

TOOL PATH MILLING INTERFACE FOR INTEGRATING STEP-NC TO OPEN-ARCHITECTURE PC-BASED NC MILLING

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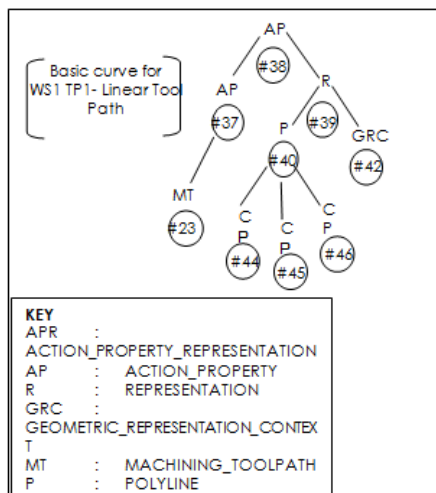
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Graphical abstract



Abstract

Standard for Exchange of Product Model Data (STEP) is a Standard associated with representation of product data model to enable data communication between different Computer-aided Design (CAD), Computer-aided Manufacturing (CAM) and other engineering systems without any ambiguities and any possible data losses. The development of Open Architecture (PC-based) Numerical Control (OAPC-NC) Interpolator has enhanced the possibilities of data communication between the systems. A tool path data interface to OAPC-NC interpolator is proposed and developed; and a hierarchical-based algorithm is used to extract the tool path data from STEP-NC tool path file of a product model. The generated output of the interpolated data is computer simulated for 3D straight-line path to verify the validity of the interpolator input generated by the proposed interface.

Keywords: STEP-NC, Open-architecture controller, tool path, parametric tool path, reference-pulse interpolator

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1.0 INTRODUCTION

STEP (Standard for the Exchange of Product data) is an exchange for product data in support of industrial automation [1]. It is a comprehensive ISO standard that describes how to represent and exchange digital product information. STEP is about sharing data, allowing parties to work together by communicating information interactively [2]. For mechanical parts, the description of product data has been standardized by ISO 10303 [3]. STEP was first issued in 1994 categorize the CAD data based on Application Protocols or AP [4]. The AP defines the collection of information required as a base of exchange unit. AP documents can be quite long, but most of this is the Application Interpreted Model. Loffredo [5] suggested that an

application protocol must be chosen first when planning a STEP implementation.

Most STEP-based feature-technology-related researches are based on one particular goal: to seek a common language for CAD, CAPP, CAM and CNC. The trend towards PC-based open architecture controller (OAPC), and open modular architecture control (OMAC) has enabled third party software to be used at the controller within a standard windows operating system. Implementation of STEP AP203 and AP214 has removed the data exchange barrier within CAD systems. However, the problem still exists between CAM and CNC systems due to the usage of G-codes [6] as CNC controller. Tsai [7] has used a PC-based OAC of a milling machine to implement his newly developed Pythagorean Hodograph variable

feed rate interpolator. Wan Yusoff in his PhD thesis [8] verified that his newly developed general parametric curve reference-pulse interpolator is successfully implemented under OAPC-NC.

Based on the previous research works related to STEP AP238 enabled CAM/CNC machining, this study attempt to apply the tool paths information available in STEP AP238 file sets as an input to the OAPC-NC interpolator developed by Wan Yusoff [8]. It is to demonstrate the interoperability of CNC machine using such controller. Thus the research goal is to provide a seamless information flow system which is portable and adaptive.

2.0 EXPERIMENT

2.1 The Proposed Tool Path Milling Interface

The main objective of the interface proposed is to extract actual tool path data which can be integrated with a PC-based-open-architecture controller developed by Wan Yusof [8]. A CAD model can be readily exported into STEP AP203 (Configuration Control 3D Design for Mechanical Part) and AP214 (Core Data for Automotive Mechanical Design Processes) using the CAD/CAM system built in translator. Then this file is saved in STEP AP21 physical file format. This physical file is computer interpretable and can be exchanged between various CAD/CAM systems. For this research, the part machining and their CC1 STEP AP238 files are the courtesy of STEP Tools Inc.

