Application of modern simulation technology to a theory of mechanics course intended for outstanding engineers

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ABSTRACT: Students' innovative ability is directly decided by the teaching quality of the fundamentals of mechanics course. The relationship between outstanding engineer training and modern simulation technology is presented in this article. Given the importance of the link between teaching and the theory of mechanics course, the function of modern simulation technology in developing students' innovative abilities is also outlined in this article. Simulation technology has the advantages of minimising the teaching cost and overcoming hardware constraints. Model predictions promote a student's innovative and manipulative ability in a cost-effective way within a university.

INTRODUCTION

Engineering education cultivates a large number of applied engineering and technical personnel of excellent ability and who are innovative, with strong practical abilities in engineering design, engineering applications and scientific research. They also have the ability to analyse and solve problems. It is impossible to achieve all these capabilities by teaching theory alone; but it can be achieved also through practical teaching. Computer simulation modules can be used to analyse and solve problems, including geometric modelling, model analysis, optimisation of control parameters, models and methods of optimisation, as well as simulation analysis. To these five basic modules, a structure analysis and motion control module can be added for specific problems [1].

Virtual prototyping technology based on computer simulations has become a relatively independent industrial technology, and will continue to have a profound impact on manufacturing industry. Simulation science and technology uses computers and special experimental equipment to produce an experimental model of a physical system using a combination of numerical calculation and theory. This may be used to research the design of the existing system or one that does not yet exist [2]. Simulations have many advantages, e.g. easier visualisation of processes and results, low cost and easy to change system parameters. With the rapid development of computer technology, simulation science and technology has been applied widely to various engineering projects, and has achieved good results and economic benefits. In addition, multimedia technology, virtual reality, artificial intelligence, object oriented methods and interfaces, have all made great progress and have had a wide and profound influence on the development of system modelling and simulation technology.

The *Outstanding engineer education programme* is a major reform project of the Chinese Ministry of Education to implement the *National long-term education reform and development plan (2010-2020)* and the *National long-term talent development planning outline (2010–2020)*. The aim was to take ten years to cultivate millions of high quality engineering technology personnel in China of various types and disciplines. This would produce the human resources to build a modern, industrialised and innovation-oriented country [3]. In general, outstanding engineers are the excellent technical personnel engaged in engineering work. Quality and technical characteristics of excellent engineers are as following:

- Rational, broad knowledge and solid professional skills; can participate in the design and development of a project, put forward technical professional opinions, propose and solve problems.
- Strong innovative ability; pay close attention to developments in industry and be on the frontiers of science and technology, be forward-looking and have an advanced specialty, be strongly competitive and have good, creative ability.
- Abundant knowledge of society, economic management and humanistic knowledge.

- Good teamwork, interpersonal and communication skills.
- Good ideological and moral quality, social morality, occupational morality, a firm and correct outlook on life and values, the spirit of seeking truth from facts [4].

The project quality refers to the basic quality of the engineering and technical personnel in the whole process of decision-making and engineering implementation [5]. The connotation of engineering quality is very broad. Technical personnel with excellent engineering quality not only have the technical knowledge and rich experience in the field, but also have many other abilities, including that of markets, management, quality, safety, economy and the law. The cultivation of excellent engineers requires an engineering education environment, which is close to the market and enterprise, so that the students can learn about all aspects of engineering through project teaching.

The aim is to cultivate high quality engineering and technical personnel with innovative ability able to adapt to the needs of economic and social development. The emphasis is on ability and all-round cultivation of talent in higher engineering education in China. This points to the need to reform engineering education, involving joint mechanisms between universities and industry; thereby, enhancing students' practical and innovative abilities and China's international competitiveness [6].

APPLICATION OF SIMULATION TECHNOLOGY TO THE THEORY OF MECHANICS

The theory of mechanics course covers aspects of machines, such as the theory behind the mechanism, i.e. kinematics, mechanical dynamics, dynamic performance of common machines and the design methods for all kinds of machine. The course objectives were to improve students' design, innovative and practical engineering abilities and to promote autonomous learning. By taking this course, students already have the basic knowledge of agency selection and dimensional design according to technical requirements. They also will have a preliminary ability of mechanical system design, which lays a solid foundation for subsequent specialised courses in engineering machinery and engineering machinery design.

