12th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2008, Istanbul, Turkey, 26-30 August, 2008

THE CL DATA APPLICATION TO TRIVARIANT MACHINE PATH PLANING

Viera Poppeová, Juraj Uríček, Ján Ďurica, Vladimír Bulej, Tibor Galbavý, Rudolf Rejda
Department of Machining and Automation
Faculty of Mechanical Engineering
University of Žilina
010 26 Žilina, Slovakia

ABSTRACT
This paper informs about design of TriVariant simulation software at Department of Machining and Automation at University of Žilina. Designed simulation software allows simulate a hybrid kinematic structure with 5DOF as a cutting machine and 6DOF as a robot, which works in manual and automatic mode. In automatic mode is tool trajectory of TriVariant controlled by CL DATA generated from CAM system. For a calculation length of legs and angle of rotation joints was designed a inversion kinematics of TriVariant machine, which allows real time computations and control.
Keywords: TriVariant, parallel kinematic structures, hybrid kinematic structures, simulation software

1. INVERSE KINEMATICS

The problem of inverse kinematics consists of solving the kinematic joint variables of a machine as function of a machine configuration and particularly depending on the position of a tool centre point and tool axis orientation. This problem is strongly related to the subject of path planning and joint trajectory since a machine movement requires the determination of join motion and finally actuator action.

2. PATH PLANNING IN CARTESIAN COORDINATES

Inverse kinematics computes the joint variables corresponding to locations of the machine extremity. In many applications those locations have got fundamental significance while the motion among them is not required with particular performances but smooth enough for the task. Those locations are usually named 'precision point', because they refer both to position and orientation. The corresponding set of joint variables can be named as precision points. They are named precision points since it is required that the motion law passes through them precisely or even the motion stops there [3]. Calculation and control of effector's trajectory is one of the cardinal functions of CNC control system. By this is providing a relative movement between tool and workpiece (in cutting machine) by trajectories, which are necessary to create a part with required shape and quality and with a maximum repeatability. For a machining are using a linear and circle interpolation and their composition we get a final tool paths.
Different between convention cutting machine with serial kinematic structure and cutting machine with parallel kinematic structure is in control of each axis. When we want move tool from one place to another by linear interpolation we can in a case of cutting machine with serial kinematics, divide a path to particular axis and control each axis so that all axis come to this programmed point in a same time. When we composite movement of each axis, then we get a linear trajectory of tool, whereas in cutting machine with a parallel or a hybrid kinematic structures we must calculate a active variable of each joint in all points of interpolated trajectory and we must change a controlled parameters of each actuators in all this points too. Another difference is in value of feed step which can have got constant value in the

case of machine with serial kinematic, whiles in the case of a machine with parallel or hybrid kinematic must feed step have got same or smaller value then is programmed value, because in some specific tool position must be moving slower or stop and wait for a rotation of some parts of machine.

3. IMPORTANT POINTS FOR CONTROL OF MACHINE

So that we can set a position of tool and a workpiece in a Cartesian coordinate system on a machine workspace are defined a few points. Then we are qualified to determine position and orientation of tool. In the control system are used these points:

- **Reference point** – this point is used for calibration between measurement systems with control system. Control system have got save the position of this reference point in a memory and when the tool is in this position the machine known a absolute position in a machine coordinate system,
- **Zero machines point** – this point is given by machine manufacturer. Zero machine point is in the centre of machine coordinate system;
- **Zero workpieces point** – this is an auxiliary point for machine operator and his position is determinate in respect to a simple description of part shape,
- **Tool centre point** – this point represent a programmed point.

Control system calculates final paths with using a coordinate transformation between these points. In all control system is use next parameter: **correction of tool length** – this parameter is use for tools with a different length with a same control program.

4. SIMULATION SOFTWARE

On the figure below we can see a screen view of simulation software for a TriVariant machine.

