Main Research Activities

Introduction At the moment, my research activities focus on kinetostatic performance evaluation and stiffness parametric analysis of translational Parallel Kinematic Machines (PKM) for their performance evaluation, geometrical design or optimization. PKM are interesting for high speed machining since they have good dynamic performances. The aim of my Ph.D. is to provide designers and end-users with performance criteria and methods to help them design translational PKM and compare them with serial machines or other PKM.

A three-axis translational PKM prototype was built at IRCCyN during my Ph.D: the Orthoglide. You can read the online review "Orthoglide: a 3-Axis Parallel Machine Tool for High Speed Machining" on the Parallel Mechanisms Information Center website (www.parallemic.org) for more information about this machine.

Keywords: robotics, mechanical engineering, parallel kinematic machines, design, workspace analysis, stiffness.

Bibliography on PKM design

At the beginning of my Ph.D., I gathered general information on PKM design in a paper that I presented at a conference mainly intended for researchers and specialists from high speed machining and metal cutting field. The aim was to create a bridge between this community and the robotics community by providing information and knowledge relative to PKM design, specifically associated with the robotics community [1]. Later, I presented the whole geometric and structural design process of the Orthoglide. While the focus was still on PKM design, this paper targeted integrated mechanical design community [2].

[1] Majou, F., Wenger, P., and Chablat, D., "The Design of Parallel Kinematic Machine Tools using Kinetostatic Performance Criteria", Proceedings of the 3rd International Conference on High Speed Machining and Metal Cutting, Metz, France, June 2001.

[2] Majou, F., Wenger, P., Chablat, D., "Design of a Three-axis Machine Tool for High Speed Machining", Proceedings of the 4th International Conference on Integrated Design in Manufacturing and Mechanical Engineering, Clermont-Ferrand, France, May 2002.

Translational PKM design and performance evaluation using the *regular dextrous workspace* concept

For a PKM to be of real interest for machining applications, it should preserve good workspace properties, that is (i), regular workspace shape and (ii), acceptable kinetostatic performances throughout. Two big problems with PKM are indeed that their workspace shape is often geometrically complex and that their performances (e.g. maximum speeds, forces, accuracy and stiffness) may vary considerably for different points in the Cartesian workspace and for different directions at one given point. To cope with these problems, most works on PKM design are based on the conditionning index or the workspace volume maximization, or both, but these are antagonistic constraints. Part of my works aims at defining a performance criteria that is more restricting towards these two constraints: for 3-DOF PKM (or 6-DOF PKM considering their constant-orientation workspace), a *regular dextrous workspace* is defined. It is a regular-shaped (square, cube, cylinder) part of the Cartesian workspace in which a kinetostatic criteria (velocity transmission factors, dexterity) is bounded. Bounding the criteria inside the *regular dextrous workspace* provides the end-user with a safe, geometrically understandable workspace to place (cutting) paths in. In the case of translational PKM, the chosen criteria is: inside the *regular dextrous workspace*, the velocity transmission factors (that relate the actuated joints velocities to the velocity of the mobile platform) are bounded. From this concept, I worked with MATLAB and MAPLE on the design and performance evaluation of 2-DOF and 3-DOF translational PKM with prismatic actuated joints (in the case of revolute actuated joints -Delta robot-, the meaning of the factors is different but they are relevant even though). I am currently updating this work, which has only been published partially. An interval analysis based method (available in a library called ALIAS designed by J.P. Merlet) for the design and the comparison of 3-DOF PKM (Orthoglide and UraneSX) was also proposed. Unlike classical methods based on workspace discretization, interval analysis provides numerically guaranteed results.

[3] Majou, F., Wenger, P., and Chablat, D., "Design of Two-DOF Parallel Mechanisms for Machining Applications", Proceedings of the 8th International Symposium on Advances in Robot Kinematics, Caldes de Malavella, Spain, June 2002.

[4] Chablat, D., Majou, F., Wenger, P., "The Optimal Design of a Three Degree-of-Freedom Parallel Mechanism for Machining Applications", Proceedings of the 11th International Conference on Advanced Robotics, Coimbra, Portugal, July 2003.

[5] Chablat, D., Wenger, P., Majou, F., Merlet, J-P., ”An Interval Analysis Based Study applied to the Design and Comparison of 3-DOF Parallel Kinematic Machines”, accepted in the International Journal of Robotics Research.

Parametric stiffness analysis of the Orthoglide

Stiffness is a very important issue in PKM design. I implemented for the Orthoglide a method proposed by Prof. Gosselin based on a flexible-link lumped parameter model. This method replaces the links compliance with localized virtual compliant joints and rigid links. A stiffness modeling of the Orthoglide was conducted and a symbolic stiffness model was implemented in MAPLE. In this model, only literal parameters are used, which allows one to conduct a parametric stiffness analysis of the Orthoglide. One can analyze easily the influence of the Orthoglide geometrical parameters on the stiffness matrix diagonal and non-diagonal elements. Critical links of the Orthoglide legs are therefore displayed, and their design can be optimized. One can also analyze the geometrical parameters influence when external forces are applied on the Orthoglide tool. These forces can model the cutting forces during a manufacturing task. This last study results in compliant displacements of the tool that are not easy to forecast at all.

[6] Majou, F., Gosselin, C., Wenger, P., Chablat, D., ”Parametric stiffness Analysis of the Orthoglide Using a Flexible-Link Model”, Proceedings of the 35th International Symposium on Robotics, Paris, France, to be published in march 2004.