Interoperability of Standards for Robotics in CIME

Falk Mikosch (Ed.)

Interoperability of Standards for Robotics in CIME

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Esprit, the Information Technology R&D Programme, was set up in 1984 as a co-operative research programme involving European IT companies, IT "user" organisations, large and small, and academic institutions. Managed by DG III/F of the European Commission, its aim is to contribute to the development of a competitive industrial base in an area of crucial importance for the entire European economy. The current phase of the IT-programme comprises eight domains. Four are concerned with basic or underpinning and the other four are focused clusters aimed at integrating technologies into systems. The domains are software technologies, technologies for components and subsystems, multimedia systems, and long-term research; the focused clusters cover the open microprocessor systems initiative, high-performance computing and networking, technologies for business processes, and integration in manufacturing.
The series *Research Reports Esprit* is helping to disseminate the many results – products and services, tools and methods, and international standards – arising from the hundreds of projects, involving thousands of researchers, that have already been launched.

Foreword

The earlier ESPRIT Projects CAD*I (ESPRIT 322) and NIRO (ESPRIT 5109) have made significant contributions to the foundations of Product Data Technology, particularly in the standardisation of product descriptions and robot kinematics in STEP (ISO 10303) and in robotics programming languages. InterRob (ESPRIT 6457), their direct successor, has been building on these results and has extended them to mature applications of Product Data Technology for robotics in high precision manufacturing.

The InterRob approach is based on standardised models for product geometry, kinematics, robotics, dynamics, and control, hence on a coherent neutral information model of the process chain from design to manufacturing. This process thus supports product design, analysis, simulation, robot programming and control by a flexible chain of software modules connected by neutral interfaces. The approach enables the off-line programming of robots relying on CAD product definitions, thus avoiding the much more tedious and inflexible teach-in programming. This capability is a key advantage in one-of-a-kind production.

Applications in plasma spraying of high-precision parts in the aerospace industry and robot welding of complex pipe connections in shipbuilding demonstrate the viability of the approach. The economic success of the methodology is based on the built-in quality control for the information flow and on significant time and cost savings.

InterRob has also made valuable contributions to PDT standardisation, both by relying on existing and evolving standards (ISO STEP AP 203, AP 214) and by extending these models particularly for robotics.

The current volume gives an excellent overview of all significant InterRob results. It is a pleasure to welcome this new book in the Springer series.

Berlin, April 1996

Horst Nowacki
Chairman of PDTAG-AM

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1 Introduction

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Information technology and robotics are important instruments to reduce costs, increase product quality and to accelerate the processes within an enterprise, especially product development and preparation of manufacturing. Today serial production e.g. of automobiles is no longer possible without robotics. However, robots are less common in one-of-a-kind and small batch manufacturing, and in manufacturing of variants. This is mainly due to the fact that, facing today's rapidly developing technology, this kind of production requires, much more than serial production, the possibility to replace single components of the production information system by more suitable installations, without impeding the overall information process. Replaceable components like these are, e.g. the CAD system, the programming system, the simulation system, and the robot with its control. These components can, however, only be easily exchanged if they have standardised interfaces. Researchers all over the world work on this subject.

The first main goal of ESPRIT Project No. 6457 InterRob (Interoperability of Standards for Robotics in CIME) described in this book was to close the information chain between product design, simulation, programming, and robot control by developing standardised interfaces and their software implementation for standards STEP (International Standard for the Exchange of Product model data, ISO 10303) and IRL (Industrial Robot Language, DIN 66312) (see Fig.1.1). This is a continuation of the previous ESPRIT projects CAD*I and NIRO, which developed substantial basics of STEP.

The second main goal of the project was to increase the accuracy of off-line programmed robots by improving the conformance of robot simulation with the real world, and by on-line adjustments in robot control to modify actual positions and speed of the robot tool. Effective off-line programming will significantly shorten production preparation, and it will increase product quality as well as productivity and return on investment for expensive installations.

