Creating a Virtual Reality Environment for Spherical Mechanism Design

Pierre M. Larochelle
Florida Institute of Technology

Judy M. Vance
Iowa State University

J. Michael McCarthy
University of California, Irvine

Abstract: In this paper we present a summary of our continuing efforts to create a virtual reality(VR) environment for the design of spherical mechanisms. This VR design environment is based upon new and existing state-of-the-art results in the fields of applied VR and spatial mechanism design. It is our hope that this project will result in: (1) a new paradigm for utilizing VR techniques in engineering design, and (2) an innovative tool that will facilitate the design of spherical mechanisms.

1. Overview: Researchers at Iowa State University(ISU), Florida Institute of Technology(FIT), and the University of California at Irvine(UCI) are collaborating to develop a virtual reality(VR) environment for spatial linkage design. The VisLab at ISU is the focal point for implementation of the synthesis and analysis compute engines being developed by the three institution team. To date the research has been focused upon the three-dimensional interaction that occurs in a Burmester-type design methodology. This methodology requires the designer to perform two activities which, by their nature, are three-dimensional: i) physical positioning of goal frames in three-dimensional space to define the task, and ii) evaluation of the spatial movement of candidate designs to assess their performance. Current research is focused on developing and implementing new methods of spherical mechanism design which take full advantage of the unique three-dimensional interaction capabilities in VR.

2. Accomplishments to Date: The first workstation-based spherical mechanism CAD program, *Sphinx*1.0, was developed by Larochelle et al [1]. *Sphinx*1.0 uses three-dimensional graphics to provide an interactive environment to design spherical four-bar mechanisms. Osborn and Vance developed the first VR based approach to spherical mechanism design, entitled *Sphere*VR [2]. This project has led to the development of the 3^{rd} generation of VR based spherical mechanism design software called *Isis*. The program utilizes the compute engine of *Sphinx*1.0 and provides virtual objects in the design environment so that the design process takes place in a virtual representation of the actual physical workspace. Instead of placing abstract coordinate systems on the design sphere the user places instances of the part to be moved, see Fig. 1(a). The part geometry is created in Pro/Engineer and is seamlessly imported into the program. The visual interface to *Isis* is provided by either stereo shutter glasses along with a projection screen or the C2 virtual projection room, or a head mounted display. Interaction is provided using contact sensitive gloves. Future work will integrate the compute engines developed at UCI and FIT into the virtual environment of *Isis*.

New computational routines have been developed at UCI that provide efficient and modular functions that generate the design curves, perform type and singularity checks, and analyze the available linkages. These routines are based on the finite position synthesis theory of Burmester [3] and follow the implementation structure of Kaufman [4]. They are intended to provide a robust and efficient compute engine. A Windows95 based interface to these routines, called *Sphinx*PC97, is currently being evaluated by more than 30 researchers.

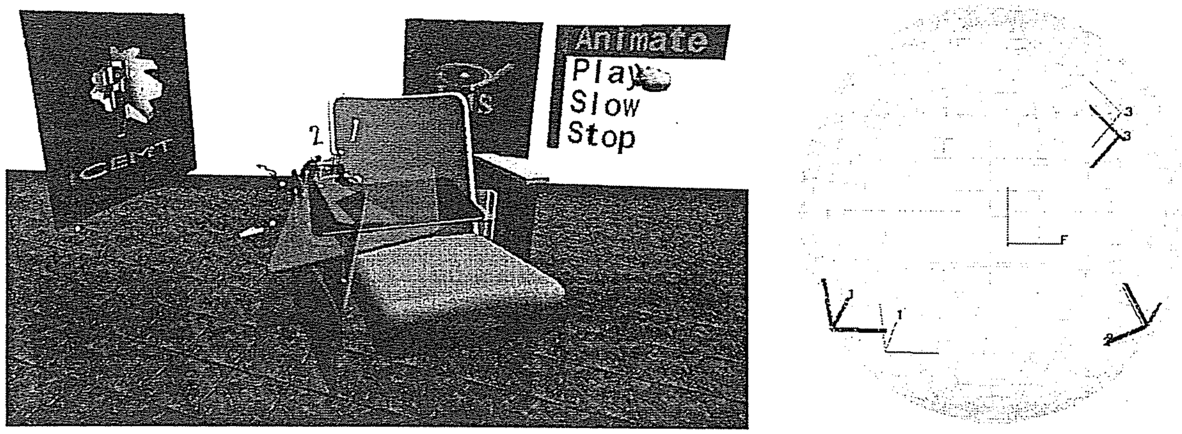

Figure 1: (a) *Isis* (b) Optimal Design Sphere

Additional work being performed at FIT has focused on a method to compute the spherical constraint surface based on the desired positions of the moving body. The design interfaces of *Sphinx*PC97, *Sphinx*1.0, *Vemecs*, and *Sphere*VR require the designer to specify the task as a set of desired positions of the moving body on the surface of a design sphere. However, the location and size of this sphere in the physical workspace of the mechanism was left to the designer to specify. Past experience indicates that the specification of the design sphere is difficult and is a major challenge facing designers. Recent results at FIT have yielded a new methodology for task specification which bridges this gap between the physical workspace of the mechanism and the design sphere. This new task specification methodology enables the designer to specify the desired positions of the moving body in three-dimensional space and then the program determines the optimal design sphere by utilizing an approximate bi-invariant metric on biquaternions [5,6] to determine the spherical positions that best approximate the original general spatial positions, see Fig. 1(b). These new routines will also be integrated into *Isis*.

References:

[1] P.M. Larochelle, J.R. Dooley, A.P. Murray, and J.M. McCarthy, Sphinx: Software for synthesizing spherical 4r mechanisms. In *NSF Design and Manufacturing Systems Conferences*, Vol. 1, pp. 607–611, Charlotte, North Carolina, January 1993.

[2] S.W. Osborn and J.M. Vance. A virtual reality environment for synthesizing spherical four-bar mechanisms. In *Proceedings of the 1995 ASME Design Automation Conference*, Vol.DE-83, pp. 885–892, Boston, Massachusetts, September 1995.

[3] L. Burmester. *Lehrbuch der Kinematik.* LeipZig, 1888.

[4] A.J. Rubel and R.E. Kaufman. Kinsyn iii: A new human-engineered system for interactive computer-aided design of planar linkages. *ASME J. of Engr. for Industry*, Vol. 99 (2), pp. 440–448, May 1977.

[5] P.M. Larochelle and J.M. McCarthy. Designing planar mechanisms using a bi-invariant metric in the image space of $so(3)$. *ASME J. of Mechanical Design*, Vol. 117 (4), pp. 646–651, 1996.

[6] K.R. Etzel and J.M. McCarthy. Metric for spatial displacements using biquaternions on $so(4)$. In *Proc. IEEE Robotics and Automation Conf.* Vol. 4, pp. 3185–3190, 1996.

Acknowledgments: The support of the National Science Foundation, grant DMI-9612062, is gratefully acknowledged.