PROJECT OF A MANIPULATION SYSTEM FOR MANUAL MOVEMENT OF CNC MACHINE TOOL BODY UNITS

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Summary

Modern CNC machine tools can be adjusted manually. For this purpose we use appropriate functions and CNC panel buttons or a more convenient equivalent in the form of a remote control is used which, owing to a flexible conductor, enables the operator to get closer to the machining zone. Remote controls, although functional, usually allow for the control of only one machine tool axis at a time. The paper presents a new approach to manual control of body units of a CNC machine tool, based on manual travel of the machine on a certain trajectory of movement or to a specific position. An innovative system of manual movement of machine tool body elements (Polish: Manualny Przesuw Elementów Korpusowych Obrabiarki, MPEKO) was used for this purpose. The paper describes two concepts of this system. The first one involves the use of this system on an actual machine tool, whereas the second one is based on the transfer of this idea onto a virtual equivalent of the actual machine tool.

Keywords: manual movement, operator interface, CNC machine tool

Projekt układu manipulacyjnego do ręcznego przemieszczania zespołów korpusowych obrabiarki CNC

Streszczenie

Współczesne obrabiarki CNC są przestawiane manualnie za pomocą przycisków pulpitu CNC lub jego odpowiednika w postaci pilota sterującego. Pilot wyposażony w elastyczny przewód umożliwia zbliżenie się do strefy obróbki. Pilot pozwala w danym momencie sterować zwykle tylko jedną osią obrabiarki. W pracy przedstawiono nowe podejście do ręcznego sterowania zespołów korpusowych obrabiarki CNC. Polega na ręcznym przemieszczaniu maszyny po ustalonej trajektorii ruchu lub do określonego położenia. Opracowano innowacyjny układ do Manualnego Przesuwu Elementów Korpusowych Obrabiarki (MPEKO). Przedstawiono w pracy dwie koncepcje tego układu. Pierwsza polega na zastosowaniu układu dla rzeczywistej obrabiarki, druga natomiast na przeniesieniu tej idei na wirtualny odpowiednik rzeczywistej obrabiarki.

Słowa kluczowe: manualne przemieszczanie, interfejs operatora, obrabiarka CNC

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1. Introduction

1.1. Current state of knowledge

Modern machine tools are equipped with increasingly more refined CNC control systems on the part of the operator interface. These systems have an extensive side of graphic presentations and simulation of the programmed machining process, the option of working in a computer network, as well as efficient management of developed machining programs which is functionally consistent with the management of files on a standard personal computer. Despite the clear development of CNC interfaces, still a very important role is played by programming with the use of the so-called G-codes [1, 2], i.e. some kind of programming language of CNC systems which with its syntax resembles languages of structural programming of high level, such as Basic or LOGO. There are also more advanced programming methods of CNC systems developed by their particular producers, for example the CNC systems of Haidenhain [3], which offer some level of graphic support of the programming process, the possibility of using the so-called machining cycles or the application of instructions programming directly the trajectory compatible with certain geometric figures, such as circles or arcs. A good example is an interactive system of programming the machining process – the ShopTurn developed by Siemens (for the SINUMERIK system).

Requirements of users concerning the operation of manufacturing machines force the designers to seek new, more intuitive methods of their use. The result of their work are software wizards which lead the operator of the machine step by step through the process of setting the machining parameters. However, the issue of intuitive movement of machine tool body units is still open.

1.2. Inspirations

CNC machine tool operators are usually employees with education at the level of technician. Introducing too complex structures and structures of high level of abstraction occurring in modern object-oriented programming languages to CNC languages may cause problems with understanding the principles of programming for an average machine operator. At the same time, the development trends of CNC machine tools programming systems are moving in the direction of simplifying the language and machine tool programming. In order for the machine to be programmed manually, i.e. using the method of learning an memorising movements, it must have the option of convenient and efficient movement of its units.

