

# RoboCAD INFELT STEP, Interoperable Platform to Manage Collaboration among CAD and Robot Programming Agents Integrated Based on STEP (ISO 10303) Standard

Omid Fatahi Valilai, Mohsen Jafari Nodeh and Mahmoud Houshmand

**Abstract**— Today's industries that use robots need solutions, which enable them to program, control and supervise their robots more efficiently. Many solutions introduce robot-programming environments. These environments facilitate the robot programming. These facilities are the results of applications and infrastructures that exchange the programming data between robots' processors and robot programming applications. Some of these solutions try to use the CAD data for robot programming. In this article, the solutions that facilitate the robot movement programming by analyzing the CAD data are studied. Finally, an integrated platform named RoboCAD INFELT STEP is introduced. This platform is an extension to INFELT STEP platform. INFELT STEP platform is an interoperable and collaborative platform for CAD/CAPP/CAM applications. This platform manages the collaboration among different CAD application in product development processes. INFELT supports the different CAD applications with their data structures while integrating the product data based on ISO 10303 (STEP) standard. The RoboCAD INFELT enables the product designers to program the robots movement for a product process plan by means of that product CAD data. RoboCAD INFELT consists of layers. These layers exchange the programming data between robot processors, robot applications and CAD applications. The RoboCAD INFELT integrates the programming data based on STEP standard while supporting the data structures related to robot application.

**Index Terms**— Automation, Robotics, CAD/CAM, ISO 10303 (STEP) standard.

## I. INTRODUCTION

Today's industries that use robots need solutions that enable them to program control and supervise their robots more efficiently [1]. These solutions should be integrated with other solutions engaged in product development processes in

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Omid Fatahi Valilai is with industrial engineering department as a PhD. student, Sharif university of technology, P.O.Box : 1155-9414, azadi road, Tehran, Iran. He is also the president of Parsian Enterprise Architecture Ltd, University of Tehran Science and Technology park, Tehran, Iran(omidf@ie.sharif.edu, CEO@parsianLtd.com).

Mohsen Jafari Nodeh is with Computer science Department as a BSc. student, University of Tehran, Enghelab road, Tehran, Iran. (mohsen85@sadi.ut.ac.ir).

Mahmoud Houshmand is with the industrial engineering department as an associated professor, Sharif university of technology, P.O.Box : 1155-9414, azadi road, Tehran, Iran (hoshmand@sharif.edu).

order to increase the product quality and reduces the product development costs [2]. By the wide use of different applications and software during the product development processes, integration can be hardly achieved through enterprises. Many solutions for enabling the interoperability between enterprise sectors have been proposed [3]. These solutions try to support different CAD/CAM application software in an interoperable product development environment.

To achieve interoperability and data integration between CAD software packages and robot software programs, researches have been done. "The off-line programming and simulation software for the Mitsubishi Movemaster RV-M1 robot" [1] proposed the creation of an application, which would generate program for the robot on a base of a drawing containing a trajectory, created in CAD type application, taking into consideration consecutive positions of the gripper and its state (open or close). This application then was able to transfer the program from a computer to the robot installed in the other room. The product data between CAD agents and Robot software packages were integrated. The application could only work with specified AutoCAD software packages with a definite dictionary file. This restricts the interoperability between different CAD agents with different CAD data structures. The information exchange between CAD agents and robot software packages was only one way from CAD agent toward the robot application software. No collaboration management was included in the structure of the proposed system. "The web-based programming interface for the Mitsubishi Movemaster robot" [4] was the improvement of the "off-line programming and simulation software" [1]. This system was based on web-based programming structure. The system was improved to support distributed agents but it has the lakes mentioned earlier. "Motion control and data capturing for laser scanning with an industrial robot" [5] shows how a standard industrial robot with a laser profile scanner can be used to achieve creating computer aided design (CAD) models of real objects by interpreting point data measured from their surfaces. The system is planned to be part of a future automatic system for the Reverse Engineering of unknown objects. The information flow has only one direction; from robot toward the CAD agents. "An interface for the data exchange between CAS and CAD/CAM systems" was the study [6] conducted to present a software interface to automate a fluent and fast data exchange between a CAS (Computer Assisted Surgery)

