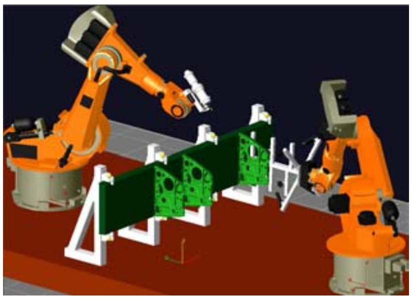
OMC Project Description – Jigless Manufacturing



Jigless Manufacturing is aimed at reducing or eliminating the need for product specific jigs during the manufacturing process, by developing new assembly concepts, models, tools and procedures.

Overview

A recent government/industry partnership funded a research and development project in the area of jigless manufacturing. The project was concerned with two aspect of jigless manufacturing: process enabling and process verification using measurement techniques. This OMC Project Description concerns the process enabling work using a stereo 3-D measurement system to guide tools and components using robots and actuators. A consortium of Universities and industrial parties worked closely together to undertake strategic work. The objective was two fold – to understand the issues involved and to demonstrate feasibility. It was expected that this work would, in the best instances, lead to an exploitation phase, which is what has happened in this case.

Industrial partners

BAe Systems, Airbus, Bombardier Shorts Bros, National Physical Laboratory

Project duration

3.5 years - project ended October 2001

Project value to OMC

£325,000 from government sources and matched by industry

Intended beneficiaries

Aerospace, automotive and general manufacturing industries

Current status

OMC is exploiting the commercial potential of the technology developed in this project. For example, the camera calibration software is in use with three aerospace companies.

Project Highlights

- The successful development of a stereo photogrammetry system suitable for embedding into a manufacturing control loop. The system was tested rigorously in an industrial environment.
- Development of Camera Calibration methodologies and software
- Winner of Metrology for World Class Manufacturing Award, 1998. The award judges said that "Near real-time photogrammetry is likely to become a powerful tool in manufacturing"
- Development of a coded photogrammetry target scheme and target datum interface scheme
- Chosen as one of 21 examples of Engineering Excellence for by British Aerospace for review by leading members of industry, politics and the press
- 1998 Winner of 'DSP in Action' award in conjunction with British Aerospace for the development of OMC's real-time image processing system.
- Successful integration of a 6 degree-of-freedom robot with OMC photogrammetry system and demonstration of drilling and assembly operations with a Kuka robot.
- Publication of the results of the project in a number of prominent conferences and magazines. For example, the Co-ordinate Measurement Systems Committee conference in the States in 1999, 2000, and 2001.

Background

In 1997 a three-year EPSRC funded 'Jigless Aerospace Manufacture' (JAM) project was set up to research and develop methodologies and technologies in jigless design, manufacture and assembly. One of the OMC sections of the project was concerned with the interfacing of a stereo photogrammetry system with a six-degrees of freedom robot, to demonstrate real time assembly of aerospace components in a manufacturing situation. Although the project was focused on the aerospace industry the technology has a wide number of applications in the shipbuilding, automotive, and general manufacturing industries.

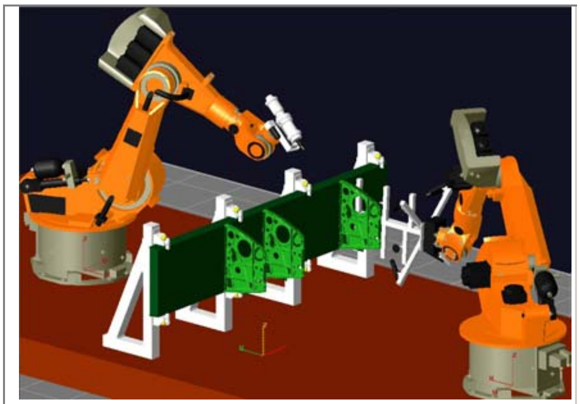
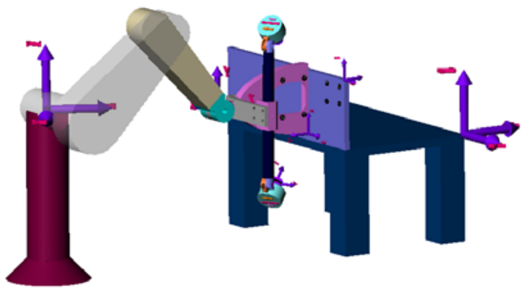
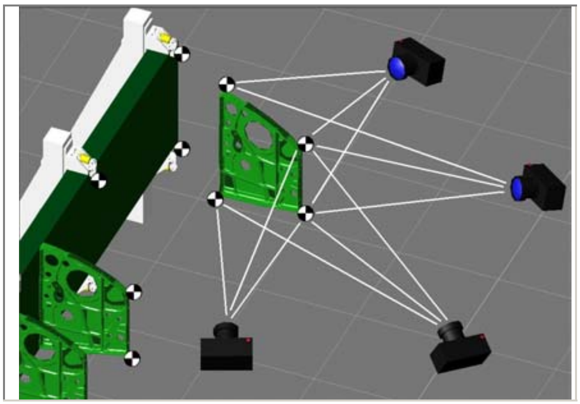
Currently, assembly of aero-structures in the civil and defence fields is done using specially constructed jigs that ensure that the final assembly conforms to the design requirements. Relying on product specific fixtures to provide part location and support during product build offers advantages in terms of guaranteeing consistency, accuracy and quality, but has the disadvantages of high costs, long lead times and inflexibility in product types and production volume. A move towards a philosophy of minimising or eliminating product specific tooling, 'jigless assembly', offers significant commercial benefits.