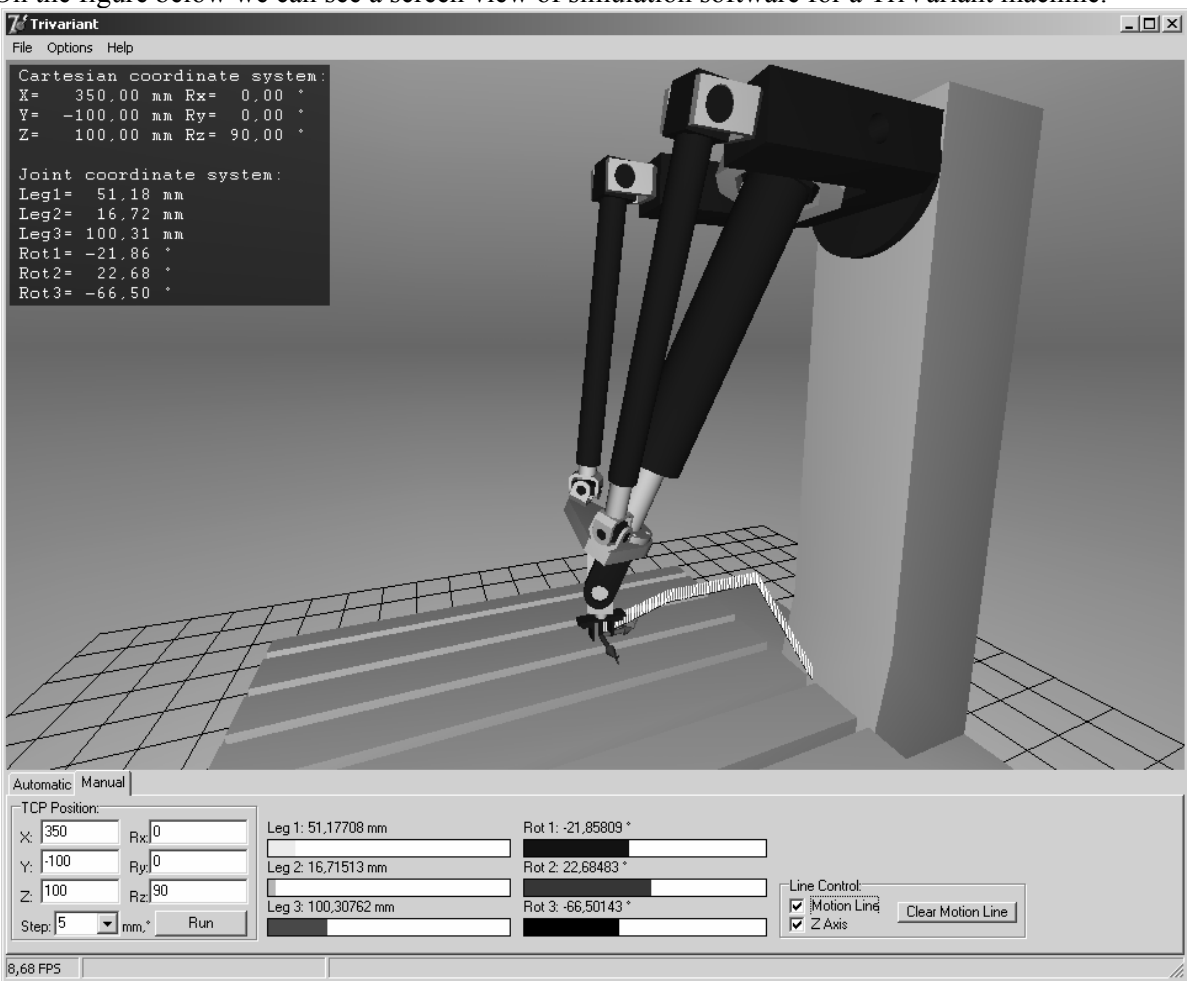

Figure 1 Simulation software of TriVariant machine with example of tool trajectory

Simulation software was created for computer analyses of machine with hybrid kinematic structure. Software allows simulation kinematic properties of TriVariant machine and off-line computer control

of tool movements. When the tool is moved from one point to another, software calculates all point of this trajectory and orientation of tool axis which are shown on figure 1. In each point are calculated important parameters by inversion kinematic of TriVariant machine and computed data are recorded into a graph (Figure 2). Position and orientation of TriVariant base in a simulation space can be changed in dependence on used frame of machine.