system and CAD/CAM systems. This study enabled a CAS system to import the geometry model of the surgical instruments or prostheses that are often provided in a Computer Aided Design (CAD) file format. The Information flow in this study was only one direction from the CAD software package toward the CAS system. The study could not support the distributed CAD and CAS systems for data exchange. No collaboration management was within the platform between agents. "Off-Line Programming of a Robot for Laser Re-Manufacturing" was the study [7] conducted to develop off-line programming system for laser re-manufacturing. The study used the CATIA software package as the CAD tools to design models of robot, workpiece, coaxial nozzle, and workspace. The information flow was based on one direction from CAD software to robot. Only one CAD format could be used for data exchange. No collaboration management procedures were implemented in the platform to check and control the data modification.

## II. PROCEEDING RESEARCH

Considering the studied platforms, to ensure the data integration between CAD software packages and robot agents, an integrated and standard data model is needed. This data model should be able to integrate the product data related to CAD software package and robot agents. There should be procedures to manage the data exchange and manage data modification among CAD agents and Robot agents. Proceeding, the article considers the STEP standard. This standard and the product data structures it suggests for product data integration will be discussed. Based on this standard, an integrated and interoperable platform called INFELT STEP that is capable of managing collaboration among Different CAD/CAM software packages is studied. The capabilities of this platform to integrate the product design data and the data related to the product process plan based on STEP standard and support the product data interoperability will be studied. Finally, the paper proposes an extension to the INFELT platform to manage the data model of robot agents. These product data structures are integrated with product CAD/CAM activities. This integration will be based on ISO 10303(STEP) standard. The proposed extension will use the information technology capabilities of INFELT STEP to integrate the robot agents with Design activities on the product development. The collaborative product development environment enables the data interoperability among different robot agents and CAD/CAM application software.

The paper discusses the different aspects of this extension in RoboCAD INFELT STEP structure. The information requirement needed to add the new interfaces to the platform will be discussed. This interfaces support different robot agents data structures. The RoboCAD INFELT STEP structure will maintain the integrity of product data based on STEP standard. At the same time the RoboCAD INFELT STEP platform, enable the different robot agents and CAD/CAM application software to exchange the product data based on their own data structure and manages the collaboration among them.

### A. ISO 10303 (STEP) standard

Since the mid-1980s, the international community has been

developing the ISO 10303 set of standards, well known as STEP (ISO 10303-1 1994), which has its foundations in many of the earlier aforementioned standards [8]. STEP has developed from a group of people popularizing emerging ideas through cycles of consensus, much as do schools of art, literature, and music [9]. The STEP standard is divided into many parts, i.e. Description Methods, Information Models, Application Protocol (AP)s, Implementation Methods, and Conformance Tools. Each part is published separately [10]. The Information Models and Application Protocols describe the data structures and constraints of a complete product model [8]. The use of STEP language can help the enterprises to have to somehow the integration of data for product design activities [11]. The overall objective of STEP is to provide a mechanism that is capable of describing product data throughout the life cycle of a product, independent from any particular system [12]. STEP has led to improvements in exchange and sharing of simple CAD information, product models and complete product structures and Furthermore, STEP has improved communications within the extended enterprise (including suppliers, business partners and customers) and helped to support global collaborations [11]. This standard can manage the design information in an integrated environment.

The first parts of STEP publication to achieve International Standard status happened in 1994, but many other parts have since been published or are under development and will eventually be added to the standard [13]. STEP has capabilities that span multiple industries. Those industries driving and actively developing standards today include architecture & construction, aerospace, automotive, electrical & electronic, manufacturing technologies, process plant, and shipbuilding [9]. Recent updates (and other relevant details) can be found at the following websites: <http://www.nist.gov/sc4>, [www.tc-184-sc4.org](http://www.tc-184-sc4.org), and <http://www.iso.ch/iso/en/ISOOnline> [13].

