Development of STEP-NC Adaptor for Advanced Web Manufacturing System

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Abstract: Information systems play a key role in the modern era of Information Technology. Rapid developments in IT & global competition calls for many changes in basic CAD/CAM/CAPP/CNC manufacturing chain of operations. ‘STEP-NC’ an enhancement to STEP for operating CNC machines, creating new opportunities for collaborative, concurrent, adaptive works across the manufacturing chain of operations. Schemas and data models defined by ISO14649 in liaison with ISO10303 standards made STEP-NC file rich with feature based, rather than mere point to point information of G/M Code format. But one needs to have a suitable information system to understand and modify these files. Various STEP-NC information systems are reviewed to understand the suitability of STEP-NC for web manufacturing. Present work also deals with the development of an adaptor which imports STEP-NC file, organizes its information, allowing modifications to entity values and finally generates a new STEP-NC file to export. The system is designed and developed to work on web to avail additional benefits through the web and also to be part of a proposed ‘Web based STEP-NC manufacturing platform’ which is under development and explained as future scope.

Keywords: STEP-NC, ISO 14649, Web technologies, Web manufacturing, open source, Information system.

1. INTRODUCTION

Numerical Control (NC) machines were evolved in 1950’s and since then many organizations like the International Standards Organization (ISO), Electronic Industries Alliance (EIA) etc are working towards standardization of input file formats for NC machines. The EIA released its standard RS-274 in 1980 called as G&M Code based program for operating Numerical Control (NC) machines. Subsequently, ISO released its relevant first standard version with number ISO 6983 in 1982. Pre manufacturing developments at CAD/CAM/CAPP lead to the development of many special commercial applications and tools which works on proprietary file formats leading to the disruption and loss, of information and flow. Need for a uniform and exchangeable data, lead to the development of new comprehensive ‘STandard for the Exchange of Product model data (STEP) - ISO10303 since 1984 [1]. STEP-NC is an enhancement to STEP for operating NC machines. ISO14649 acts as an Application Reference Model (ARM) for STEP-NC with details about actual machining features, NC control and all other supporting activities at shop floor. ISO14649 is being developed and validated by SC1/WG7 of TC184 since 2002 with the support of many research organizations, institutions to realize many STEP-NC manufacturing platforms across globe. These platforms demand development of varieties of information system, depending on the way of implementation. Inertia with long running G/M code based controllers, features withholding real implementation of STEP-NC systems for actual production. Contemporarily, it’s also been observed that open standards in combination with open source systems enable interoperability with positive impact on competitiveness, growth, innovations, and sustainability of any developing system [2]. Latest concepts of IoT, Social manufacturing too calls
for open and web technologies for mass participation and global infrastructure development [3]. In this regard an attempt is made towards development of STEP-NC adaptor on open and web technologies. Developed Web based Step-nc Adaptor (W-STA) helps in importing a STEP-NC file, organizing files contents, enabling to edit entities, regenerating new STEP-NC file and finally to export it. Section2 discusses brief details about ISO 14649 along with the data model. Review over existing STEP-NC viewers, adaptors developed as part of various STEP-NC systems are briefed in section3. The methodology used for the development of Web based Step-nc Adaptor (W-STA) is explained with step by step procedure and programming flow chart in section4. Final system developed is explained with interface pictures in section5. W-STA can work independently and helps in modifying generic files to native files to realize any STEP-NC manufacturing system. Purpose and scope of W-STA as part of a developing ‘web based STEP-NC manufacturing platform’ is explained in section 6 as future scope.

2. ISO 14649

AP238 of ISO10303 and ISO14649 standards together are known as STEP-NC. AP238 acts as an Application Interpreted Model (AIM) whereas ISO14649 acts as an Application Reference Model (ARM) for STEP-NC. ISO 14649 is less complex, less geometry integration, but is the best to work for actual manufacturing with NC. Similar to any STEP standard, ISO14649 follows a schema structured by data models [4].