The teaching of mechanical principles used the *five horizontal, five longitudinal* matrix model. This solved the problem of the integration of training and the isolation of the teaching. The teaching goals are refined into five basic abilities: knowledge, engineering practice, analysis and calculation, software application and innovation ability (five horizontal columns in Figure 1). The teaching is divided into five key links or areas: classroom teaching, experiment teaching, course design, homework and innovation design competition (five longitudinal rows in Figure 1). The new model facilitates an exploration of the connection between teaching and training, and helps to identify primary and secondary links. The implementation of the teaching is based on this matrix teaching mode.

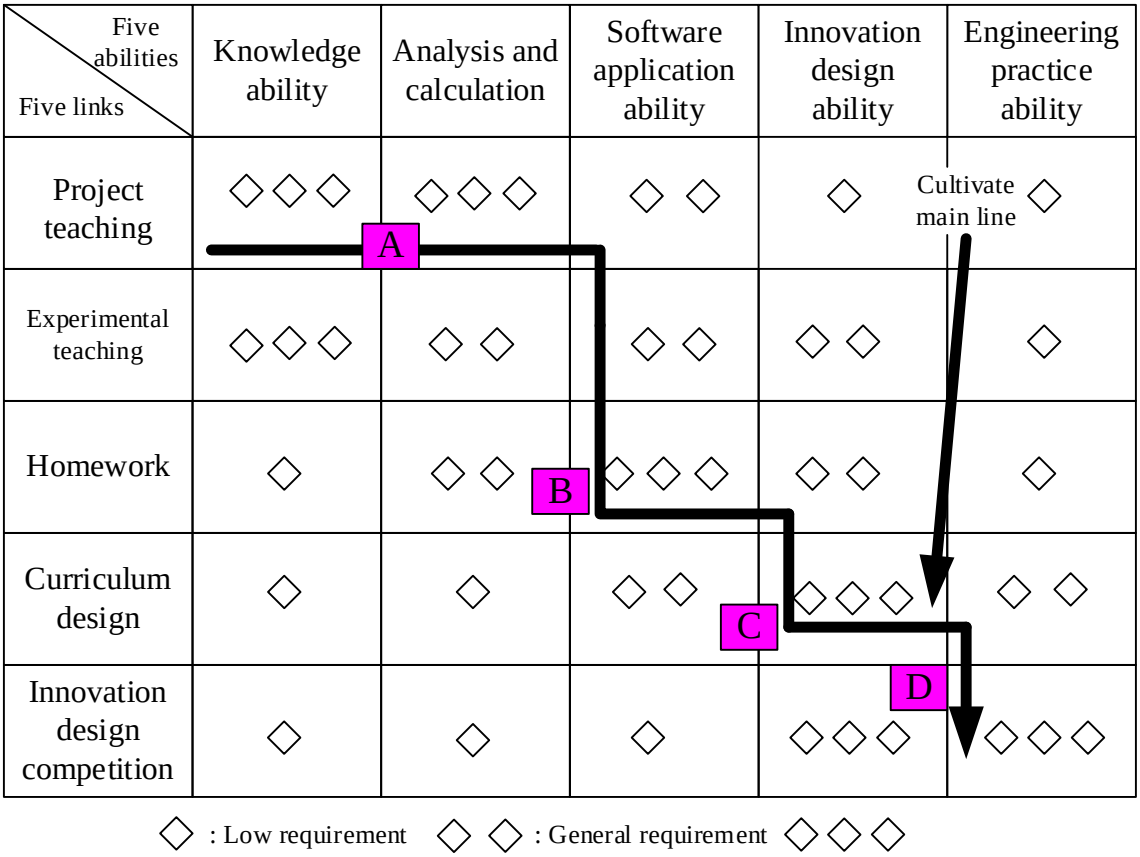

Figure 1: Matrix type teaching mode of the mechanical principles.