ISO 10303, also informally known as the Standard for the Exchange of Product model data (STEP), is a family of standards defining a robust and time-tested methodology for describing product data throughout the lifecycle of a product [14]. When the STEP effort began in 1984, it was envisioned as a more encompassing set of standards for the exchange of all product data that included CAD/CAM and Product Data Management (PDM) systems [15]. STEP is widely used in computer-aided design (CAD) and product data/lifecycle management (PDM/PLM) systems [14]. The ISO10303 and ISO14649 Standards (STEP and STEP-NC) have been developed to introduce interoperability into manufacturing enterprises to meet the challenge of responding to production on demand [16]. It is stated that Major aerospace, automotive, and ship building companies have proven the value of STEP through production implementations resulting in actual savings of \$150M per year in the US (and potential savings of \$928M per year) [14].

STEP is a proactive effort, the focus being placed on developing a standard that caters for various user groups, which are usually associated in an industry or according to a common application such as CAD data, which can be used throughout multiple industries [17].

The STEP standard categorizes the various types of product data around APs. An AP includes at least three formal

documents:

The Application Activity Model (AAM) describes the activities in the lifecycle of a product.

The pieces of product information that are needed for the activities are called the Application Reference Model (ARM)

The Application Interpreted Model (AIM) is formed by using an EXPRESS information model to capture everything in the ARM and to tie it to a library of pre-existing definitions [8].

STEP will enable us to iterate designs based on manufacturing suggestions, then evaluate and analyze the results before manufacturing the pieces. It also offers a tremendous benefit for exchange and managing information from several engineering and manufacturing disciplines in an effective way [18].

Some of the most relevant APs used in the CAD/CAM domain include [8], Part 203: Configuration controlled 3D designs of mechanical parts and assemblies (ISO 10303-203 1994), Part 214: Application protocol: Core data for automotive mechanical design processes (ISO 10303-214 1994) and Part 224: Application protocol: Mechanical product definition for process plans using machining features (ISO 10303-224 2001).

**B. INFELT STEP platform**

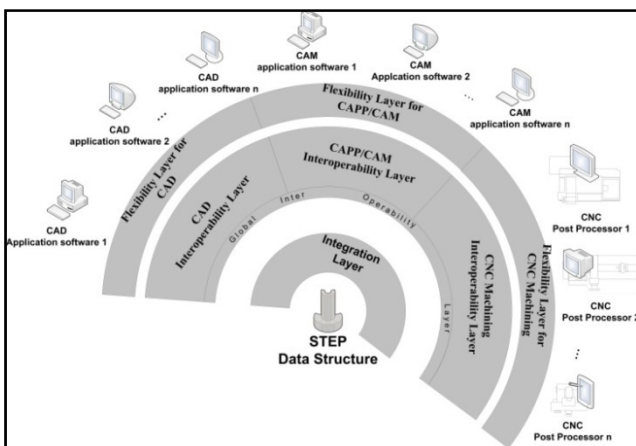


Fig. 1 INFELT STEP platform overall Structure

INFELT STEP is a collaborative and interoperable platform for CAD/CAPP/CAM software integrated based on STEP standard [19]. INFELT STEP platform is an integrated Platform. The Product data are stored in this platform based on STEP Standard. The INFELT STEP overall structure is shown in Fig. 1. This Platform is consists of three different layer. These layers enable different CAD/CAM application software and CNC post processors to collaborate with each other. The platform supports the different CAD/CAM Application software's data structures. It enables them to collaborate with each other for Product design and product process planning based their own data structure. The Integration layer maintains the integrity of product data based on STEP standard as shown in Fig. 5. The Interoperability layer control and manage the collaboration among different CAD/CAM application software and CNC post processors as shown in Fig. 3 and Fig. 4. The Flexibility layer is comprised of interfaces. These interfaces exchange the CAD/CAM data with CAD/CAM application software and CNC post processors as shown in Fig. 2. The Integration layer stores the

product data based on STEP application protocols. The CAD product data are stored based on application protocol 203. The product data related to product process are stored based on application protocol 214& 224. The CNC machining data are stored based on application protocol 238. INFELT STEP has procedures and functions that exchange the data with different CAD/CAM application software and CNC post processors. These procedures and functions manage the modified product data.