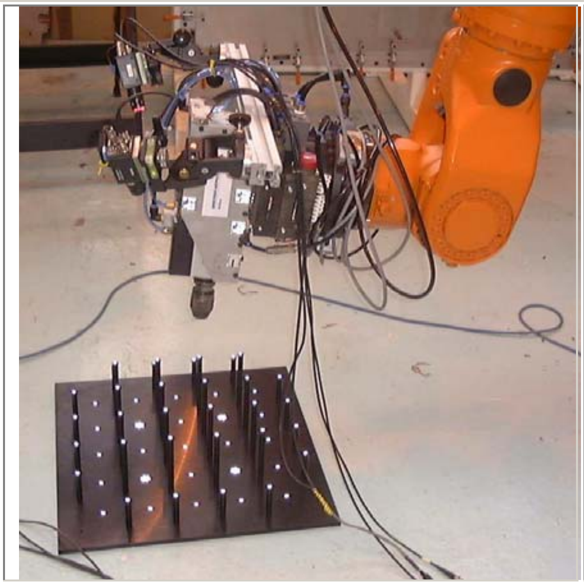
The development phase for a civil aircraft typically lasts two to four years. The tooling cost is one of the major investments made during this phase. This represents a massive forward investment with long payback periods. Reducing the number of jigs and fixtures required to produce an aircraft would significantly reduce costs and the time from concept to market. However there are sound technical reasons for the use of some form of fixtures. A jig can be defined as *'a manufacturing aid that either holds a part or is itself located on a part, it is fitted with devices to guide a cutting tool ensuring the correct location of the machining path relative to the part'*. A fixture can be defined as *'a manufacturing aid for holding and locating parts during machining or assembly operations, it does not provide definite guidance for the cutting tool'*. At present these jigs and fixtures are product specific, in that they cannot be economically modified for use on other aircraft types. Jigless manufacture does not mean that it is fixtureless, clearly simple fixtures will still be needed to hold and support parts during particular operations, but the philosophy is to make these fixtures as generic as possible. The overall objective of the JAM project was to demonstrate the feasibility and economic benefits of adopting a jigless assembly philosophy in the aerospace industry. To do this requires the development of new assembly concepts, models, tools and procedures. To meet the project objectives, OMC worked in conjunction with BAE Systems, Airbus, Bombardier Shorts Brothers, and the National Physical Laboratory to carry out work in various areas.

Industry is moving towards Digital Manufacturing, seamless integration of design and manufacturing. This will be facilitated through 3D CAD, digital pre-assembly, flexible tooling, jigless manufacture and 3D Metrology. A key requirement will be for measurement systems to be in the real time control loop. In the future jigs will be replaced, with advanced manufacturing technologies. Measurement will increasingly be the link between design and manufacture. The project concerned itself with the embedding of a photogrammetric measurement system into the manufacturing control loop. The basic requirements were, online operation, rapid measurement, low latency, high reliability, and a data link from the measurement system to the CAD design.

