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3D Technology in the Construction Machinery Processing Industry

Yang Li*

The School of Art and Media, Guangzhou Vocational University of Science and Technology, Guangzhou 510000, Guangdong, China

2100617010@qq.com

**corresponding author*

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Abstract: With the development of the Internet, computer technology is developing rapidly. The virtual reality system of machining can realize the software of hardware equipment, and trainees can complete the experiment through virtual simulation software, which effectively overcomes the limitations of traditional experimental teaching, and at the same time can provide a quick introduction to machining technology under the premise of ensuring safety. Therefore, this paper focuses on the 3D virtual reality system and augmented reality assisted system for machine processing and conducts an in-depth study. The paper provides a brief analysis of the application of 3D technology in the engineering machining industry from three perspectives: the basic overview of machine machining, machining systems and machining analysis.

1. Introduction

The machining virtual reality system introduces 3D virtual reality technology into the machining system, providing a visual virtual space for communication and understanding between those involved in process development and fixture design, avoiding the possibility of safety accidents during actual operations [1-2]. The current machining process uses machining process cards to carry information, however, the machining process cards display information in two dimensions, displaying information with professionalism and limitations, leading to difficulties in reading process information, a long training period for professionals, and not conducive to the improvement of machining efficiency [3]. In today's rapidly developing technology, the application of 3D virtual reality technology to mechanical manufacturing and machine tool industry has become one of the important research directions, opening a new mode for craft personnel to develop process protocols and fixture design solutions [4-5].

In recent years, a number of researchers have explored and achieved results on 3D technology and engineering machinery machining. For example, Raj A et al. used graphene nanoplates to improve the machinability of Inconel 718 with graphene in two forms: as a solid lubricant and as an inclusion in the cutting fluid; the performance was compared by measuring cutting forces, cutting temperatures, tool wear and surface roughness, and the results showed that both forms of graphene exhibited superior performance to dry machining [6].Singh P et al. experts prepared Al-4032 based composites with SiC mass fraction of 6% by stir casting apparatus and tested the composites for tensile strength, micro hardness and impact strength. Cutting speed, feed rate and depth of cut were the cutting parameters selected to check the response surface finish and energy consumption and the results showed that the expectation value approach based on response surface methodology was used to obtain the desired goal of achieving optimal combination of parameters [7]. It was found that there is relatively little research into machining applications based on 3D technology.

The 3D virtual reality system for machining transforms theoretical knowledge into a concise and realistic visual image that can be interacted with and has a strong sense of immersion [8]. Therefore, this paper is based on 3D virtual reality technology to study and explore machining. The research content of this paper is mainly divided into three parts: the first part is the basic overview part, mainly from 3D technology and quality inspection subsystem for the basic overview of machining; the second part is the machining system, through the overall system design, auxiliary system design and cutting area temperature model for the construction and analysis of 3D virtual reality system; the third part is the analysis of machining, including Optimisation of resource allocation and optimisation of product structure in two parts, and conclusions are drawn through the analysis.

2. Basic Overview

2.1. 3D Technology

With the continuous breakthrough of binocular vision technology, vision-based 3D tracking technology is rapidly developing in the mobile world. 3D technology is divided into two aspects: on the one hand, the spatial location of objects is determined by a visual positioning system, and on the other hand, virtual objects are placed in real-world coordinate positions [9-10]. According to the development trend of 3D technology, 3D technology is divided into vision-based, sensor-based and sensor vision-based hybrid tracking and registration technologies. In this paper, 3D registration of sample artefacts is done based on computer vision technology using a mobile camera [11]. The computer vision-based 3D registration approach can be subdivided according to the working principle of each module into: tracking and registration based on natural object geometric features, tracking and registration based on artificially created markers, and tracking and registration based on virtual 3D models of actual objects [12-13].

2.2. Quality Inspection Subsystem

The relationship diagram of the quality inspection subsystem was drawn and qualitatively analysed. The relationship diagram of the quality inspection subsystem is shown in Figure 1.

The analysis of the relationship diagram of the quality inspection subsystem leads to the following.

(1) Product quality is closely related to customer satisfaction and production costs [14].

(2) Factors that directly affect product quality include raw material quality, process level, inspection records, dimensional checks, appearance checks and other influencing factors. In the machining process, improving the level of process inspection can promote the accuracy and

effectiveness of dimensional inspection and ensure that the product meets the specification requirements, while process inspection provides inspection data support for process improvement and has a facilitating effect on process improvement [15-16].