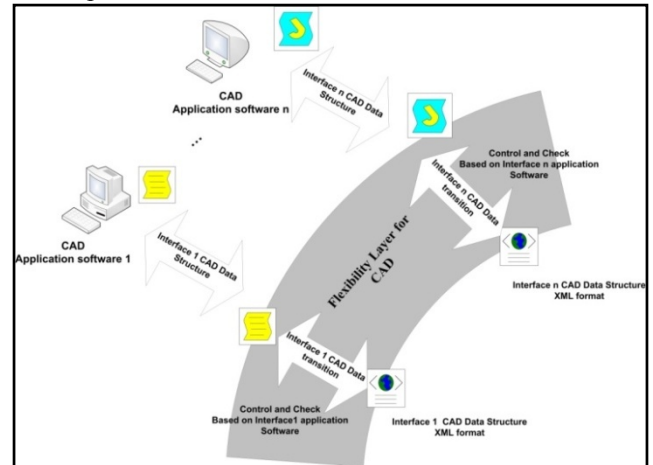


Fig. 2 CAD Flexibility Layer

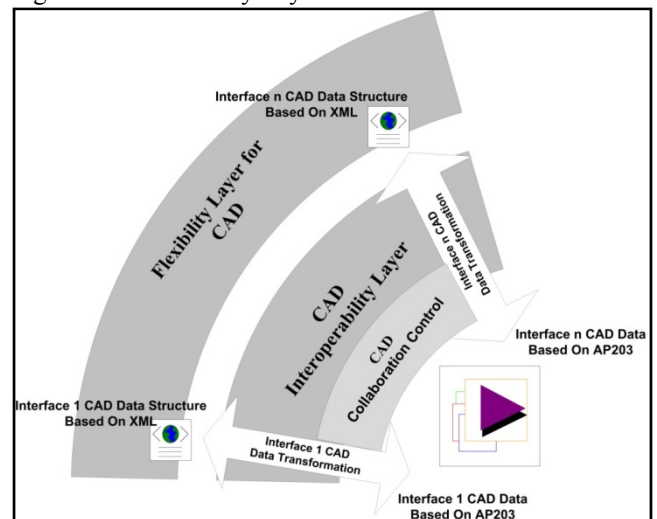


Fig. 3 CAD Interoperability Layer

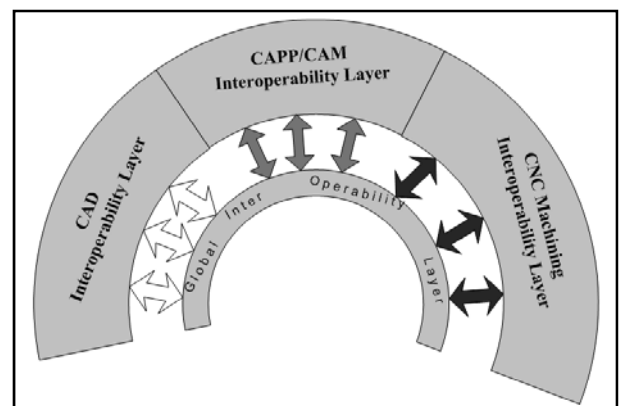


Fig. 4 Global Interoperability Layer

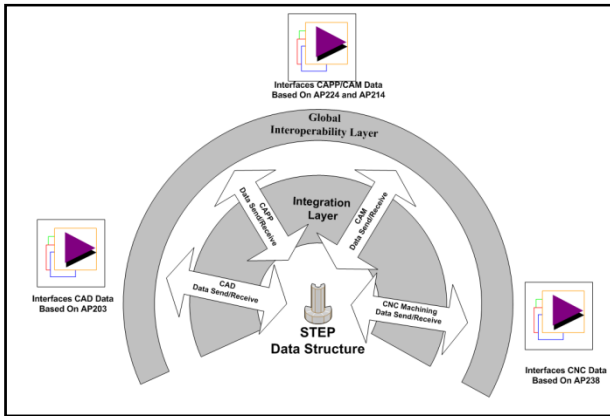


Fig. 5 Integration Layer

INFELT STEP data structure is integrated based on (ISO 10303) STEP standard. The different CAD/CAM application software can collaborate with each other in product design and product process planning in this platform.