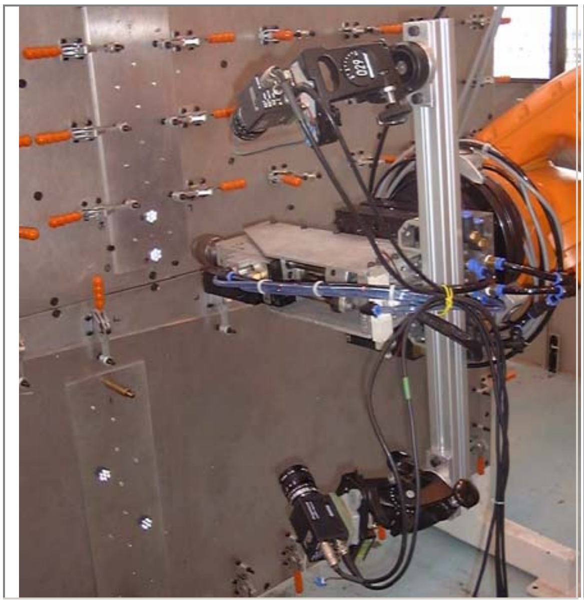
Optical Metrology Centre

Pictorial highlights

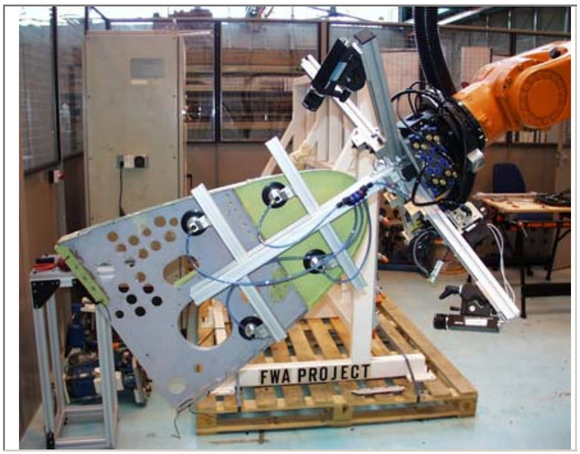
	The project considered whether robots that were used in the automotive industry could be used in aerospace manufacturing. Robots of this type are typically not accurate enough for this application. The objective was to determine whether the stereo measurement system would be able to guide the robot to the final position with greater accuracy than the robot itself possessed.
	One of the main tasks involved in the control of multi-degree actuators such as robots is determining the movements required in one co-ordinate system with respect to another. The figure illustrates six co-ordinate systems that may need to be taken into consideration for a jigless assembly operation.
	Measurement of component locations takes place using two or more cameras to estimate the 3-D locations of the targets and hence the 6-D location of the component. Reference to the CAD model and the task list allows the actuator movements to be determined.



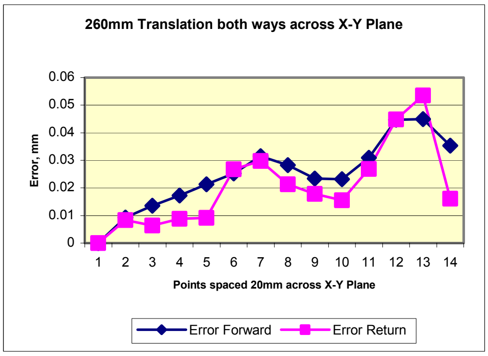
The relationship between the stereo camera system and the robot tool centre point can be estimated by various methods. One method that was used in the project was to move the camera system to a number of locations with respect to a static array of targets.



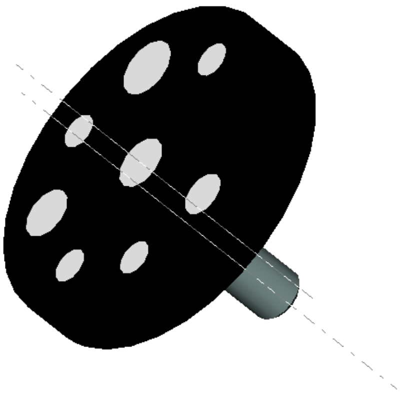
To demonstrate a drilling application a dummy spar was constructed and targets were placed in known positions with respect to the spar. The location of a drill with respect to the component to be drilled was achieved by the stereo measurement system. The robot was then able to navigate into the desired location.



Assembly of components was demonstrated using an Airbus rib. Targets on the dummy spar and the rib were used to identify the desired location of the rib with respect to the spar. The rib was then driven into the desired location by the KUKA robot under the control of the metrology system.



The accuracy of this type of system was estimated using various methods including interferometers, high accuracy rotary tables and sensitive linear encoders.



A valuable output of the project was the creation of a coded target scheme with a number of advantages over competitor systems. One of the key advantages of the scheme is the small size of the target relative to the number of codes available. The recognition reliability of the target has been found to be excellent. Methods of manufacturing and calibration were also explored.