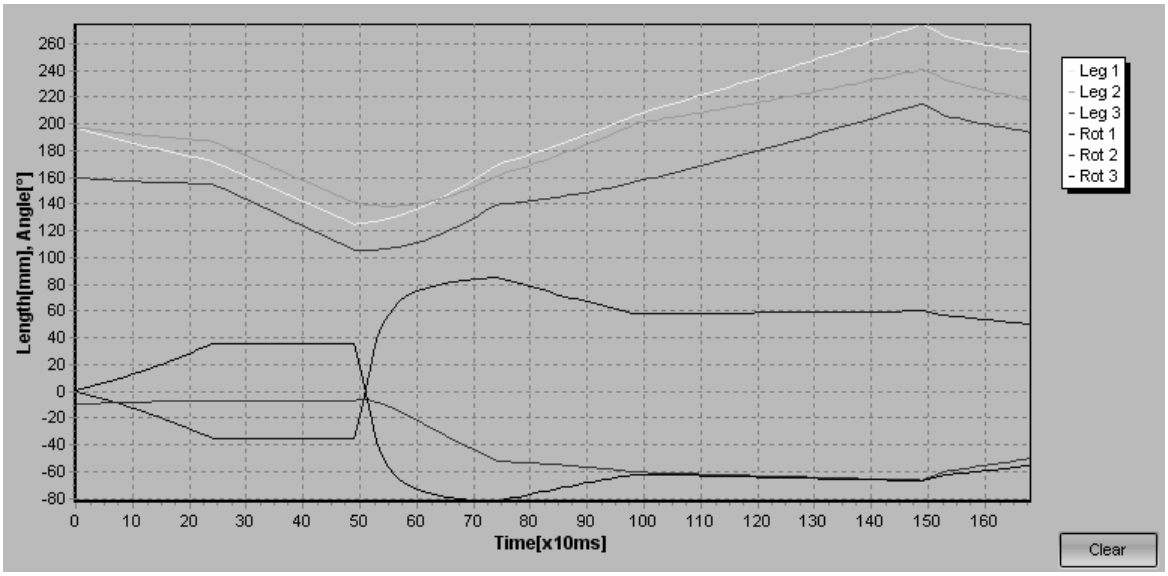

Figure 2. Graph of active legs values and rotation joints

5. CUTTER LOCATION DATA

Theories and algorithms which related shapes and geometries of CAD models to the path and motion controls of CNC machine tools constitute a subject area called: motion intelligence. This area of concerns consists mainly of three categories [7]:

- CAD models to tool path conversion,
- tool path to motion trajectory conversion ,
- motion trajectory realization (which deals with control theory and controller design of CNC machine tools).

The category of CAD models to path conversion deals with the issues such as the surface representation methods and the generation of corresponding tool path. In machining sculptured surfaces, the off-line part programming approaches are utilized, in which the CAM systems divide the design surface into a set of line segments that approximate the design surface with the desired tolerance. The end points of each segment and the geometric properties of the machined surface are then used to generate the cutter location data (CL DATA). These CL DATA are further processed by postprocessors to produce NC-codes for machining realization. The present CL DATA generation approaches consider only the geometry of the machined surface, and disregard the machine – dependent machining kinematics. As a result, the generated tool paths (the machining NC- codes transformed from these CL DATA) commonly cause obstacles to meeting the machining precision requirements, particularly for the cutter orientation generations in 5-axis CNC machining. Cutter orientation variations in 5-axis CNC machining are kinematically related to the machining rotation movements, which in turn are functions of the machining motion trajectory as well as machining errors. Therefore, the problem with preset off-line tool path generation approaches is that the real machining kinematics is not directly interpolated. To ensure machining precision, cutter orientation generations must be based not only on the geometry of the machined surface but also on the machine depended machining kinematics [7].

Cutter-location data (CL DATA) is a description of the tool positions, tool axis orientations and the desired sequence of operations. Whereas CL DATA provide all information which is important for a tool path control, therefore we use it for TriVariant machine trajectory control in off-line automatic mode. On a figure 3 is shown a tool trajectory generated by ProEngineer for a 5-axis machining (finishing operation) the top of sphere and there you can see a short listing of a generated file.