(3) Inspection processes are directly affected by quality audits. Quality audit has a supervisory role on the quality inspection process, quality audit is strict, staff take it seriously, according to the process, norms, then promote the inspection process to improve the level of inspection; quality audit is lax, the lack of supervision of the inspection process, prone to leakage, wrong inspection events, inspection level is reduced [17].

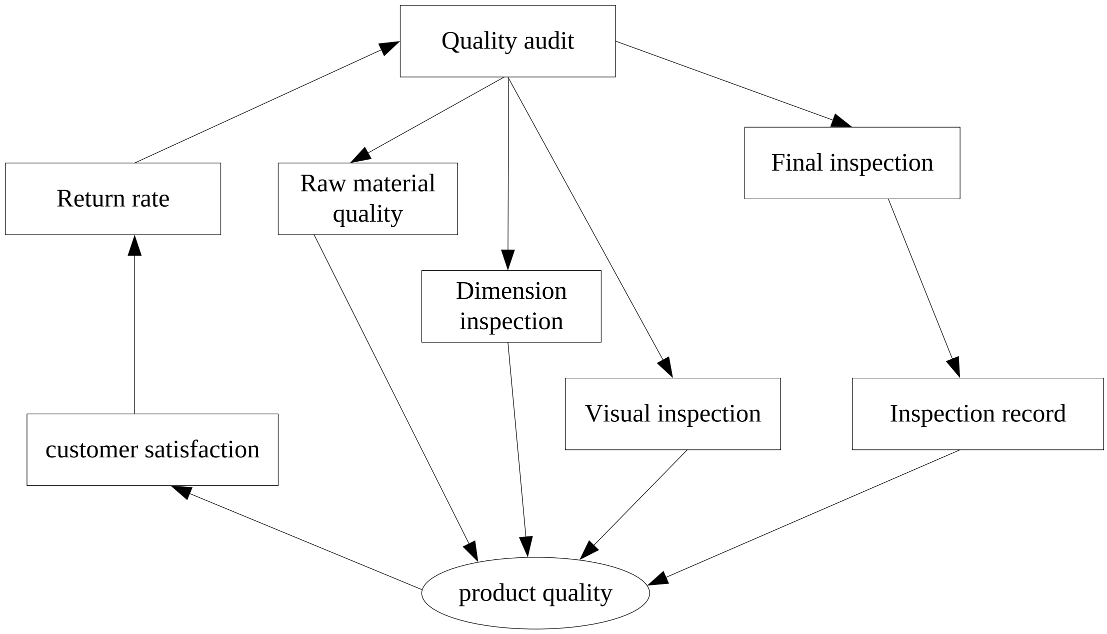

Figure 1. Relationship diagram of the quality inspection subsystem

3. Machining System

3.1. Overall System Design

According to the demand analysis of the virtual machining system, the whole system can be divided into four main modules: machining cognition module, simulation module, assessment module and toolholder box disassembly module. According to the modular design principle, the overall design block diagram of the virtual machining system can be designed, as shown in Figure 2.

(1) System cognition module

The cognitive module mainly includes the basic introduction of the system and 3D dynamic observation of the machine tool. When entering the module, the mouse will click on a component, the surface of the component will be highlighted and the system prompt box will appear with the basic information of the component, so that the students have a preliminary understanding and knowledge of the components of the machining machine, and deepen their knowledge of the name and function of each component.

(2) Experimental simulation module

Trainees can select the machining method and then operate the machine according to the different machining methods. Using collision detection, the machining process is simulated by editing scripts to control tools, workpieces and other components. The predictive model is also used to obtain the cutting temperature and cutting force, while the real-time temperature and cutting force are displayed to the screen.

(3) Toolholder box component disassembly module

The system also has an interactive disassembly function that allows trainees to disassemble and assemble the main components of the machine by dragging and dropping them with the mouse. When trainees carry out disassembly and assembly training, the parts will only be dragged if the disassembly and assembly sequence is correct. If the sequence of operation is wrong, the system will prompt the trainee to proceed to the next step.

(4) Training assessment module

When the user has completed all tasks, the user can use this function to assess the learning tasks, the assessment mainly revolves around the machine tool cognitive part and the disassembly function.