In the new matrix teaching mode applied to mechanical principles, each teaching link is summarised as follows: the foundation is classroom teaching and the key is experimental teaching; homework is the bridge to curriculum design, leading to the innovation competition. Through the establishment of the five horizontal five longitudinal matrix teaching mode, the abilities gained are closely linked to the teaching. Training is stressed and the teaching organisation follows the main line as shown in Figure 1, i.e. A) Basic knowledge and skills training is emphasised; B) The application of theory is based on the design of a process of an existing institution; C) Innovation is encouraged with the new curriculum design; and D) Innovative ability is improved by the Innovation Design Competition. The main line is composed of a series of training processes, such as the basics of applications; theory to practice; and a single ability to comprehensive abilities. The classroom teaching has been thoroughly changed.

Using computer simulation technology, such as a combination of VC (variant configuration) and OpenGL (open graphics library) students can easily see the motion of a mechanism in 3D to verify that a design meets requirements. So, it is important to use computer simulation technology to teach mechanical principles.

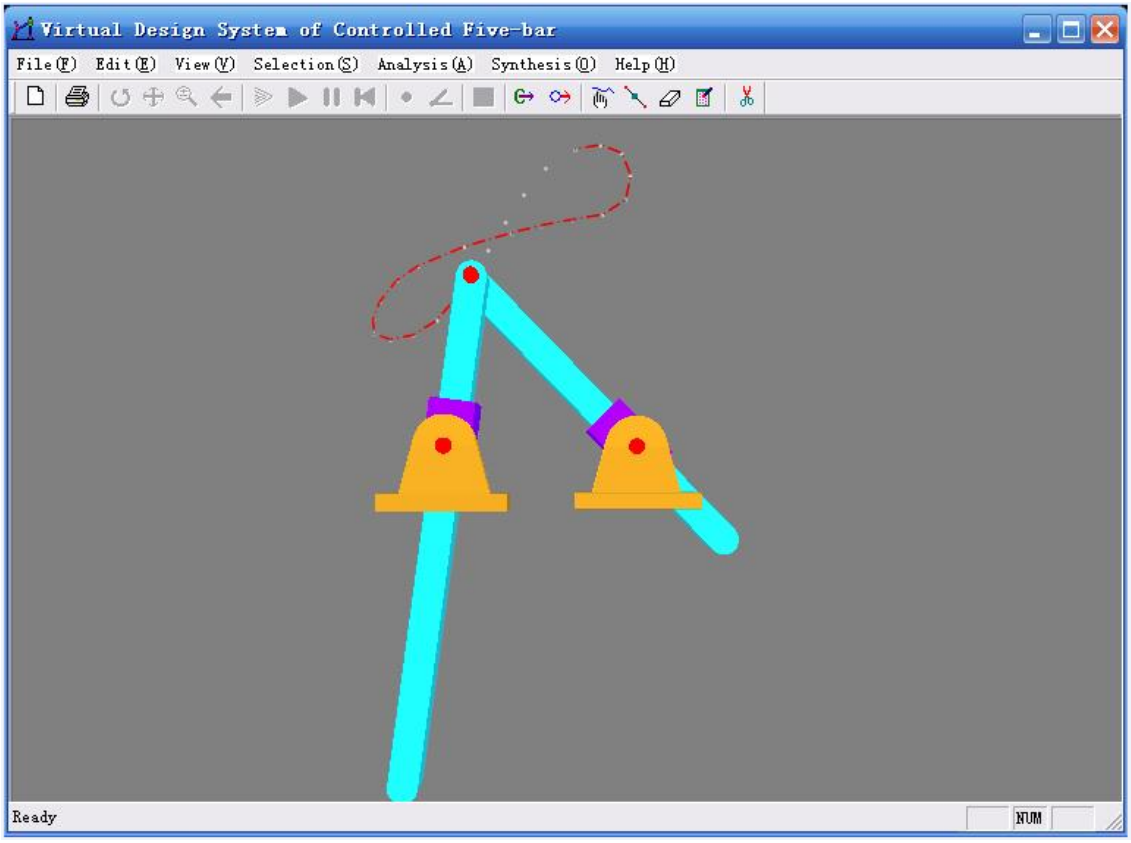

Figure 2: Mechanism of a virtual machine system.