Modern CNC machine tools may be adjusted manually. Buttons on the control panel or a special remote with a cable are the typical solutions applied in the current human-machine interfaces. Operation from the CNC panel is often inconvenient due to the remoteness of the panel from the machining area, and therefore, a widely used solution is a remote control with corresponding buttons, similarly to the CNC panel, connected with a flexible cable with the machine tool. Such a remote control enables manual control of machine tool movements, while the operator is located near the machining area. Remotes of this type usually enable the control of only one axis of the machine tool at a time (Fig. 1).

Fig. 1. View of a typical remote for manual control of a CNC machine tool

Using buttons for the movement of body elements is not intuitive, since it causes problems such as confusing the buttons, i.e. using buttons of an axis different than the one which was intended to be moved or confusing the turn to which the movement was to be made. Since the use of this type of solutions for the operation of one axis only may cause the aforementioned problems, the simultaneous use of both axes by means of this solution is not intuitive and may lead to dangerous situations. A deliberate procedure of constructors is therefore limiting the possibility of using the buttons for one axis only. Another limitation of this class of solutions is that they work in the ON/OFF system, which means that they do not enable the change of movement speed of the machine tool, depending on the force applied by the operator. Knobs or additional buttons are used for changing the speed, which makes the operation of the device more complicated.

For the aforementioned reasons, works have been initiated on an intuitive system for Manual Movement of Machine Tool Body Elements (Polish: Manualny Przesuw Elementów Korpusowych Obrabiarki – MPEKO). The task of the system is to increase the interactivity and intuitiveness of CNC machine tools' operation, in accordance to which the movement e.g. of the machine tool table should not deviate from the usual method of moving an ordinary table, i.e. by moving it with the muscle strength.

2. System for manual movement of CNC machine tool body elements

2.1. Idea of operation of the MPEKO system

The idea of the manipulation system for the manual movement of body units of a CNC tool is based on enabling the gripping of a body element and its movement by hand, on the trajectory set by the hand. This movement should be possible to perform within all the available axes of the machine tool simultaneously. The speed of movement of body elements should be dependent on the movement speed of the operator's hand. Gripping the body element ensues at the secure place determined on the end elements of kinematic chains of a CNC machine tool or by a handle.

A VC 760 milling machine with the open control system (O.C.E.A.N.) [4, 5] developed at the Centre for Mechatronics was used for research on the MPEKO system. This machine tool has two kinematic chains of body element movement: object branch and tool branch.

2.2. Idea of manual control on a real machine tool

The MPEKO system (Fig. 2) installed on the machine tool is designed to allow the person staying directly near the machine to move individual body elements of the machine tool.

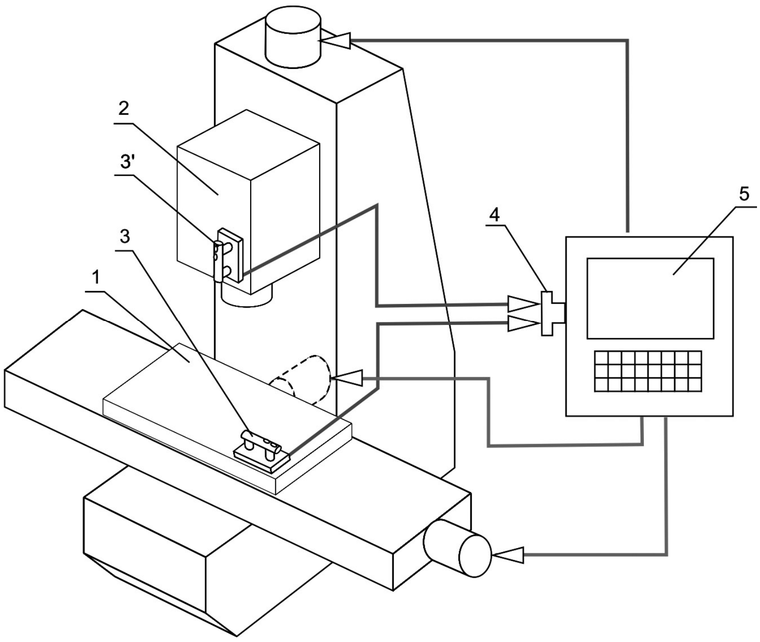

Fig. 2. The idea of manual movement of machine tool body elements: 1 – table, 2 – head, 3 – lever to control the cross-table unit, 3’ – lever for controlling the head, 4 – signal interface, 5 – open control system