### III. THE PROPOSED ROBOCAD INFELT STEP PLATFORM FOR INTEGRATION WITH ROBOT AGENTS

#### A. Robot STEP based data structure

As described above, the INFELT STEP is an integrated platform based on the STEP standard. To include data structures of robot agents in this platform, a subset from STEP standard integrated resources is needed. As the article aims to integrate data of CAD agents with robot agents', following integrated resources are needed in the INFELT STEP Integration layer:

- 1) Part 41: Fundamentals of Product Description and Support
- 2) Part 42: Geometric and Topological Representation
- 3) Part 43: Representation Structures
- 4) Part 56: State

These parts let the INFELT STEP platform to integrate the data structures of CAD agents with robot CAD data. They

also let the INFELT STEP to store and retrieve the robot agents commands based on the STEP standard data structure.

The Fig. 6 shows the needed data structure for robot STEP based data structure.

#### B. The Proposed RoboCAD INFELT STEP platform

The proposed RoboCAD INFELT STEP platform is shown in Fig. 7. The integration layer uses Robot STEP based data structure explained above to support data structures of robot agents. The robot command data gained from different robot agents will be stored based on this data structure. This makes the INFELT STEP integrated based on STEP standard. The different CAD/CAM application software can then exchange the robot agents' data based on STEP standard for product design and product process planning.

The RoboCAD INFELT STEP platform has two new layers. These layers are the Flexibility layer for robot programming and the Interoperability layer for robot programming. These layers support different robot agents to collaborate with each other in using and modifying CAD data for robot movements. The Interoperability layer for robot programming converts the robot programming data. This data is converted to data structure based on Robot STEP based data structure. The global interoperability layer is also active in this part and manages the collaboration between all the robot agents and CAD/CAM software packages.

##### 1) Extension in the Flexibility Layers

To enable the different Robot software packages to collaborate in an interoperable environment, the paper extends the INFELT STEP platform. A new flexibility layer called "The Flexibility layer for robot programming" is added to the flexibility layers. This layer is responsible to send and receive the data and information to the different Robot software packages based on their own data structure. This layer facilitates to join the new Robot software packages easily. This layer has data structures based on Robot software