In addition, developments in science and technology outside the course play a very important part in the teaching. Many mechanical engineering students concentrate on the development of robots that perform certain specific actions. In the pre-design, it is necessary to determine if the actions have the correct displacement, velocity and acceleration to meet the design requirements before actual manufacturing begins. Computer simulation technology is a good method by which to meet these requirements. Through simulation technology, it is easy to modify the organisation of a machine, its size, observe its operation and determine its output parameters. This greatly shortens the development cycle and costs. Computer simulation technology can be used to solve some difficult theoretical problems. This can stimulate the students' sense of achievement and also improve creative thinking and practical ability. It also might overcome the situation where there is a shortage of school hardware facilities. So, simulation technology has a positive effect in many ways. Therefore, it is worth considering the inclusion of computer simulation technology in the teachers' education course.

The simplest multi-degree mechanism is the controlled five-bar mechanism. The controlled five-bar mechanism has two parts, with one part moving constantly and the other controlled by a computer to give a compensating motion. The required track is generated by one or more links on the mechanism [1]. To simulate the five-bar structure and kinematics requires developing software with motion analysis and path synthesis. A controlled five-bar design platform (CFDP) is designed to simulate the structure, and dynamics, and to produce path synthesis for all 13 five-bar basic types. Therefore, the platform can parameterise the structure with dynamic selection of the point generating a path. This also provides path motion analysis, control of the driving links and path synthesis based on a generic algorithm (GA). In designing the software, professionalism and versatility should be considered. Functions should be well arranged, but without too many details, to avoid increasing the complexity of operation. Figure 3 is the function tree of the platform.

As can be seen, there are two modules, viz. motion analysis and path synthesis. Functions included in the motion analysis module are intuitive and have more interactive operations. The path synthesis module uses more professional knowledge and has fewer detail functions. So, this module mainly contains the intelligence of the platform. Cai et al, and Zhao and Wang provide a detailed explanation of the functions of the two modules [7][8].

The goal of motion analysis is to complete the simulation of the given five-bar basic type and produce the results. The user should form a particular five-bar basic type using a pair of similar parallel groups. Then, initialise each parameter by hand or by input from the dimension file. Since a five-bar mechanism has two degrees of freedom, the driving parts, including the initiating and compensating parts, must be controlled correctly. In order to ensure the inputs for the two parts are co-ordinated, the position data and index must be correct. In order to complete the motion analysis an added bar is required (of course the point can be directly on the mechanism body). The simulation results, including the curve and data, are produced at the end. To display the state of the mechanism in a more vivid way, CFDP has a virtual 3D environment with OpenGL for motion analysis. There are several operations on the view available, including scaling, rotating and translating. Figure 4 is the interface of motion analysis of RRRRP (that means that there are four rotating pairs and one prismatic pair in controlled five-bar mechanism) [9-11].