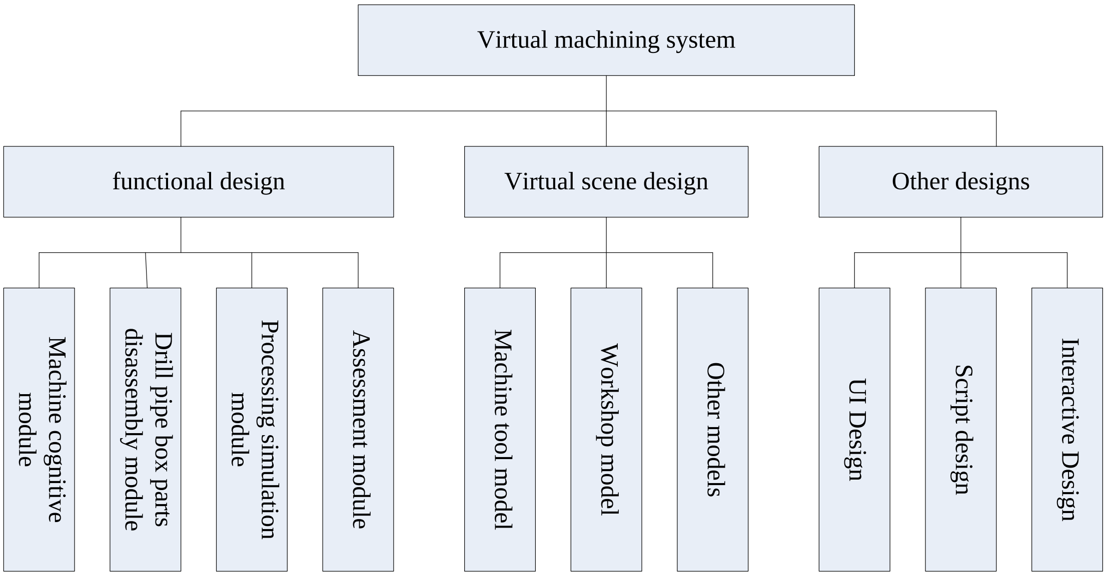

Figure 2. Virtual machining system design

3.2. Auxiliary System Design

When building the system, the principles of reduced development cycles and green design were used [18]. The structure of the auxiliary system consists of three main parts: the image recognition module, the augmented reality display module and the interactive display module. The system structure is shown in Figure 3.

(1) Image recognition module

The main function of the image recognition module is to use image processing as well as image recognition theory to achieve accurate recognition of workpiece processes in mobile devices, to precisely locate the position information of workpieces in real scenes and to place augmented reality machining information in the correct spatial position.

(2) Augmented reality display module

The augmented reality display module is the core module of the system and consists of two parts, one is the 3D registration of the target workpiece with the augmented reality model; the other is the layout of the augmented reality machining process information display. 3D registration is to ensure that the augmented reality information is displayed with the correct pose and requires good robustness. and processing animation and other related information.

(3) Interactive display module

The interactive display module is mainly used for interacting with augmented reality information through computer human-computer interaction technology, and this paper is mainly used to achieve simple human-computer interaction through mobile touch screen operation instructions. The design of the interactive display module will enable the operator to have a more comprehensive understanding of the machining process information.

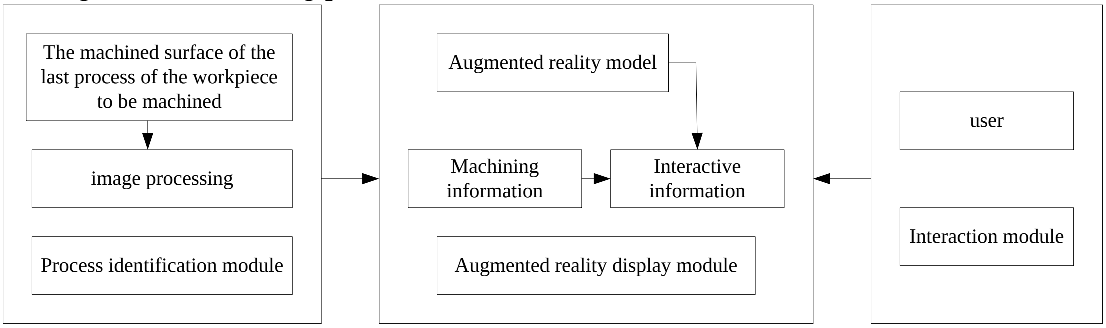

Figure 3. Structure of the auxiliary system

3.3. Cutting Area Temperature Model

When the tool is cutting, the front face of the tool is in contact with the surface of the workpiece, which is approximated as a shear plane, so the deformation of the workpiece is generated in this plane, and the deformation of the metal is considered to be completely transformed into the heat generated by the cutting. The deformation of the workpiece on the shear plane and the heat generated can both be considered as uniformly generated, so that we can obtain:

$$\frac{\partial^2\theta}{\partial y^2} = \frac{\lambda\partial\theta}{\mu\partial x} \tag{1}$$