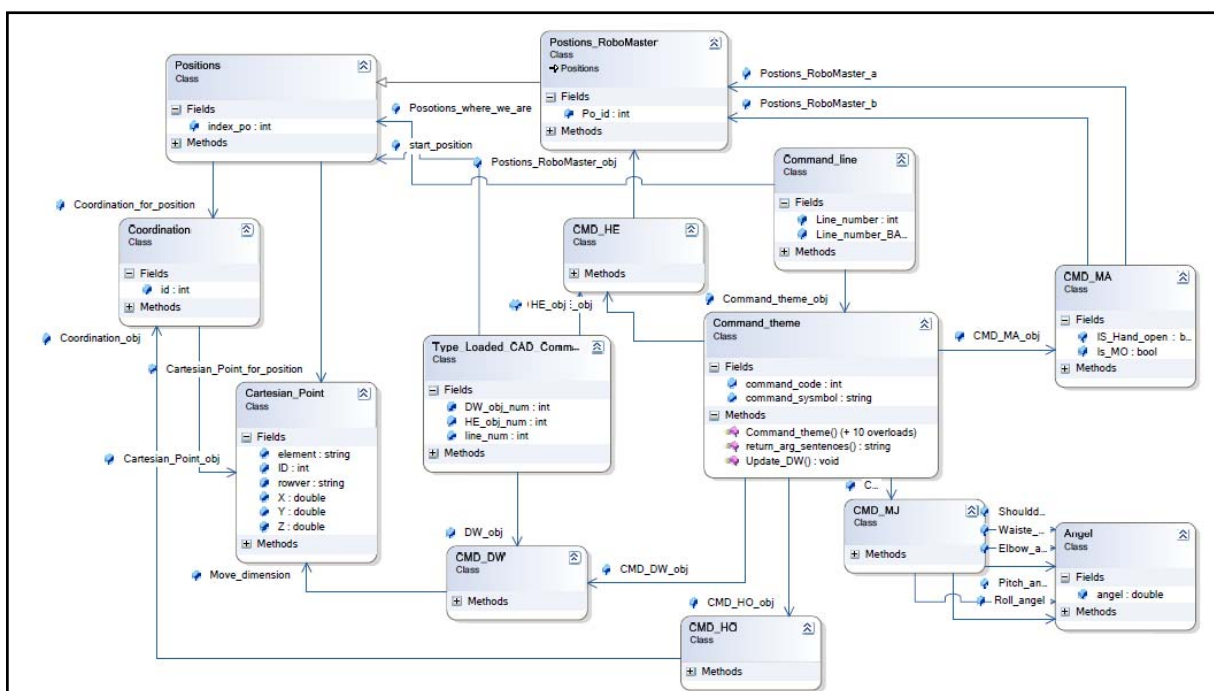


Fig. 6 Robot STEP based data structure

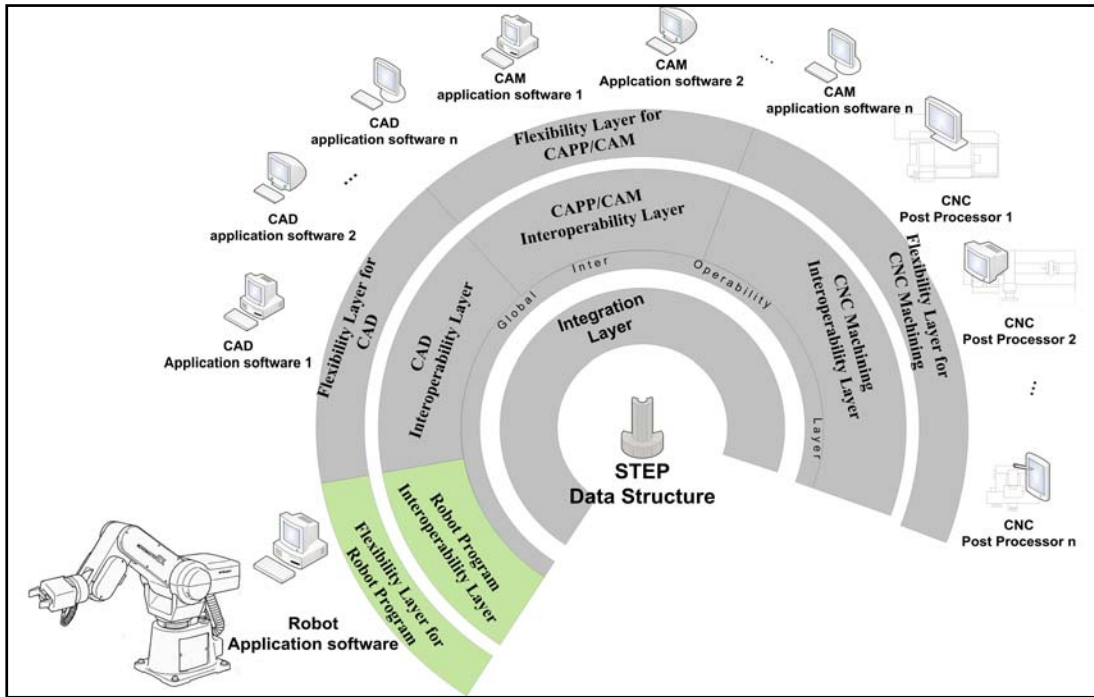


Fig. 7 The Proposed RoboCAD INFELT STEP platform

packages data structures. Like other CAD/CAM flexibility layer structures, the Flexibility layer for robot programming consists of interfaces for each data structures of Robot software packages. The data and information is exchanged based on Robot programming packages data structure within these interfaces. The developed interfaces are parts of the flexibility layers. The main function of the interfaces in the flexibility layers is to check the data validity of exchanged information. These layers communicate with Interoperability layers in XML data format. With this new flexibility layer, INFELT STEP gets four flexibility layers:

Layer called “Flexibility Layer for robot programming packages” that supports different robot programming software packages as shown in Fig. 8.