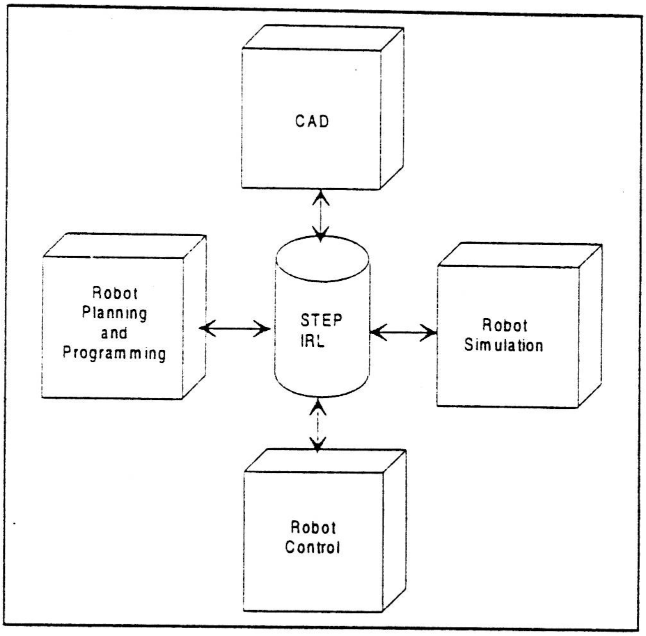

Fig. 1.1. Information Exchange in InterRob

The needs and requirements of one-of-a-kind and small series manufacturers for a consistent bi-directional information flow with open systems in robotics and for the possibility to programme robots fully off-line for precise manufacturing tasks are shown in the pilot applications of the two user companies in the InterRob consortium: Automated off-line programmed plasma spraying and arc welding of parts with a very complex geometry. This new techniques were made possible by combining product data technology, data base technology, and off-line programming and simulation of robots.

The results of the project show an innovative solution for precise manufacturing with fully off-line programmed robots resulting in enormous benefits at the industrial applications. Off-line programming with a much higher accuracy was achieved by the assistance of a simulation tool which takes into account the full geometric information of the work piece and the robot working cell, the kinematic and dynamic behaviour of the robot, calibration data of the individual robot, information about the robot control and the robot tools, and information on process data (welding, spraying etc.).

Fig. 1.2 shows that all data incorporated in the simulation tool are described by STEP or InterRob extensions to STEP, i.e. model schemata which follow the STEP methodology: geometrical data, process data, and robot performance characteristics at any level of available detail.

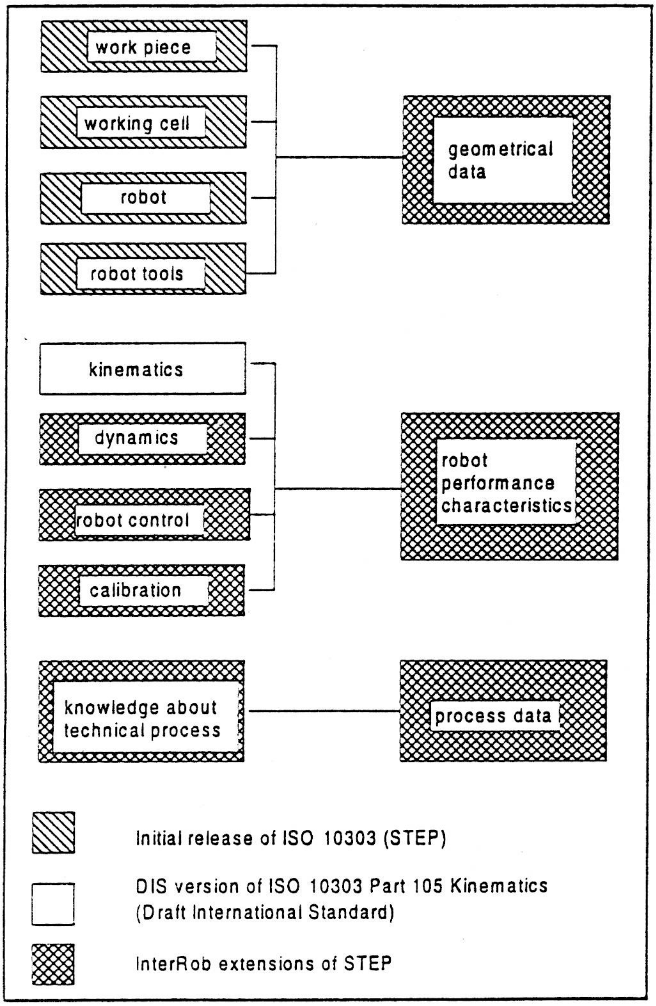

Fig. 1.2. Product Data Transfer in InterRob

The document "Specification of a STEP Based Reference Model for Exchange of Robotics Models" [FZKA-PFT 176/1996] contains a detailed description of all developed schemata. It can be acquired from InterRob Project Management.