Further derivation leads to a differential equation model for the cutting temperature.

$$\frac{\partial^2\theta}{\partial y^2} - \frac{\lambda\partial\theta}{\mu\partial x} = 0 \tag{2}$$

where x represents the coordinate in the direction of the cutting speed, y represents the coordinate perpendicular to x and μ represents the exothermic value of the material.

4. Machining Analysis

4.1. Optimisation of Resource Allocation

The results of the comparison of different optimization methods are shown in Table 1. For example, it can be seen that the total payment utility of the tolerance strategy under the three optimization methods is 53.781, 109.872 and 74.539 for k=1000, and the quality loss is 26, 64 and 38 respectively, because the demand side of the manufacturing service accesses the machining system to seek a high quality and high price service provider, so the smaller the total payment and quality loss, the better the tolerance strategy, so the evolutionary game The evolutionary game method reduces the total payment by 51.05% and 27.85% and the quality loss by 59.38% and 31.58% respectively compared to the non-cooperative evolutionary game method and the linear weighting method.

Table 1. Comparison of resource optimisation methods

Optimization method	Tolerance design variables				Total payment	Mass loss
	T_1/mm	T_2/mm	T_3/mm	T_0/mm		
Evolutionary game method	0.05	0.05	0.05	0.15	53.781	26
Non cooperative game method	0.15	0.15	0.10	0.20	109.872	64
Linear weighting method	0.10	0.10	0.05	0.15	74.539	38

4.2. Product Structure Optimisation

With the intensification of product diversification, the machining workshop from the beginning of the large-scale, high-volume production mode gradually evolved into a small batch, multi-variety production mode, in order to be able to adapt to the flexible and variable order plan, which also means that the frequency of switching production lines in the machine shop increased, and the frequent change of production brought about by the disadvantage is the decline in production efficiency, equipment idle rate increased, when the workshop equipment and personnel quality When the quality of workshop equipment and personnel can not keep up with the changing product varieties, it is necessary to optimize the classification of existing products, part of the low value-added and high occupancy rate of equipment, seriously affecting the efficiency of the workshop products, can be outsourced accordingly. After statistical analysis, it is found that the frequency and time of product line change in the machining workshop is shown in the following statistics in Table 2.

Table 2. Workshop changeover frequency schedule

Summary	October	November	December
Number of production changes	86	72	67
Production change time	4937Min	4016Min	3389Min

From Table 2, we can see that the average production change time of one product is 50-60 minutes, not counting the special circumstances, affected by the season, the number of product change is reduced, but the average is about 2 times, which means that frequent production change will waste a lot of time, significantly reduce the effective operation time of workers and equipment utilization, in the process of frequent product change is also prone to product quality instability. This means that frequent production changes waste a lot of time, significantly reducing the effective working time of workers and the utilisation of equipment. Although the composition of products varies at different stages of development, if you want your business to last forever, you must take into account the changes in production costs, adjust the product mix, optimise and abandon orders that do not generate profits for the company and affect other core products, help the company to allocate resources more rationally, and make the integration of personnel, equipment and other elements of the production plant more efficient, so as to maximise the profitability and efficiency of the production plant. Maximise the profitability and efficiency of the production plant.

5. Conclusion

A 3D-based machining process system is a complex and large project. In order to realistically reproduce the real machining scene of the machine tool, the model of each component of the machine tool and the cutting model of the workpiece during machining are required to be more detailed, and the interaction with the machine tool system through the mouse is more perfect and close to the reality; in order to facilitate the communication of the machining process of a specific workpiece and the discussion of the design of the workpiece fixture, the design of the virtual clamping module needs to be more in-depth and perfect. The application of augmented reality technology to the machining process support field, using augmented reality machining process information instead of traditional process flow cards, promotes the diversification of machining process information transfer methods... There are still many shortcomings in this paper that need to be improved.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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