Editorial: A brief overview of artificial intelligence applications in machining

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1 Introduction

At the present, almost every branch of science and engineering uses the artificial intelligence (AI) tools. In machining, AI techniques have achieved several applications. Almost certainly, the most remarkable of them are cutting processes monitoring and control, cutting parameters modelling, processes optimisation and computer-aided process planning (CAPP).

Due to their complex nature, machining processes are very difficult to be understood, modelled or simulated. Relationships between cutting variables are highly non-linear and poorly known; therefore the current analytical models, in spite of their theoretical relevance, have a very limited practical application. Furthermore, using conventional techniques, such as statistical and numerical methods, for modelling cutting processes, have not shown a completely satisfactory effectiveness.

On the contrary, AI, which is based on simulation of human and nature behaviour, has the ability of deal with complex problems. Some AI techniques, such as neural networks, fuzzy logic and neuro-fuzzy systems, can model complex relationships and extract information from raw noisy data. On the other hand, other AI tools, such as evolutionary computation, simulating annealing, and ant-colony algorithm, allow carrying out the optimisation of complex systems, where conventional techniques fail.

In the following sections, a very brief overview of the main applications of AI in machining is carried out. This does not pretend to be and exhaustive review but a simple outline of current state-of-the art and future trend in this branch. In accordance with this, only review papers or very representative and recent works are cited.

2 AI applications in machining

2.1 Machining process monitoring and control

Monitoring and control aim to identify the relationships between transient parameters, i.e., those which change with time and, therefore, must be measured online. In machining processes, monitoring is focused on estimating parameters or identifying events which are difficult to obtain, from other parameters which are easily directly measured, such as vibrations, cutting forces or motor current.

Tool condition monitoring systems can significantly improve the performance of machining processes by providing information on some important aspects, including tool wear, tool breakage and fault detection, chatter, surface roughness, and so on (Sick, 2002).

AI is mainly used in the model level of the monitoring systems. The most widely used AI techniques in tool condition monitoring are the artificial neural networks and fuzzy logic (Rehorn et al., 2005), which are implemented principally for estimating or classifying tool wear. However, using some others tools like hidden Markov models, support vector machines and analytic hierarchy, have been reported in tool condition monitoring and control (Liang et al., 2004).

2.2 *AI in off-line modelling of machining processes*

Off-line modelling of machining processes deal with stationary parameters, i.e., variables that remain constant in the time. These models not only aid understanding the principles ruling the cutting processes, but also allow planning rational and efficient processes. They play a crucial role in the optimisation of cutting processes.

AI methods have been less frequently applied in off-line modelling of cutting parameters than in online modelling. The reason for this is the popularity of simple statistical-based correlations (such as the Taylor's equation), which have been widely used for a century with an acceptable accuracy.

However, with the introduction of new complex materials and the use of higher cutting speeds, prediction of cutting variables, especially tool wear, by means of traditional statistical regressions, using linear or linearised models, has hard limitations (Dolinšek et al., 2001).

Interesting AI applications have been reported for off-line modelling chiefly of tool wear and tool life (Wang et al., 2008; Quiza et al., 2008) surface roughness (Benardos and Vosniakos, 2003) and cutting forces (Sheikh-Ahmad et al., 2007; Cus et al., 2006). As in online modelling, artificial neural networks are the most used tools (Mukherjee and Ray, 2006). Nevertheless, other techniques such as fuzzy logic, neuro-fuzzy approaches and support vector machines are recently becoming very popular.

2.3 *AI in cutting processes optimisation*

Machining process optimisation is a key aspect in order to design competitive efficient manufacturing processes. However, it is a very difficult task, dealing with complex models of cutting parameters, which makes the involved objective functions and constraints being very complex, non-lineal and multimodal. Consequently, non-conventional techniques, mainly based on AI, have been successfully applied on cutting processes optimisation (Mukherjee and Ray, 2006).

The most used AI-based techniques, in cutting parameters optimisation, are the evolutionary algorithms, chiefly genetic algorithms, which simulate the natural organisms' evolutionary process. These algorithms can successfully deal with non-linear, discontinuous, non-differentiable and multimodal functions. Furthermore, in multi-objective optimisation, they can obtain several Pareto-optimal solutions in a single run (Quiza et al., 2006).

Other non-conventional tools frequently reported in machining optimisation are the heuristic and metaheuristic search techniques, tabu search and simulated annealing (Mukherjee and Ray, 2006).

2.4 *AI in process planning*

Process planning (especially CAPP) involves many complex tasks which usually are difficult or impossible to be implemented as an algorithm. Therefore, AI founds here a natural field for its applications.

There are two main directions involving most of the reported researches on AI applications in CAPP: automatic features recognition from CAD models and operations selection. Obviously, both are closely related and, frequently are difficult to separate. Neither the first one nor the second one, are, at the present, definitely solved tasks, so they are currently receiving a great amount of attention from researchers.

In automatic features recognition the most used AI techniques are those that allow carrying out pattern extractions from data. Artificial neural networks are the most cited between the AI tools (Abouel Nasr and Kamrani, 2006), although there are some other intelligent and conventional techniques that have been often used.

Operation selection encloses not only operation sequencing but also tolerances and surface finish analysis; machine-tools, cutting tools, fixtures and cutting fluids selection; and tool path generation. Actually cutting parameters optimisation is an operation selection topic too, but, due to its relevance was considered independently. In operation, selections mainly used AI techniques for pattern recognition such as expert systems, neural networks and fuzzy logic (Vasant, 2006) and for optimisation, such as genetic algorithms, simulated annealing, particle swarm optimisation algorithm, etc. (Pan et al., 2008).

2.5 Concluding remarks and future works

Even though AI techniques commonly claim to attain better results than conventional techniques, in machining applications, there is not a general consent on this assertion. It have been pointed that AI are usually hard to be implemented, and computational expensive. Moreover, a lack of comparisons between the outcomes of AI-based and conventional models is frequently noted in most of the reported work, so the actual utility of AI techniques in this field is easily overvalued.

In addition, theoretical aspects of many AI techniques are complex and, sometimes, not well-established yet. So, serious misusing can be frequently found in their applications.

In spite of the above-mentioned facts, and despite some possible snobbism in their use, the popularity of AI techniques is a clear indication of their ability for attaining successfully applications.

As can be foreseen, future works in this field, will be directed to two main goals:

a to develop more effective and efficient AI tools, including the improvement of their theoretical foundations

b to obtain more general, adaptable and flexible applications.

In this sense, it is very important to achieve robust, reliable and practical AI-based systems, to be used in the workshop floor environment.

3 Current special issue

This special issue includes 13 peer-reviewed papers, dealing with the most important current research topics on AI applications in machining. The four above-mentioned fields: monitoring, off-line modelling, optimisation and process planning, are represented. A review of AI approaches in part accuracy prediction is also included.

There is also a good representation of the different AI tools, applied in machining: artificial neural networks, fuzzy logic, evolutionary algorithms and others non-conventional optimisation techniques, data mining, etc., although neural networks are the most widely represented technique.

The guest editors hope that assembling these papers in a special issue will be useful for researchers and, in general, for all readers. They would like to thank all the authors for their contributions. Also, they would like to acknowledge the invaluable constant support of reviewers and advisors.

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