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The application of multi-agent systems for STEP-NC computer aided process planning of prismatic components

A. Nassehi[a,*], S.T. Newman[b], R.D. Allen[a]

[a]*Advanced Manufacturing Systems and Technology Centre, Wolfson School of Mechanical and Manufacturing Engineering, Loughborough University, Loughborough LE11 3TU, UK*
[b]*Department of Mechanical Engineering, University of Bath, Bath BA2 7AY, UK*

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Abstract

For many years, manufacturing firms have been seeking more efficient ways of manufacturing components with CNC machines. The emerging standards ISO 14649 and ISO 10303 (AP238) present an opportunity to revolutionize the way CNC machines are traditionally programmed. These standards better known as STEP-NC replace the traditional tool movement description languages with hierarchical data structures that allow a new breed of CNC to store part geometry together with the working steps of the operations required to manufacture the part.

STEP-NC provides the ability to store and utilise high level and detailed information from the CAD system to the intelligent STEP compliant CNC controller. With the advent of STEP-NC, computer aided process planning has become a critical link in the CAx process chain with the major requirement to generate interoperable process plans. The authors therefore believe it is necessary to redefine CAPP to reflect the change from the traditional tool movement based programming to STEP-NC based programming.

This paper examines the application of distributed artificial intelligence methods, namely collaborative multi-agent systems in designing an object-oriented process planning system for prismatic components in a STEP-NC compliant environment. The specification and design of a prototype system entitled the Multi-Agent System for Computer Aided Process Planning (MASCAPP) is outlined. Two test components have been designed, process planned, simulated on the machine controller and finally machined, to demonstrate the capabilities of the system and illustrate the activities required to implement STEP compliant manufacturing.

Keywords: Multi-agent systems; STEP-NC; CAPP

1. Introduction

Since the invention of CNC machines in the 1950s, enormous advances have been made in the machines' capabilities, precision and speed. Today 5-Axis machining centres are able to accurately manufacture complex parts in a single set-up for a fraction of the time that would have been needed, were the parts to be manufactured using the traditional NC machines. Despite these advances in the machining centres' hardware and technology, the programming language used to program them, is essentially unchanged from that of the 1960s. These programming languages based on G&M codes formalised in the ISO 6983 standard [1] are used to define tool movements and simple switching operations for the low-level programming of CNC controllers.

An international effort is now being made towards development of a new data model and a new approach to programming of CNC machines that can open the path for exploiting their advanced capabilities with greater ease and efficiency. This framework is materialising in the form of standards collectively known as STEP-NC. STEP-NC replaces the traditional G&M codes used to program machines with a hierarchical data structure that contains product geometry and working steps required for part manufacture. While the ISO 6983 compliant programs contained information on *how* to build a part, the contents of the new data structure indicate *what* needs to be done for the product to be manufactured [2]. Within the STEP-NC standard [3], the main manufacturing workplan for each part is comprised of several working steps. Each working step

* Corresponding author.
E-mail address: a.nassehi@lboro.ac.uk (A. Nassehi).

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can either be a manufacturing working-step or a combination of other working-steps. To achieve maximum performance in STEP-NC manufacturing, it is necessary to define the working-steps existing within the hierarchical data model in the optimum order.

Through a STEP compliant [4] process planning system, a major function of the system is to detect conflicts and efficiently plan the interactions between the working steps to achieve the optimum order. Thus it is desirable to have an automated system capable of planning the manufacturing process of each part optimally.

While many techniques can be used for determining the optimum order of objects, the developments in distributed artificial intelligence [5,6] and intelligent agents [7], make them a potential candidate for this purpose. Multi-agent systems perform well when it is possible to break the main problem down into a set of connected less complex problems and as it happens process planning can be treated as such a problem.

Employing multi-agent systems on complex data sets requires a robust and efficient information backbone for achieving reasonable performance. Information storage techniques are numerous and a careful study is required to determine which method is more suitable for the purpose of developing the automated agent-based process planning system. This paper recognises and extends the earlier research on agent-based process planning by Allen et al. [8] by employing simpler and fewer agents, an object oriented environment, advanced feature interaction algorithms and an interface to Siemens STEP-NC interpreter using STEP 10303-21 files [9].

The paper investigates the application of multi-agent systems in STEP-NC compliant process planning. First a brief review on the agent technology and multi-agent systems and their application in manufacturing is presented. A prototype process planning system is then created using the Java programming language. To develop this system, a robust information backbone is a necessity. A short study was made on the different information handling methods and an object-oriented database system was chosen to serve as the data provider. To limit the scope of the research a limited set of components were needed and since definition of features of prismatic components is straightforward, this type of component is selected. The developed system, entitled Multi-Agent System for Computer Aided Process Planning (MASCAPP), focuses on two of the many geometric features (i.e. general closed pocket and round hole) defined in ISO14649 to illustrate the functionality of multi-agent systems. Sample parts are designed, process planned and exported as STEP-NC compliant files within the system to demonstrate its capabilities. The exported STEP-NC files are then interpreted and simulated on a SIEMENS controller with SHOPMILL™ OPEN 6.03 software.

2. Review of STEP-NC technology and multi-agent technology

The MASCAPP system proposed in this paper relies on three major elements, namely:

- CAPP within STEP-NC manufacturing environment;
- Multi-agent systems;
- STEP-NC compliant information modelling tools.

It is therefore necessary to define process planning in the STEP-NC environment and specify what it entails, introduce intelligent agents and multi-agent systems based on the collaboration of a group of software agents and finally explore different strategies for STEP-NC information modelling to identify the best potential method of information handling to support process planning.

2.1. CAPP within STEP-NC manufacturing environment

In ISO 6983, the current standard for numerical control, tool motions are defined using G codes and simple switching instructions are issued by using M codes [1]. This method of machine programming, results in loss of product information along the manufacturing process chain. As the product geometry designed in CAD software is passed on to the CAPP and CAM software, toolpaths and switching instructions specific to an individual machine are generated to optimize the manufacturing effort.

The output from the CAM system consists of only low level description of toolpaths with all the geometric features and tolerances discarded. There are a number of inherent problems with this traditional process chain; the most important of which is perhaps the one-way flow of information. Here, the information generated in the CAD system is passed on to the CAPP system and then onto the CAM system and finally to the machine controller for manufacturing. As a result of this uni-directional information flow, changes made in the final part program generated by the CAM system on the shop floor are not reflected in the product model existing in the CAD/CAM systems.

STEP-NC allows bidirectional flow of information [10]. Since features and part geometry are maintained throughout the manufacturing process, the changes on the shop floor are immediately reflected in the CAD/CAM models. Fig. 1 shows this fundamental difference.

With ISO 6983 (G&M code) programming, process planning determines the order in which toolpath instruction chains should be executed. In STEP-NC, process planning is used to determine the order in which different features or multiple features should be manufactured. In addition a major and critical requirement is that a process planning system in the STEP-NC framework should be able to detect conflicts and interactions between working steps required