The placement of a lever at the end elements of kinematic chains was proposed in order to upgrade the machine with the manipulation functions. This lever is a sensory system built on the basis of a piezoelectric sensor for the measurement of forces (Fig. 3). Levers are coupled via the signal interface with the O.C.E.A.N. open control system. In this way the CNC tool control system receives information that we want to move a given kinematic chain and information about the position and/or speed value. The control system generates the setpoint position and speed for drives which support the operator. Acting on the lever rod with small force enables the movement of the guide unit in one or more axes of travel. Fig. 2 presents a schematic diagram of the MPEKO system, whereas Fig. 3 presents the prototype solution of a control lever.

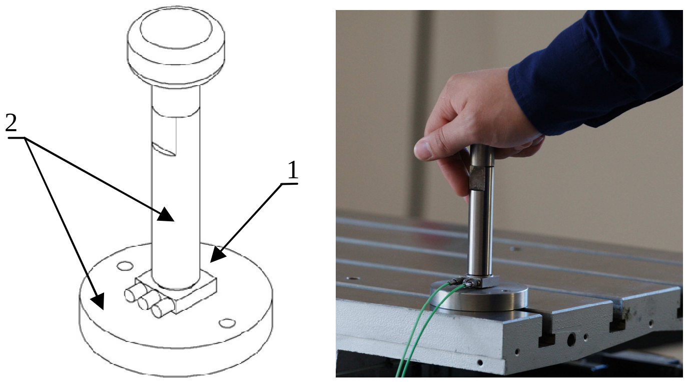

Fig. 3. Lever with a piezoelectric sensor: 1 – piezoelectric sensor, 2 – body of the lever

The presented solution, owing to the application of levers, naturally eliminates the problems of the machine tool operator with the application of correct orientation and direction of movement described in the introduction. Since the speed of machine movement is dependent on the force applied by the operator, moving the body elements is intuitive. In order to improve the accuracy of positioning, the system is equipped with the option of sensitivity change. Since the movement of human upper limbs and the eye has a limited accuracy, the precision of achieving the desired position can be increased through the use of quantisation. The final position may be further adjusted from the keyboard of the CNC control system.

Fig. 4. presents a block diagram of the MPEKO system, extended with the option of programming, i.e. automatic processing of the operator's movements to a G-code. At the next stage the system enables the retrieval of the saved program. The MPEKO system implementation has been performed on the PXI platform developed by National Instruments by means of the LabVIEW graphical programming language. The signal from the piezoelectric sensor built into the lever is amplified by an amplifier, and then processed by the analog-digital module of the PXI platform. This signal is used for setting the movement speed of machine tool body units. Individual operations may be entered or corrected by means of a communication touchscreen.