2.2 Tool Path Data Structure

In STEP AP238, tool path is located in the second part of DATA section; the technology description structure. Parameterized path describes parametrically the approach and connect moves of the tool on work piece so user will know the absolute tool position. It is used when working with cutter contact trajectories for the milling operations. As cutter contact trajectories can only be used for motions on the work piece surface itself there is a need for defining the connecting movements between the individual tool paths in an indirect way. Also, the parameterized paths can be used to connect cutter contact and cutter location trajectories.

The STEP AP238 file set in this research use cutter location trajectory for its tool path. Thus the extracted data would be in form of the tool center point. The entire data in the STEP file is stored in a hierarchical tree-like structure in "bottom-up" fashion. When considering the geometry of a tool path, the root element of the tree can be considered an "ACTION_PROPERTY_REPRESENTATION" entity while the bottom elements are "CARTESIAN_POINT" entities. Other elements such as POLYLINE, COMPOSITE_CURVE, and other entities are located in between in a hierarchical manner. This structure is

illustrated in Fig. 1 for straight-line tool path. Based on this structure, the data required for a specific application can be extracted starting from the top element to the bottom element by descending down the tree.

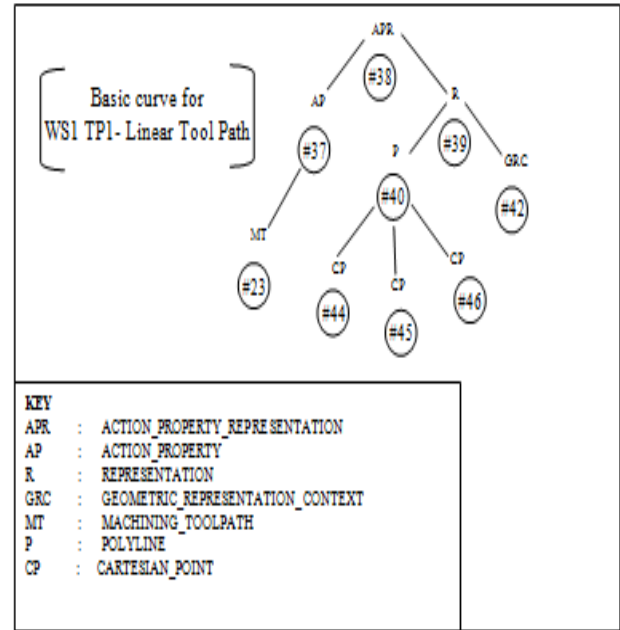


Figure 1 Hierarchy of elements in STEP AP238 for Straight-line Tool Path

The following algorithm is used to extract geometric data from the straight-line tool path file.

Algorithm to extract geometric data from STEP AP238 CC1 part file

Read STEP file line by line.

```

While reading strings in file line by line,
  find string matches 'POLYLINE'
  store the entire line in cell PL;
  if PL > 0
  then find position of # in PL (i.e.
    CARTESIAN_POINTS) and record the
    number of elements found: CP,
    find position of WS in PL (i.e. Working
    Step) and record the number of
    elements found: WS,
    find position of TP in PL (i.e. Tool Path)
    and record the number of elements
    found: TP,
    DO store WS in 1st column of cell
    lastnum
    if the fifth character after TP is
    " " then store TP and one
    number after TP in 2nd
    column of cell lastnum
    else store two numbers after TP
    or k = 1:sizeCP
    if the 3rd character
    after # is ",", "=" & ")" then
  
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store two numbers after # in
the 3rd column onwards
else store three numbers
after # in the 3rd column
onwards
end
end
END

```

In the algorithm, PL, CP, WS and TP are defined as follows:

PL = number of lines which contain string POLYLINE;
 CP = number of #s in PL which contain CARTESIAN_POINT data;
 WS = the working step of the process;
 TP = the tool path number

The outputs of this algorithm include the coordinates of the tool center point on the tool path, the tool path id and the connectivity information as shown in Table 1.