Layer called “Flexibility Layer for CAD” that supports different CAD application software as shown in Fig. 2;

Layer called “Flexibility Layer for CAPP/CAM” that supports different CAPP/CAM application software.

Layer called “Flexibility Layer for CNC Post Processors” that supports different CNC machining post processors.

Any applications and devices use their own data structure. These layers are consists of different interfaces that have data structure based on related robot/CAD/CAM application software and CNC machining post processor data structures.

Fig. 8 The Flexibility layer for robot programming structure and functionality

These layers send the robot/CAD/CAM/CNC machining data and information to lower layers named Interoperability layers in XML format. Vice versa, flexibility layers receive the robot/CAD/CAM/CNC machining data and information from interoperability layer in XML format.

The Flexibility layer for robot programming enables the INFELT STEP to have flexibility to support different Robot software packages based on their own data structures. The new interfaces can be developed to this layer where they are required.

2) *Extension in Interoperability Layers*

These layers are the brain of INFELT STEP platform. Different robot/CAD/CAM/CNC machining data and information structures in XML format are delivered to these layers. These layers enable different robot/CAD/CAM software collaboration. To support Robot software packages for interoperability and collaboration the extension in INFELT STEP interoperability layers include a new interoperability layer for robot programming packages as shown in Fig. 9.

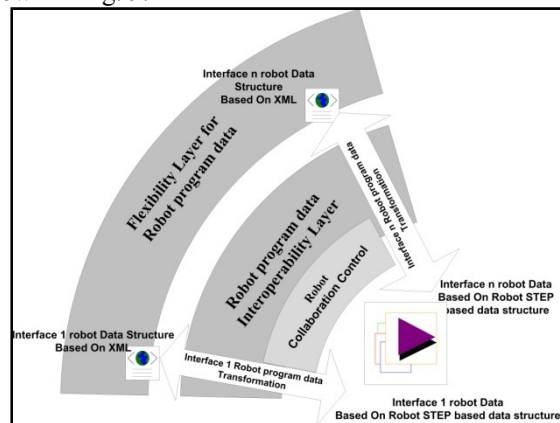
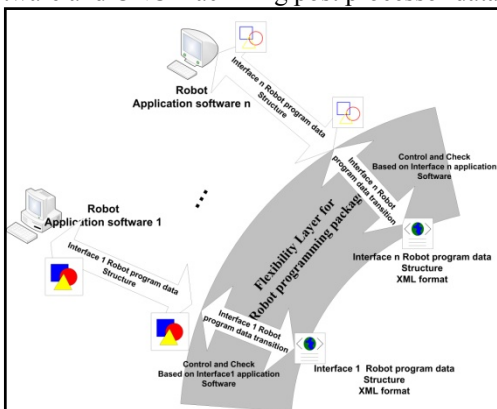


Fig. 9. Robot programming Interoperability layer structure

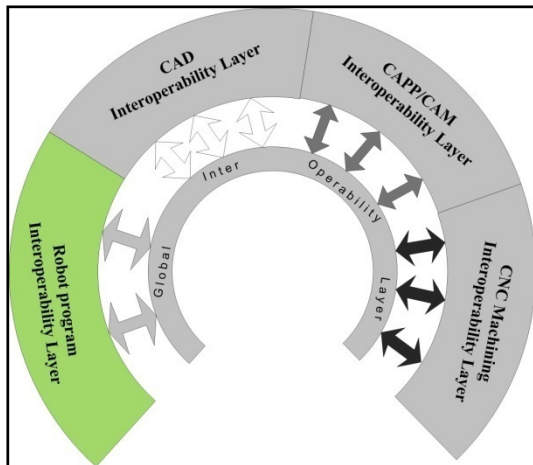


Fig. 10 Extended Global Interoperability Layer structure

The new robot programming Interoperability layer enables different Robot software packages to collaborate in the platform. The interfaces in the Flexibility layer for robot programming sends the data and information based on their own data structure in XML format to Robot programming Interoperability layer. The Robot programming Interoperability layer processes the data and converts them to STEP standard data structure based on Robot STEP based data structure mentioned above.