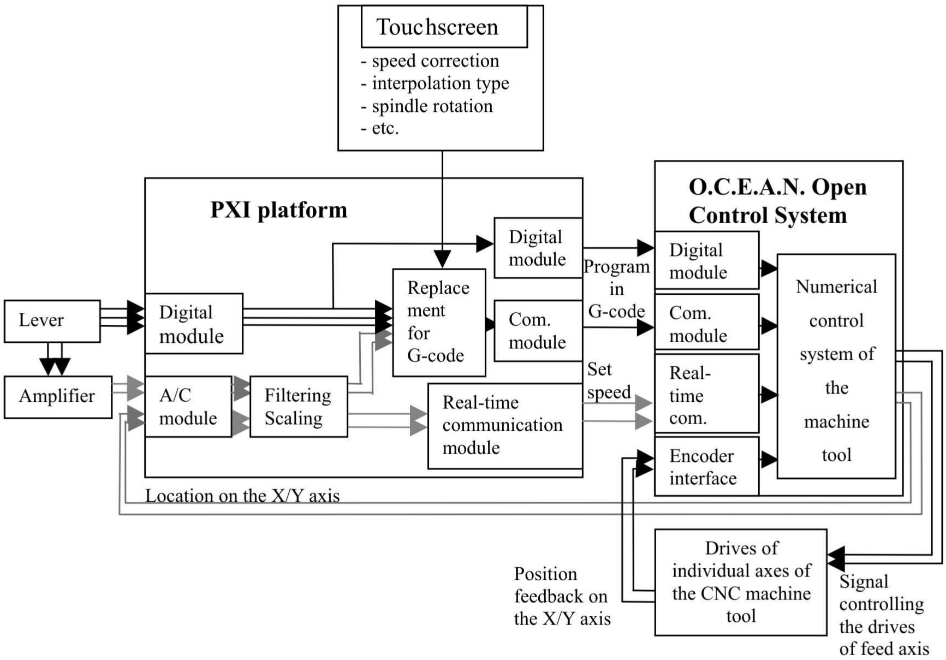

Fig. 4. Block diagram of the MPEKO system

2.3. The idea of manual control in virtual reality

Simultaneously with the MPEKO system for actual machine tools, a virtual environment is designed in order to enable the operator to perform analogous operations without the necessity to work in direct contact with the machine tool, and even without the necessity of presence nearby the machine tool.

In the designed Virtual Reality (VR) a machine tool model was implemented along with the so-called effector, i.e. a virtual hand of the operator. Kinematic links reproducing the basic feeding movements of a milling machine were imposed in the virtual model of the machine tool. The individual body elements have limitations which prevent them from moving outside the allowable range consistent with the range of movement of an actual milling machine. With the use of a virtual hand it is possible to grasp markers on the machine tool model, which correspond to the levers on the actual machine tool. The hand movement in the VR at the present stage of development is implemented by means of a 3DConnexion manipulator. Ultimately, the control in the VR will be carried out with the application of orientation sensors placed directly on the operator's hand, which will make the control more intuitive. Information about the hand orientation and the finger movement is taken from the manipulation glove.

The virtual machine tool model is equipped with special markers in the form of arrows which are used for the control of machine tool movements. Grasping the appropriate marker with the virtual hand enables the movement of individual machine tool body elements in the selected direction. The arrows represent the axes of movement of individual CNC machine tool elements.

Since in the case of a 2D screen we lose one dimension, it is not easy to determine the depth, even with the use of shadows and depth of field. We decided to solve this problem by means of the stereoscopic display technology. For this purpose, the operator uses a Head Mounted Display (HMD) in the 3D version. Additionally, equipping the display with an orientation sensor enhances the reality of simulation, since the orientation of the virtual camera in the VR is dependent on the orientation of the operator's head. It is also possible to change the camera position in relation to the observed object. Figure 5 presents the visualisation window with the virtual VC 760 machine tool model.

