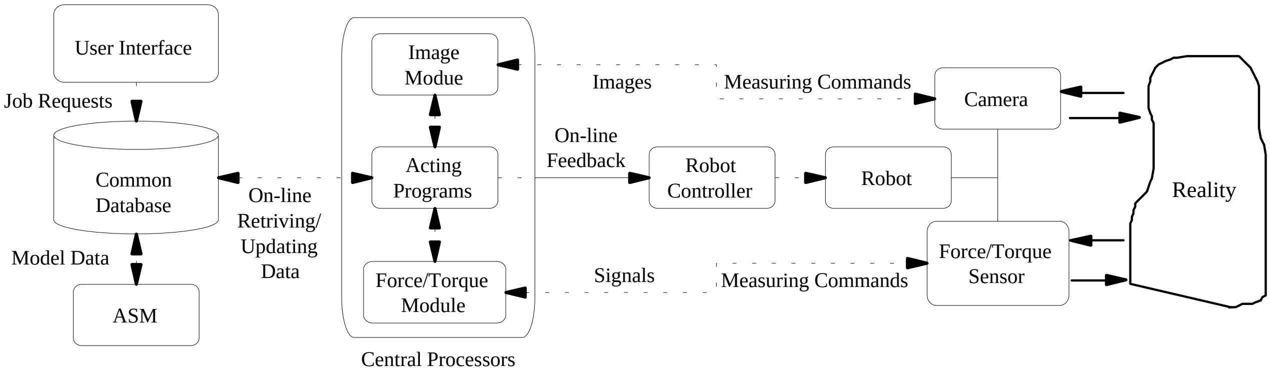

Figure 2: System functional modules

- Robot initial data - keeps the data for initialising robot and vision system.
- Force/Torque sensing module [7] - to detect and compensate for positioning errors.
- Acting programs - This module coordinated the time and working sequence of the image module, F/T sensing module and robot control. It also handled the system information passing, data extracting and updating and system level decision making.

3.3. Working Principles

This system contains off-line simulation and on-line running two aspects. The off-line tasks include designing products, deciding raw materials, setting up the workcell in the simulation environment, simulating camera functions, and simulating robot movement. For on-line running, the robot firstly reads in the requested jobs from JQC and checks the corresponding machine status. If the machine is down, the robot ignores this job and reads in the next one; otherwise, the job is executed. To issue a job, the format below should be followed:
machine-name job-number action workbench destination F/T-function
Where 'machine-name' is the name of the machine. 'action' is the physical job. 'workbench' is the place where parts are located. 'destination' is the place where the robot unloads the part. Finally, 'F/T-function' specifies a function for calibrating robot positioning inaccuracy.

When one task is completed, the robot goes back to home position and reads in the next job. The first issued task is executed firstly in this system.

4. Experimental Results and Discussion

Due to the constraints on equipment availability, in this study, windows in UNIX environment were opened to represent computers and handle communication issues. Fixed positions were assigned to represent various machines vice positions. The main difference between this set-up and the real system is that the opened window did not physically control a machine. But, it handled all the other aspects. Therefore, the tests should be able to effectively represent the real integration and demonstrate the system capability.

The assumption made for the test was that only one machine in the workcell initially. The following scenarios were tested to demonstrate the system capability:

- Machine 1 is down while robot is loading.
- A new machines is introduced
- Machine 1 is fixed. Its status is updated to be ready in FRC
- Robot is commanded to pick up parts from randomly located positions.
- Robot is commanded to automatically calibrate the positioning errors with F/T functions.

In these tests, the presented intelligent robot has successfully demonstrated its capabilities in dealing with the dynamic workcell changes as expected.

5. Conclusions

In this paper, an intelligent workcell robot system is presented, which was experimentally proven robust and valid in dealing with the defined dynamic workcell changes. The time-consuming system re-setup, calibration, and re-programming were eliminated. A significant amount of time can therefore be saved. One simplified system has been successfully implemented in Adelaide, which can accommodate up to 56 combinations of product [8].

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