Within the framework of InterRob a number of pre- and post-processors for STEP were developed to enable the data exchange between the different systems involved, to prove the conformity of the enlargements (schemata) with the entire STEP standard, and to demonstrate their benefits in industrial applications. For the analysis system ADAMS, the CAD systems BRAVO and CATIA, and for the simulation and off-line programming systems GRASP, KISMET, and ROPSIM a total of six pre-processors and four post-processors with different functionalities according to their tasks were developed. The involved systems and their processor functionalities have been selected in the first place to test and to demonstrate the compatibility of the novel STEP schemata.

The seven European partners of the InterRob Project have developed a consistent bi-directional information flow between product design, simulation, programming, and robot control with open systems based on standards. In addition to the neutral representation of product data with STEP the standard IRL was applied for robot programming and control.

For the simulation and off-line programming systems GRASP and ROPSIM and for robots from Reis and ABB IRL translators have been developed.

The potential for rationalisation by new solutions in information technology can in most cases only be exploited if there is total integration. For handling huge amounts of data, a database system was developed which provides standard access to all product and process information, and automatic programming of special robot applications.

Fig. 1.3 shows the realised system consisting of an integrated object oriented database which combines several subdatabases for product model, equipment, process data, robot program file management, and production data. The system can be operated via a uniform user interface. Through STEP the CATIA, GRASP, and ROPSIM systems are connected. Robots of Reis GmbH & Co and two other robot vendors are operated via IRL programmes.

The InterRob database concept provides uniform access to robotics information. The database is mostly based on STEP and uses an EXPRESS driven database model. All this allows to handle one central model for a product within a company (master model concept).

By this way the database is an interoperability concept integrating standards in the robotics area, facilitating the extension of the data model for specific application areas, and working as a server for STEP based product models within a company.

Important input to the standardisation process of the standards STEP and IRL has been given by the project partners in order to facilitate and improve their use and allowing interoperability.

The InterRob project run within the subprogram "Computer Integrated Manufacturing and Engineering" (CIME) of the ESPRIT Programme (European Strategic Programme for Research and development in Information Technology) supported by the European Commission. It started in January 1993 and lasted for three years.

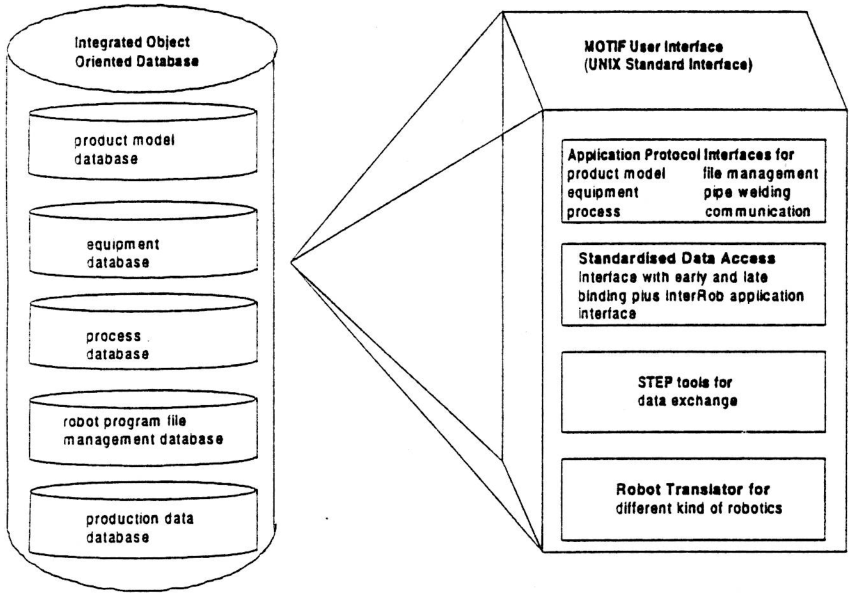

Fig. 1.3. Integrated object oriented database with user interface for uniform access to robotics information at Odense Steel Shipyard

The following companies and research institutes are partners in InterRob:

BYG Systems Ltd, United Kingdom	simulation systems
Danmarks Tekniske Universitet, Denmark	research
Forschungszentrum Karlsruhe GmbH Technik und Umwelt, Germany	research and Project Management
Odense Steel Shipyard Ltd, Denmark	user
Reis GmbH & Co, Germany	robot manufacturer
Rolls Royce plc, United Kingdom	user
SINTEF, Norway	assistance to users

In this book the results of the 3-years work (1993-1995) of the above mentioned consortium are reported. It begins in Chap. 2 with a short description of the baseline and rational of the project.