As like the other Interoperability layers, in Robot programming Interoperability layer, there is a procedure called collaboration control. After interoperability layer converts the interfaces' modified data to STEP data structure, collaboration control checks the data. Robot collaboration control ensure that once a Robot programming packages modified data is received and converted to STEP data structure, it doesn't contradict with other robot software package.

To check the processed data and information validity, the interoperability layers check data and information based on STEP standard. If interoperability layers identify any invalid processed data, they will return these data to related interfaces in flexibility layers. If the converted data validate the constraints, the interoperability layers send this data to Global Interoperability Layer.

The Global Interoperability layer has the responsibility to enable interoperability between robot/CAD/CAM software packages and CNC Post Processors. This layer is extended to support the interoperability during the collaboration among robot and CAD/CAM activities as shown in Fig. 10. The Interoperability layers act in two stages:

Captures modified product data and information from their related flexibility layer's interfaces. They convert those data to STEP structure based on application protocols defined in those interoperability layers. The interoperability layers perform the control and check operation for validating the modified data among their own layer.

The interoperability layers deliver the data to Global Interoperability layers to check and control the modified data among all interoperability layers. The modified robot programming data may be in contrast with other scopes like a CAD modification on design that may endanger CAM modified data for that product.

The global interoperability layer interchanges the product data with lower layer called Integration layer. It receives the stored data from Integration layer and processes it to control and validate the modified data.

The Interoperability layers interchange the data among Flexibility layers and Integration layers. At the flexibility layers, the robot/CAD/CAM software packages work with their own data structure. The product data is stored in Integration layer based on STEP standard. The role of Interoperability layers can be defined as a medial structure between flexibility and Integration layer. These layers convert the product data to STEP structure and control the modified data with other information stored in Integration layer to avoid the contrasts.

### 3) Extension in Integration Layer

The extension in this layer should enable the INFELT STEP platform to integrate the robot programming data based on STEP standard.

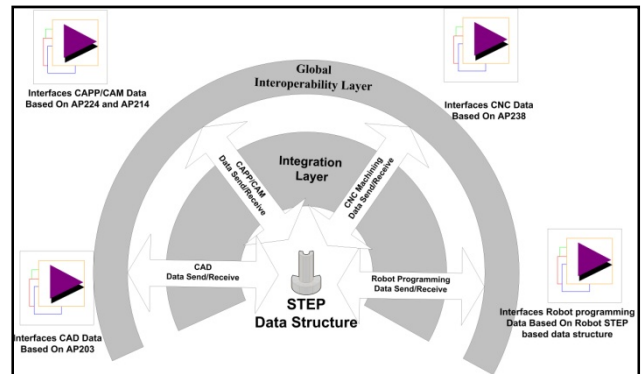


Fig. 11 Extended Integration Layer structure and functions

One of the major operations of the INFELT STEP platform is its storage operations. The integration layer is responsible for saving and managing the data. This data is the result of collaborative works. It includes the design of the product, the process plans of the products and the data that lead to the production of this product by means of the CNC machining tools. The extension in this layer adds Robot STEP based data structure and extra functions for robot programming to current data structures as shown in Fig. 11. This enables the Integration layer to send and receive the robot programming data and maintains the integrity based on STEP standard.

## IV. CONCLUSION

Today's information technology tools can integrate the different processes in enterprises. Exchanging data between CAD/CAM, CNC machining packages and robots software packages can reduce time for developing products by sharing product data. Integration of robot programming data and product design and its process plan design can reduce time for product development. INFELT STEP is an integrated platform based on ISO 10303 (STEP) standard. It enables different CAD/CAM application software and CNC post processors to collaborate with each other in product development. This paper proposes an extension in INFELT STEP platform to enable it manage the robot programming software packages. Different robot software packages can collaborate in this platform with each other. They can specify the product specification based on their own data structure.

The INFELT STEP platform manages the collaboration and store the data based on STEP standard. STEP standard data structures have been used and a data model for managing robot programming commands has been developed. This data can be used by CAD/CAM application software for product design and product process planning. This links the robot programming activities with product design activities. This reduces time to market and increase the integration between product data structures. New extensions for improving the INFELT STEP platform capability in other product development processes can be further searched.

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