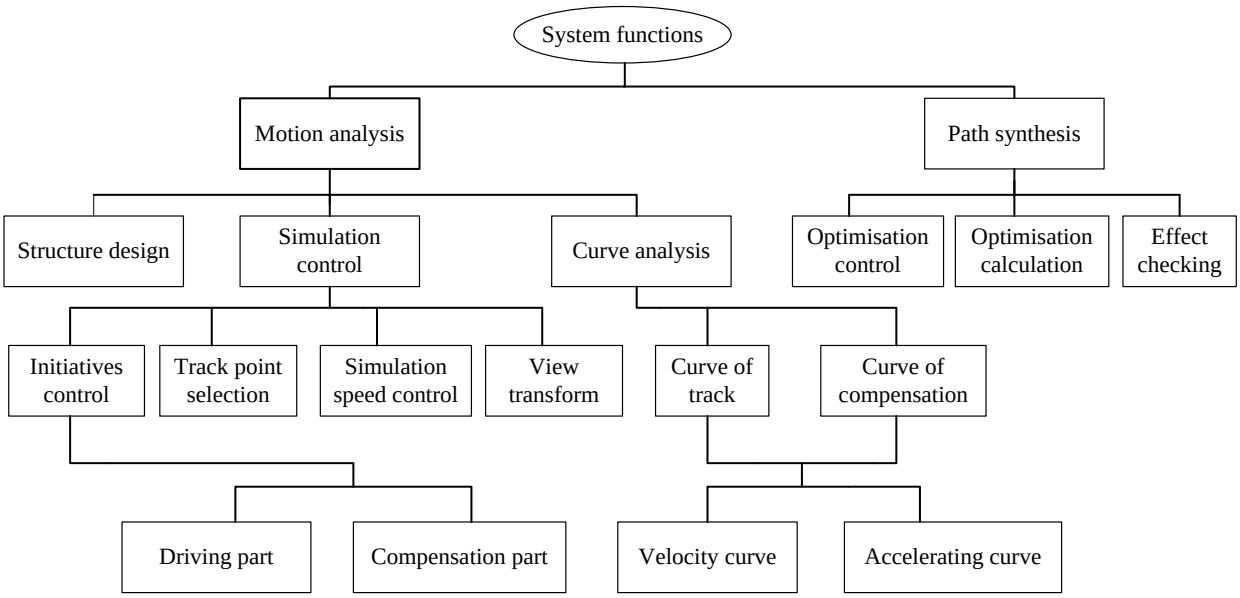

Figure 3: Function tree for CFDP.

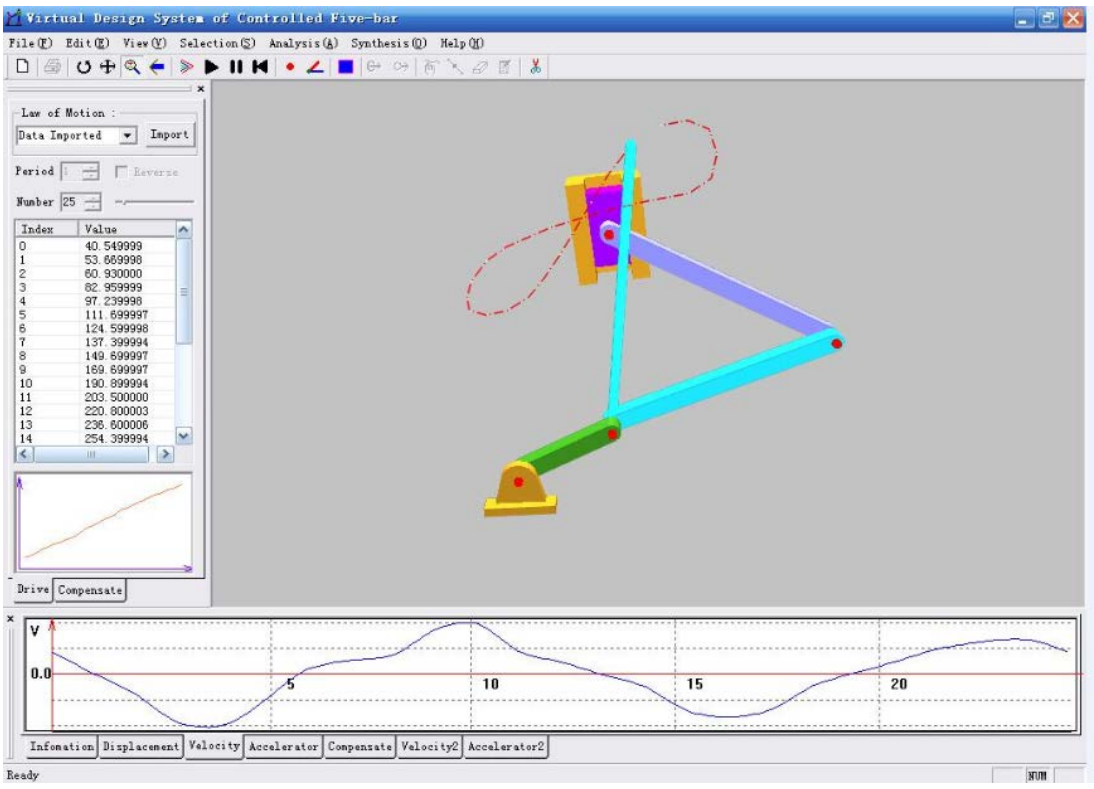

Figure 4: Motion analysis interface of RRRRP.

In order to integrate the two function modules, the results of path synthesis will return to the view of motion analysis for modelling and simulation, and check the effects by comparing the generated path and the ideal path.

