Title:
Multi-User Collaborative Tool Path Planning Using Process Decomposition

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Introduction:

Red [1] notes that single-user tools constrain developers in collaborative work environments at every step of the product development process, from idea generation to manufacture. Single-user applications like CAD, CAE, and CAM force a strictly serial design process, which ultimately lengthens time to market. New multi-user applications such as NXConnect [4] address the issue during the design stage of the product development process by enabling users to work in parallel. Could not multi-user collaborative tool path planning software address the same serial limitations in tool path planning, thereby decreasing cost and increasing the quality of manufacturing processes?

As part complexity increases, lead times are magnified by serial workflows. Multi-user tool path planning can shorten the process planning time. But, to be effective, it must be possible to intelligently decompose the manufacturing sequence and distribute path planning assignments among several users. Tool path planning is unique in that the processes naturally decompose into distinct activities that can be divided among users. The processes can be defined independently of each other with little regard for what other users have done. There has been some research conducted in decomposition of features in multi-user modeling CAD, but a literature review has not discovered similar research in multi-user tool path planning.

Main Idea:

Most CAD packages come with manufacturing tools that assist in process planning; sometimes, third party applications are used. At the beginning of the planning stage, a solid CAD model is opened in the CAM application. The application is then used for planning setups, defining parameters and tools, creating CNC tool paths, and so on. In single user applications both simple and extremely complex part processes are planned serially by a single user, feature-by-feature. Furthermore, a single user may not be knowledgeable in all relevant manufacturing processes and available equipment.

In contrast, multi-user CAM process planning addresses part complexity by involving multiple users, allowing them to work in parallel. The parallel workflow also means that relevant tasks can be assigned to experts in various processes. Using this approach increases quality, decreases cost and reduces lead time.

The application NXConnect [4] successfully addresses these same issues in the part modeling phase of the design process. The application creates a multi-user design environment that lets multiple users model a part at the same time. The developers of NXConnect have shown that "collaboration decreases the product development time in proportion to the number of multi users."[2]

Other researchers have recognized the need for a multi-user environment for product development. Hepworth [3] lists ten different multi-user CAD systems that have been developed to address this need. By employing the same approach to manufacturing process planning a similar improvement in efficiency is expected, enabling companies to be more competitive.

In multi-user CAD, features are rarely independent so independence is maintained by working in distinct locations of a part that will not cause interference among users. The next step in development, process planning, then uses the finalized CAD model to extract tool paths. The key concept in the success of multi-user CAM system is the natural way that manufacturing processes decompose into a series of steps that can be defined independently. At CNC code generation time the operation order is important and the processes must be arranged accordingly, but at process definition time it is not necessary to define the processes in any particular order. Tool path planning software is an ideal candidate for a multi-user environment because this natural decomposition sidesteps many of the issues encountered by other multi-user applications, including NXConnect. Figure 1 demonstrates how a simple die can be broken up into processes that can be divided among users. User 1 defines the roughing paths while user 2 simultaneously defines the finishing passes and user n takes care of slotting and chamfering etc.

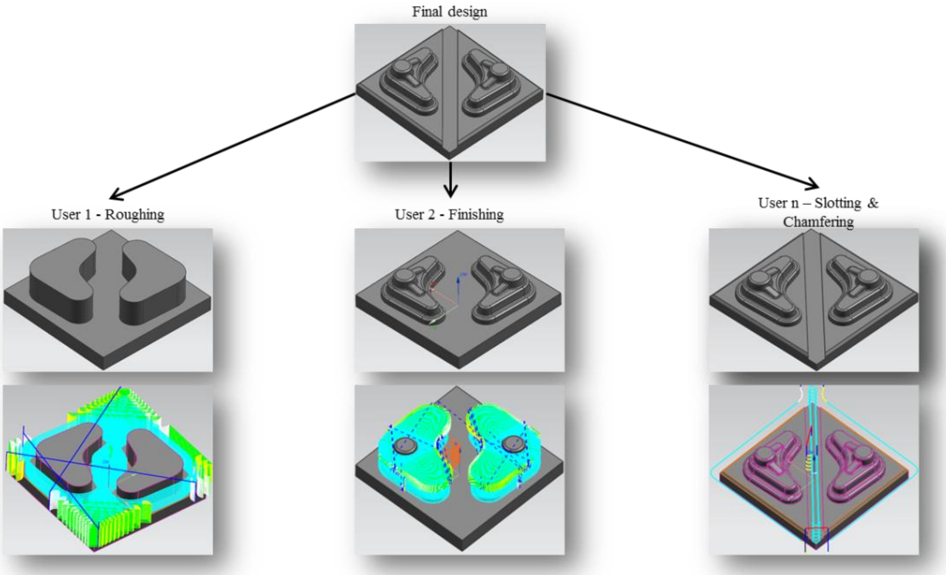

Fig 1: Manufacturing processes can be divided among users and defined simultaneously.

Once each user has defined the assigned paths a single user will complete the final integration of the tool paths in the proper order. The final user will adjust the order of the operations as needed to follow the proper sequence, perform any process verification steps necessary, then export the CNC code.

When the tool path planning stage begins, it is vital for the users to decompose the process into distinct independent activities. Then the activities must be distributed among the users in an intelligent way. Parts often require transfer to other machines to complete all the required material removal. This must be taken into consideration when assigning activities to users. General principles will be presented that describe how to arrange the users according to capability.

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The time savings can be quantified in the following manner. First we analyze how much time it takes for a single user to plan a process. Each operation is assigned a weighting factor, w. This weighting factor is multiplied by the average time it takes to complete an operation. The total time to plan a process is a function of the number of operations, the average time to plan a single operation, the weighting factor, and the setup and finishing times.

$$T_{Total} = \sum w_i * t_{task,avg} + t_{setup} + t_{finish} \tag{2.1}$$

The time needed for a team to plan a process can be analyzed as follows. If it is assumed that each user has the same level of expertise then the total time is a function of the number of operations, the number of users, the average time to plan a single operation, the weighting factor, and the setup and finishing times.

$$T_{Total} = \frac{\sum w_i * t_{task,avg}}{N_{users}} + t_{setup} + t_{finish} \tag{2.2}$$

The time savings is the difference between the single user time and the multi-user time.

$$\Delta T = \sum w_i * t_{task,avg} * \left(1 - \frac{1}{N_{users}}\right) \tag{2.3}$$

Equation 4.3 shows that the time savings is proportional to the number of users. This matches the findings of the NXConnect developers.

The simultaneous collaborative nature of multi-user CAM has several other benefits. Group awareness helps catch errors earlier and coordination between users is better. The users participating in process sessions are more accountable and motivated by each other. There are also benefits of collaborative in context problem solving and educational training by expert interaction.

A multi-user tool path planning plugin has been developed for Siemens NX that is capable of simultaneous tool definition, tool path definition and path generation. The software is built using a client server architecture that allows tool path planning data to be easily shared among users. Each item created by a user is reflected through a server to each multi-user connected to the session, so progress and updates are visible to all users in real-time.

Conclusions:

Manufacturing processes naturally decompose into a series of operations that can be defined independently of each other. The operations can be divided among users and defined simultaneously in CAM multi-user software. Tool path planning software currently is limited to a single user who must define all operations regardless of part complexity, or the knowledge of the user, which extends the overall design process. Multi-user tool path planning software allows expert users to be assigned to planning tasks in which they are most knowledgeable. Ultimately, multi-user tool path planning will reduce errors and shorten time-to-market.

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