3.0 RESULTS AND DISCUSSION

The tool path data extracted is stored in computer memory according to its identifier and the ascending order of '#' as given in the exchange file. As final part of the interface implementation procedures, interpolator developed by Wan Yusoff (2003) with input from the interface is simulated in computer for performance comparison. This is done to verify the accuracy of input from data extraction interface. For the purpose of illustrating the interpretations of computer simulation results, "exaggerated" 3D parametric curve is simulated. The "exaggerated" simulation means that the curve is simulated with big step size (BLU=1) so that the curve tracing can be observed.

The "exaggerated" plot and data are useful to validate the interpolator method of selecting next interpolated points and to observe the distance of interpolated points from the associated points on original curve. The curve with "•" points are the interpolated tool paths while the curve with "O" points is the original tool path. The original tool path are derived from parametric equation of 3D Straight-line

as given in Eq. 1 to Eq. 6. P₁ and P₂ are the start point and end point respectively.

$$P_1 = (x_1, y_1, z_1) \text{ and } P_2 = (x_2, y_2, z_2)$$

$$Deltax = x_2 - x_1 \tag{Eq. 1}$$

$$Deltay = y_2 - y_1 \tag{Eq. 2}$$

$$Deltaz = z_2 - z_1 \tag{Eq. 3}$$

$$x(u) = x_1 + Deltax * u \tag{Eq. 4}$$

$$y(u) = y_1 + Deltay * u \tag{Eq. 5}$$

$$z(u) = z_1 + Deltaz * u \tag{Eq. 6}$$

Curve boundary $0 \leq u \leq 1$

The simulation plot is given in Fig. 2 for the 3D Straight-line WS1 TP1 with input data as shown in Table 1. Table 2 presents detailed numerical results.

Table 1 Input Data for 3D Straight-line Interpolator

W S	TP	Ref. Point	Start Point (P1)	End Point (P2)
1	4	(#127)	(0, 0, 40)	(76.6078, 112.6997, 28.)