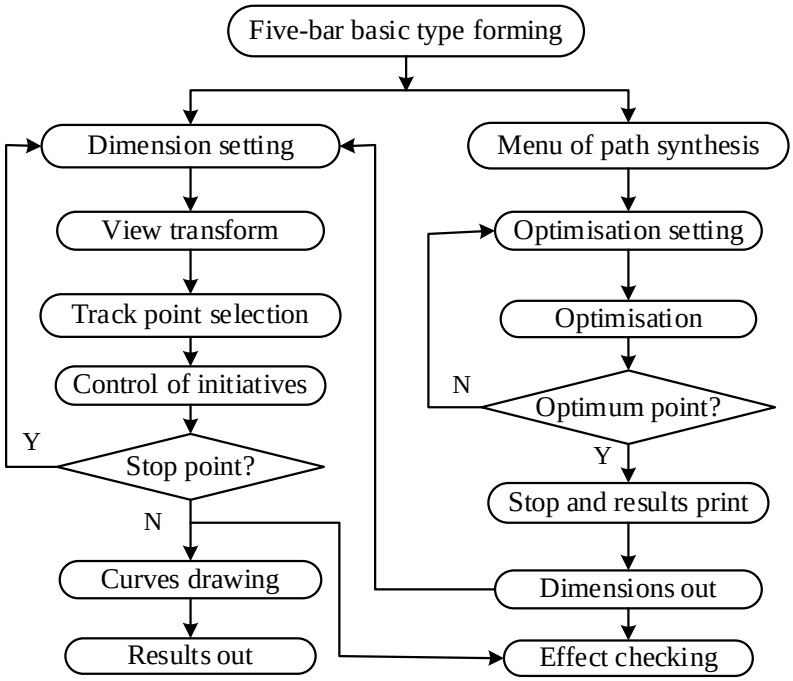

Figure 5: Operating sequence of two main functions.

Analytic methods provide the basis of computer technology. Two-dimensional simulation with 3D motion through virtual design and kinematic analysis can stimulate the students' learning and their use of modern technology. With regard to scientific computing and software programming ability, the proportion of software analysis by students increased by 50%, from the initial 10% to about 60%. The CAM motion simulation software, gear generating dynamic simulation software, and the typical mechanism motion analysis software are copyright and widely used in the classroom.

EFFECTS ON TEACHING

Application of the digital approach to the design of mechanisms, promotes the training of individuals and groups in innovative design. It inspires the enthusiasm of students, and improves students' creative thinking. Training strengthens the contact with knowledge and improves the student's ability to apply what they have learnt. Upon completion of their training, students will have mastered the basic theory and calculation methods of the course, which deepens their understanding. They also will understand how these theories are applied in engineering practice and will develop an ability to solve practical engineering problems independently.

The innovative techniques applied by the students in mechanical innovative design competitions, has had remarkable results in the past five years. There have been more than 60 award-winning students in various provincial innovative games. Significant results have been achieved in improving the students' innovative abilities. Students participating in various scientific and technological competitions have obtained the national first prize in the competition for Mechanical Innovation Design; third prize in the National Challenge Cup; first prize in the Mechanical Products Digital Design Competition, and 22 national awards.

Students have applied for eight patents in the field of mechanics and have published more than 20 papers. Students have developed simulation software for the motion of a CAM mechanism, and dynamic simulation software for gears. They have acquired three software copyright registrations; namely, *based on the motion mechanism of rod group analysis and simulation system (2008SR19352), the controlled five-bar mechanism of virtual design system (2008SR19354)* and *mechanism motion simulation software based on OpenGL (2011SR006789)*. The employment rate has reached 99% and their average salary is more than general undergraduates receive.

CONCLUSION

The authors of this article have studied the effectiveness of teaching using modern simulation technology and taking the theory of mechanics, mechanical design and mechanical signal analysis as examples. The simulation technology not only can be used to teach students about the content of the three courses, but also can strengthen students' understanding and ability. Through combining simulation software on the three courses with multimedia courseware, no

real hardware resources are required. For example, as a practical achievement, software about the five-bar mechanism can help students quickly understand the theory of mechanics and also how to use the simulations to analyse a problem. Presentation directly in the classroom allows students to see the results of the real-time simulation and to increase their awareness. Results from the teaching of practical sessions show that the teaching methods reported in this article can reduce learning difficulties of these courses and better stimulate students' interest in learning, while developing their ability to solve problems at the same time.

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