Chapters 3-7 cover the results in detail: Chap. 3 describes the STEP based InterRob interface for the product definition data followed by the description of the implementation of STEP interfaces in InterRob (Chap. 4). Accuracy aspects of off-line programmed robots are dealt with in Chap. 5 under the heading aspects of model fidelity. The two industrial applications and demonstrations of InterRob results are described in Chap. 6. Chap. 7 explains the contribution to STEP and IRL standardisation activities of the project partners. An outlook on the future use and exploitation of the project results concludes this book. Some important details are covered extensively in the Annexes.

2 Rational and Baseline of the InterRob Project

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The programming of robots is a bottle-neck in many companies, whose production is mainly based on small batches of frequently changing products. Teach and learn routines for the robots have proven to be difficult, time consuming and the robot and the equipment to be served by the robot are idling during the programming phase. Off-line programming systems with software tools for modelling, task planning, path generation, simulation and programme verification are the obvious solution.

All robot manufacturers use their own programming systems with special programming languages, which differ in various aspects concerning syntax, program structure, and features. Companies using different robots need specialist experts for all systems. An existing robot program for one robot system must be re-programmed in order to be executed by another robot system even though the robots may have a similar kinematic structure.

Robot program portability requires a standardisation of the interfaces between robot planning and programming systems and the robot real-time controller. The project consortium compared the neutral software interfaces

- IRL (Industrial Robot Language)
- ICR (Intermediate Code for Robots)
- IRDATA (Industrial Robot Data)

and chose the IRL standard [DIN 1994] as basis for the development within the InterRob project. None of the three standards has reached so far the status of an accepted European or international standard.

The choice of an appropriate standard interface (neutral file format) for product data description and data transfer from the CAD systems to the robot planning and programming systems was also a central issue in the project formulation. After a long period of development the selected International STandard for the Exchange of Product model data (STEP, ISO 10303) had its initial release during the project time. Baseline for the work done in the InterRob project have been the ESPRIT Projects 322 (CAD*I), 2195 (CADEX), and 2614/5109 (NIRO) which developed substantial basics of STEP. In order to enhance the development of STEP the work was coordinated with the ESPRIT Projects PRODEX and MARITIME and the industry initiative ProSTEP that aims primarily at the implementation of STEP in the European industry.

Precise manufacturing with off-line programmed robots normally requires a considerable amount of on-the-job correction. Simulated and actual robot positions can vary considerably. The main problems occur because robots usually have a good repeatability but a poor accuracy and most simulation systems do not use actual robot control and performance data. The latter information is seen as commercially valuable by the robot vendors and is not generally available to simulation software companies. These problems are being addressed from different points of view.

A project initiated by robot vendors and the automotive industry called Realistic Robot Simulation (RRS) [Bernhardt 1994] is an attempt to provide users with the necessary control characteristics, primarily path planning of a robot in an encoded form via a "black box", thus protecting vendors' proprietary information. A specification for the interface between simulation packages and robots has been published by the RRS consortium and a limited number of robots have had RRS "black box" implementations. RRS, however, does not address robot dynamic performance, which is important for robots moving at high speeds and quickly changing directions.

The InterRob approach aims at the use of open architecture neutral file formats in the STEP methodology. Not only the product structure and geometrical data on work piece, working cell, robot, and robot tools shall be described by STEP files but also all robot performance characteristics like kinematics, dynamics, robot control and calibration data. STEP schemata have been developed accordingly and were positively evaluated together with a schema for process data describing technical processes like plasma spraying and arc welding. This open system concept is user driven and it will take a lot of time and effort to convince robot system vendors in a similar way as the CAD system vendors.

To improve simulation fidelity besides calibrating the robot and the working cell in the InterRob project the ability to bi-directionally communicate data between the robot controller and the simulation package was developed to aid iterative error correction. If detailed dynamic and control data of a robot are lacking it can be attempted to identify dynamic performance characteristics by measuring taught robot movements at different velocities using a laser triangulation system. From the results a correction factor may be derived that can be applied to the off-line created program. In this case corrections will be valid only for specific motions and robot orientations and will not cover the full robot working envelope.