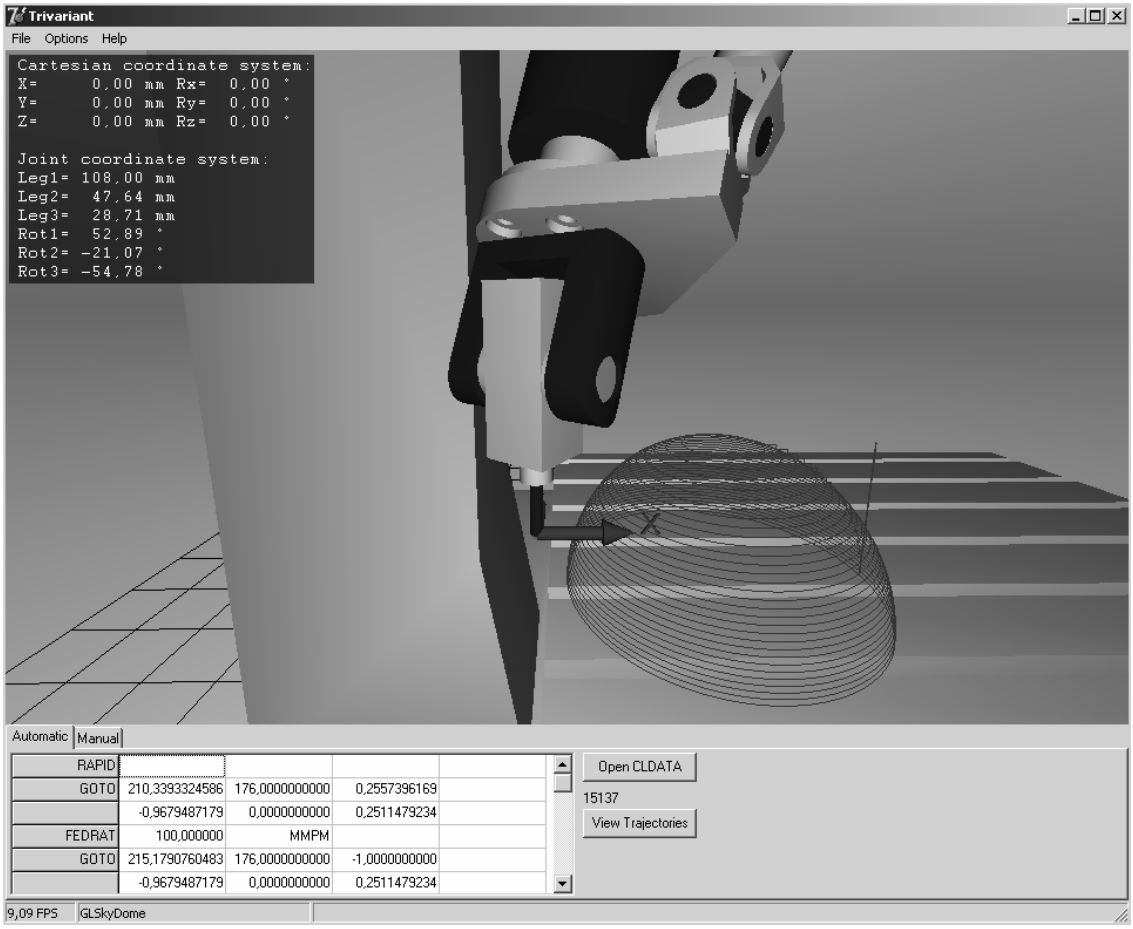

Figure 3. Tool paths of 5 axis machining of half of sphere (finishing operation)

6. CONCLUSION

Simulation software created for computer analyses of machine with hybrid kinematic structure allows simulation kinematic properties of TriVariant machine and off-line computer control of tool movements. When the tool is moved from one point to another, software calculates all point of this trajectory and orientation of tool axis. In each point are calculated important parameters by inversion kinematic of TriVariant machine and computed data are used for control of TriVariant movement.

7. ACKNOWLEDGEMENT

This paper was made under support of Slovak Republic Grant Agency KEGA– project No: 3/4098/06.

8. REFERENCES

[1] Marek, J.: Konstrukce CNC obráběcích strojů, MM průmyslové spektrum, 2006
[2] Zelený, J.: Vysokorychlostní obrábění, MM Prúmyslové spektrum, Špeciální vydání, 2000
[3] Ceccarelli, M.: Fundametals of Mechanics of Robotic Manipulation, Kluwer academic publishers, Londýn, 2004
[4] Knoflíček, R., Plšek, L.: Paralelní kinematické struktury výrobných strojů a průmyslových robotů, Prednáška v rámci projektu Sokrates/Erazmus, VUT Brno, 2006
[5] Merlet, J, P.: Parallel Robots, Kluwer academic publishers, Londýn, 2000
[6] Chren, O.: A kinematical variation of the tricept, In: ERIN2007 medzinárodná konferencia mladých výskumníkov a doktorandov, príspevok v CD prílohe, sekcia Production engineering, 25. – 26. apríl 2007, Katedra výrobnej techniky Strojnícka fakulta STU, Bratislava, ISBN 978-80-227-2636-8
[7] www.collectionscanada.ca/obj/ s4/f2/dsk1/tape8/PQDD_0021/NQ43585.pdf
[8] http://www.parallemic.org/
[9] Mádl, J., Zelenka. A., Vrabec, M.: Technologičnost konstrukce. ČVUT Praha, ISBN 80-01-03288-4
[10] Pilc, J., Čilliková, M.: *Trendy vývoja výrobnej techniky.* Journal Strojárstvo 2/2004, Žilina