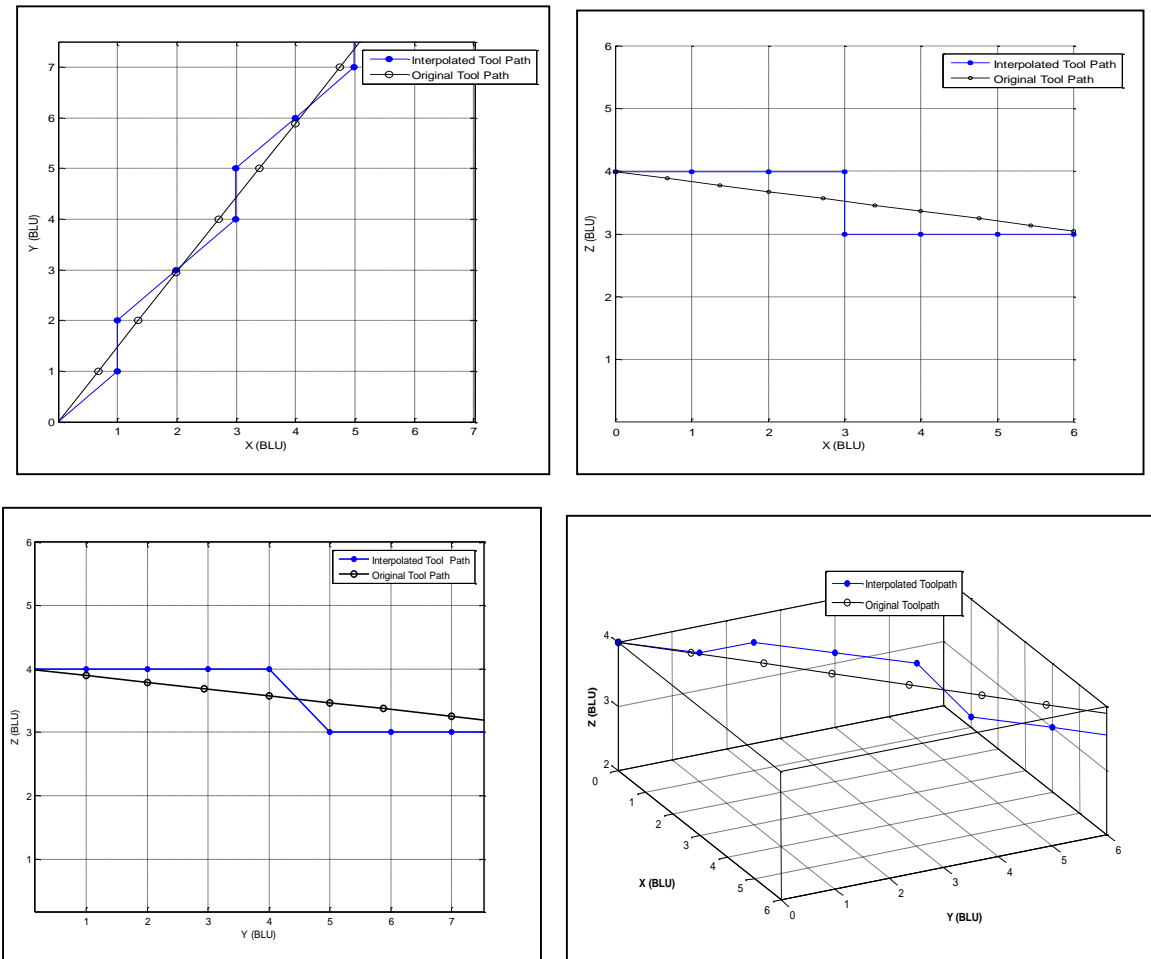


Figure 2 Plots of 'Exaggerated' Interpolator Simulation Result of 3D Straight line on X-Y-Z plane

Table 2 Result of 3D Straight-line for Curve in Fig. 2.

Iteration(k)	X_k	Y_k	Z_k	x_k	y_k	z_k	Error _k
1	0.000	0.000	4.000	0.000	0.000	4.000	0.000
2	1.000	1.000	4.000	0.777	1.000	3.899	0.245
3	1.000	2.000	4.000	1.300	2.000	3.841	0.349
4	2.000	3.000	4.000	2.000	3.000	3.733	0.268
5	3.000	4.000	4.000	2.923	4.000	3.643	0.358
6	3.000	5.000	3.000	3.434	5.000	3.533	0.684
7	4.000	6.000	3.000	4.000	5.901	3.442	0.452
8	5.000	7.000	3.000	4.833	7.000	3.301	0.344

In Table 2, it is observed that the maximum error for 3D Straight-line is at point 6 (0.684). This point is below maximum allowable error for 3D curve (0.707BLU).

4.0 CONCLUSION

In relation to the research objectives, the research has successfully developed a tool path data interface utilizing STEP AP238 CC1 neutral file to transfer tool path data from STEP file to OAPC-NC interpolator. Computer simulation output verifies that the tool path data from STEP file can be used as input for the OAPC-NC interpolator in the form of Cartesian coordinates. Since both the interface and the interpolator are developed and simulated using computers, hence it is portable and adaptive for design and manufacturing activities. Moreover, the interface has enable the process of transferring geometric tool path data from STEP AP238 file to OAPC-NC interpolator. Thus, it is not required for machine-part programming to be done by machine operator before actual machining. Hence, it will reduce human intervention thus reducing human error in machining activities.

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