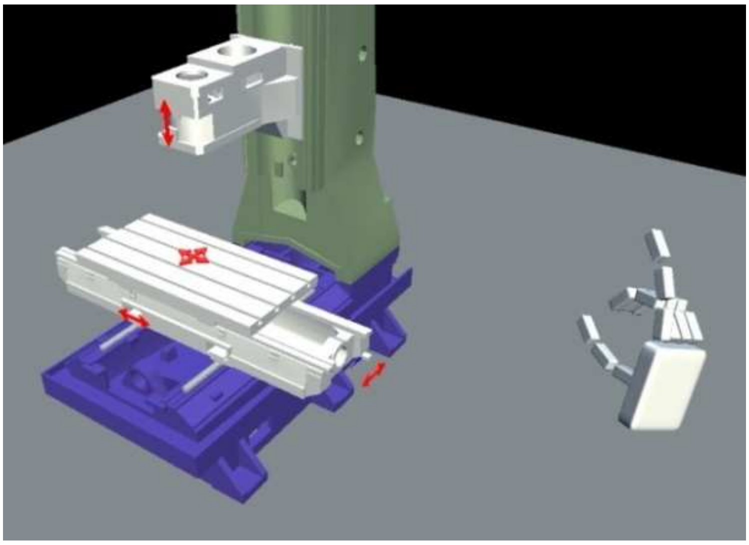

Fig. 5. Virtual Reality for controlling the machine tool manually

Virtual Reality is run on a PC. The .NET platform with the C# programming language was used for its construction. Microsoft Visual Studio 2008 programming environment was used for programming. The choice of this language was conditioned by its simplicity, safety, modernity, as well as object-oriented approach and high performance. The .NET platform is an environment that provides a new interface for application development (application programming interface – API) which facilitates the use of services and API classic operating systems from the Windows family. The XNA Game Studio package was used for visualising the machine tool model in the developed software. This package extends the IDE (Integrated Development Environment) with the Visual Studio options. The package includes XNA Framework i.e. a set of libraries used for writing DirectX applications dedicated to the .NET 2.0. platform.

Schematic diagram of the VR system for manipulation of a machine tool has been presented in Fig. 6. The developed VR simulation system facilitates the transmission of coordinates describing the position of particular body elements of the machine tool to the O.C.E.A.N. open control system of an actual machine tool. This transmission takes place via an OPC server. The application of the OPC server enables the data transmission via the Internet. The O.C.E.A.N. control system can move individual machine tool axes in accordance with the data coming from the VR environment. In order to prevent losses of synchronisation of movements of the virtual and actual machine tool, feedback on the current location of the actual machine tool and used to animate the virtual model.

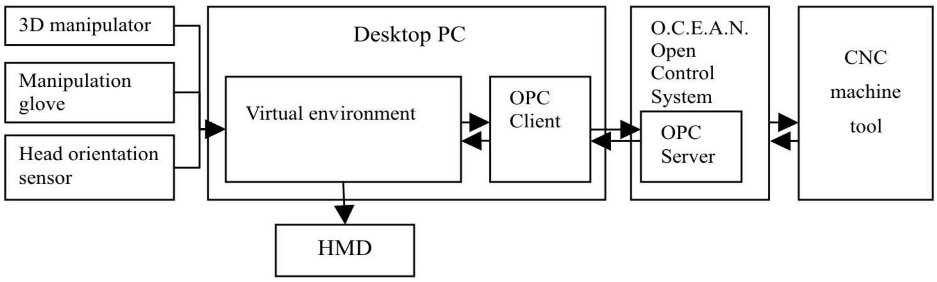

Fig. 6. Schematic diagram of the VR system for machine tool manipulation

Work in the VR environment may be conducted online and offline. Online work is necessary when the system is used for moving body elements of the machine tool in real time. The offline mode is provided for programming the machine tool. Owing to this approach, there is no need to engage the machine tool and it may perform other technological tasks at this time.

3. Summary

The presented MPEKO system enables manual movement of CNC machine tool body units. In comparison with the classic solutions it is intuitive in the sense of setting directions and turns of movement of body units by the operator. In this way, frequently occurring errors of operators are eliminated.

These systems can be extended by the possibility of programming. It applies mainly to simple machining operations. Such an approach to programming requires no additional knowledge of the operator, and to program the machine it is not necessary to type the machining code manually.

The MPEKO system has two complementary varieties. The first one applies to the actual machine tool, whereas the other one is its implementation in the virtual environment. The MPEKO system adapted to work in the VR has several advantages in comparison to the MPEKO system on an actual machine tool: it enables removing the operator from the machining zone, it makes it possible to use machine tools with larger sizes and does not take the machine time during virtual manual programming.

In addition, the MPEKO system increases the functionality of the machine tool within the scope of conducting measurements of the machined workpiece with the use of measurement heads mounted on the spindle. The application of this solution facilitates and accelerates the measurement process due to the easier and more intuitive movement of the machine subassemblies.

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