Fig1. Example work piece & sample STEP-NC file program [6]
spindle speed, etc., whereas all other auxiliary activities like coolant, mist, chip removal, etc. covered by machining functions. Feature placement provides the local origin and axis system for feature dependent information defined by axis2_placement_3d which contains point information, normal direction and an optional reference direction. The entire information is placed at respective entity values following the data model and these values to be interpreted properly for developing any real time systems or implementations. Express-G diagrams described by ISO manuals [5-8] explains the hierarchy and type of various entities carrying out information. Fig1 shows work piece of the example1 along with part of file program mentioned in part11 of ISO14649: Process data for milling [5] and is considered during the development of STEP-NC adaptor.

3. STEP-NC INFORMATION SYSTEMS

Many numbers of information systems were developed by many researchers across the globe. Some of these systems are independent tools whereas other systems are developed as part of STEP-NC based manufacturing platform. Also, some systems are designed only to extract the entity value or to show a structured view of imported STEP-NC file. Very few other systems work as an adaptor which can import, display tree view, editable and rebuild a new STEP-NC file to suit shop floor facility. As part of EU STEP-NC project, Laboratory for Machine Tools and Production Engineering (WZL) of RWTH Aachen University developed a simple file checker and STEP-NC tree viewer in 2002 [4]. The tool can import STEP-NC file and shows the tree view structure of the contents for users. The tool works as standalone and cannot really interpret the entity values of the imported file. Y Luo et al, in 2009 [9] developed a standalone application 'STEP-NC - Information extraction system Model' to view the tree structure along with CAD geometry from ISO14649 file by using VC++6.0 and OpenGL functions. The application was developed only to extract and display but cannot modify or rebuild a new STEP-NC file. J Tan et al, in 2009 [10] proposed a framework for on-machine inspection based on STEP-NC. As part of the work a STEP-NC interpreter was developed using Java & Java3D. Developed interpreter extracts the STEP-NC file content and displays the tree view of it. H Wang et al, proposed a new control strategy for CNC machines via STEP-NC in 2009 [11]. As part of the work, an adaptor is developed using VC++, ST-Developer & OpenGL. Developed adaptor extracts STEP-NC file information and displays the structural view along with entity values. The tool allows users to modify the entity values and then to rebuild a new native STEP-NC file but works as a standalone application. K Suresh Babu et al in 2010 [12] developed an application to create manufacturing data base from STEP-NC file. The system is developed using VB & MS-Access and works as a standalone tool. An idea for converting STEP-NC to XML format with self-learning mechanism is proposed by J Han et al in 2010. Proposed model checks the errors in the input STEP-NC file with a corresponding XML schema database which can also be updated in case of no suitable XML schema in the database for any new entities [13]. An interpreter is developed for reading STEP-NC file and to implement a feature oriented objects for subsequent modules of STEP-CNC and is proposed by W Xiao et al, in 2015 [14]. The proposed system works on CATIA, TwinCAT and EtherCAT.

From the literature, it’s been observed that every STEP-NC system uses an interpreter for extracting relevant data for their needs, but most of them cannot work as adaptors or rebuild a new STEP-NC file with modifications. No such independent adaptor is observed to be suitable for web manufacturing needs. In this regard, an attempt is made to develop an advanced adaptor using JS and AngularJS features. The methodology can be continued for adding new features without much difficulty.

4. DEVELOPMENT OF WEB BASED STEP-NC ADAPTOR (W-STa)

Development of W-STA follows collecting data with references and downstream linking by following STEP-NC data models. Adaptor imports the selected STEP-NC file and stores each line information as JS object. Following STEP-NC schemas, the pre-defined array of argument structures, fetches the respective entity values and have reference to the line. The process continues till the end of
the file to begin downstream connectivity starting from PROJECT. Connectivity from top to bottom objects allows the adaptor to show the tree view of the imported STEP-NC file. The tree view structure would be compressed by default. Users can expand the required entities or ‘expand all’ or ‘collapse all’ as additional options. Editing values from the user, modifies the corresponding JS object values. Finally, all the line JS objects are rewritten in the increasing order of line numbering. Save option download/export the new STEP-NC file local system. New features and data models can be easily incorporated and can follow the same methodology of the adaptor. Fig2 shows the flow chart of the methodology used towards the development of W-STA. Final adaptor is tested successfully in open source, cross platform web server environment (XAMPP).

