Chapter 4
Interactive and Collaborative Virus–Evolutionary CNC Machining Optimization Environment

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ABSTRACT
Research on the area of sculptured surface machining optimization is currently directed towards the implementation of artificial intelligence techniques. This chapter aims at presenting a novel approach of optimizing machining strategies applied to manufacture complex part geometries. Towards this direction a new genetic-evolutionary algorithm based on the virus theory of evolution is developed as a hosted module to a commercial and widely known CAM system. The new genetic algorithm automatically evaluates pairs of candidate solutions among machining parameters for roughing and finishing operations so as to optimize their values for obtaining optimum machining programs for sculptured parts in terms of productivity and quality. This is achieved by introducing new directions of manipulating manufacturing software tools through programming and customization. The environment was tested for its efficiency and has been proven capable of providing applicable results for the machining of sculptured surfaces.

1 INTRODUCTION
Scultured (or free-form) surfaces (Choi & Jerard, 1998) constitute the fundamental geometrical features of specialized products found in aerospace, automobile, shipbuilding and consumer electronics industries. Such products are aircraft fuselage, turbine blades, compressors and impellers, automobile body panels, mobile phone castings and moulds/dies. Manufacturing processes to produce free-form products

DOI: 10.4018/978-1-4666-8693-9.ch004
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include casting, injection molding, stamping and metal cutting operations (Kalpakjian & Schmid, 2008). In the case of metal cutting processes, 3- and/or 5-axis machine tools are employed to remove the extra material from the raw stock as it occurs in prismatic parts comprising regular surfaces. The difference between sculptured and regularly-surfaced products lies on the fact that an inherent freedom exists when designing sculptured surfaces whilst regular ones contain features that can be easily designed and thus characterized in terms of their machining strategies and tools to be applied for their manufacturing. Moreover, morphological features of sculptured surfaces involve combinatorial machining operations as opposed to common surfaces that may be normally manufactured by individual stages.

The machine tools utilized for sculptured surface machining are computer numerical control (CNC) machining centers that realize material removal by repetitively moving a rotating milling cutter along pre-determined trajectories known as tool-paths (Choi & Jerard, 1998). The quality of tool-paths is of paramount importance and characterizes not only the efficiency but final product quality as well. Tool-path generation is a direct output of computer-aided manufacturing (CAM) environment, and is a result from end-users’ selections made for strategies and process parameter sets in terms of machining modeling. This implies that tool-path creation lies thoroughly on human expertise and experimentations towards the selection of optimal parameter values satisfying pre-determined quality objectives. Since manufacturing software has been characterized as being the center of gravity for modeling complex machining operations (Lopez de Lacalle et al., 2007), it is essential that research efforts ought to be directed and carried out utilizing CAD/CAM technology.

State of-the-art research studies and cutting-edge approaches concerning tool-path generation involve CAM systems either to integrate them with new tool positioning algorithms introduced as novel machining strategies (Warkentin et al., 2000; Wang et al., 2006) or optimize mathematical expressions/predictive models including discrete quality targets (dependent variables) and process parameters (independent variables) from which targets are greatly influenced (Karagiannis et al., 2013; Vaxevanidis et al., 2013). Even though both research directions have already provided remarkable results to academia and industry, the latter seems to be the practically viable one against tool positioning methodologies. Unless other mechanisms are implemented to evaluate given quality objectives rather than mathematical relations used as “objective functions”, machining optimization with the use of CAM systems can be a quite promising research field, directly applicable to industry.

Noticeable research contributions falling to both aforementioned categories include the work of Quinsat and Sabourin (2006) in which optimum machining direction is investigated when applying 3-axis machining for sculptured parts. In their work machining direction is considered to be key objective on optimizing both machining time and surface quality. On the basis that machining strategies applied to machine complex geometries are of major importance to objectives such as part quality, machining time and cutting forces, Ozturk et al., (2007) studied the proper selection of related machining parameters via simulations mainly conducted employing multi-axis machining. In order to utilize the potential of the five-axis milling process, Kersting and Zabel (2009) presented an optimization approach based on recent multi-objective evolutionary algorithms. Their optimization module was integrated in a simulation environment for 5-axis milling whilst provides a link in the process chain between CAM environment and actual machining operation. Zeroudi et al., (2012) took advantage of tool positioning points obtained by CAM software so as to calculate local inclination angle of the generated surface and then the tool engagement to the work piece material, hence: predicting cutting forces. Fountas et al., (2014) conducted simulation experiments by implementing both 3- and 5-axis sculptured surface machining tool-paths and their related machining parameters so as to study their influence on productivity and quality.
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