Fig2. Flow chart for Web based STep-nC Adaptor (W-STA)
5. WORKING WITH W-STA

Working with the developed adaptor ‘W-STA’ is made simple to use. User can import a STEP-NC file from web interface and then process it to show the tree view or structural view of STEP-NC. User can downstream the tree view by expanding the corresponding top level entities. User can update entity values and save values alone first. With all modifications, user can regenerate a new STEP-NC file. User can even view the new STEP-NC file to proceed for export/download. Overall working is explained with respective web interface diagrams as follows in five stages.

5.1 Import STEP-NC file
Users can select any local STEP-NC file to import and see its content.

Fig3. Import and view Generic STEP-NC file

5.2 Generate Tree View & Expand
‘Process’ button generates the tree/structural view of the imported STEP-NC file. User can expand the entities manually by selecting ‘+’ button against each entity. ‘Expand All’, ‘Collapse All’ are optional buttons as needed by the user.

Fig4. Tree view generation and options

5.3 Editing entity values
User can select any entity value to modify it. ‘Save’ button updates the new values against the respective entities in the tree view.
5.4 Generate output

Finally ‘Generate Output’ button regenerates a new STEP-NC file called ‘native STEP-NC file’ and shows in the ‘Output’ web interface.

5.5 Download/Export new STEP-NC file

‘Save’ button at the bottom of ‘Output’ file area download/Export the Native STEP-NC file to local system. User can open the downloaded file for testing of W-STA.
6 Future Scope

W-STA acts as a first web module of ongoing developments for STEP-NC manufacturing system. A complete Open and Web compliant Step-NC (OW-StepNC) manufacturing system is being developed with an aim of gaining common advantages from, open source, open standards via STEP-NC, and web technologies. Framework of developing OW-StepNC is shown in Fig8. The System makes use of four subsystems. A Web based STep-nc Adaptor (W-STA) is the first subsystem, that lets user to import existing STEP-NC file and allows the user to modify its contents according to the shop floor capabilities. W-STA creates a new STEP-NC file fits to a shop floor or machine and is called as ‘Native STEP-NC file’ and is well explained in the current paper. Generated Native ‘STEP-NC file’ further be processed at another Web based STep-nc Converter (W-STC) and is the second module which is under development. W-STC converts the Native STEP-NC file into two new formats, namely JSCAD file & G/M Code file formats. W-STC is built with all needed algorithms which can extract the manufacturing features, related information and process it through respective algorithms for tool path generation. Tool path information along with geometry would be to create a JSCAD file to view at the OpenJSCAD platform (open with MIT license) [15]. Tool path algorithms for face milling, drilling and pocket finishing operations as specified in the example STEP-NC file of Fig1 was already tested individually on the OpenJSCAD platform [16] that acts as third subsystem i.e Web based Tool Path Viewer (W-TPV). Additional algorithms help to convert native STEP-NC file information to a G/M code file to operate any CNC. Another open application ‘GRBLWeb’ a free Affero General Public License (AGPL) [17], is identified to be suitable for operating CNC and acts as ‘Web based CNC (W-CNC)’ the fourth subsystem of the OW-Step NC.

Fig8. Open and Web based Step-NC Manufacturing system (OW-StepNC)

7 Conclusion

STEP-NC, a powerful standard intended to operate CNC with rich feature based information creates new opportunities across the manufacturing chain of operations in liaison with other STEP AP’s. Rich information requires a proper information system to identify and extract required data from STEP-NC file. Many information systems were developed by many researchers to meet their research needs. With a goal of developing a complete ‘Open and Web compliant Step-NC (OW-StepNC)’ manufacturing system, an independent web based STep-nc Adaptor (W-STA) is developed in the present work. Unlike the previous information systems, W-STA can work independently via web, imports selected STEP-NC file (ISO 14649), shows the structural/Tree view of it, allows modifications from user to suit
shop floor capabilities for all entity values and finally regenerates a new STEP-NC file. Development and Working of W-STA is explained with flowchart and step by step web interfaces. Future scope and use of W-STA is also explained with framework of developing OW-StepNC manufacturing system.

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