Asymmetric Bimanual Interface Configuration and Interactions for Virtual Assembly

Vikram S. Vyawahare[1*], Richard T. Stone[2]

[1]Department of Mechanical Engineering,
Iowa State University , Ames , Iowa US 50011
E-mail: vikramsv.isu@gmail.com

[2]Department of Industrial and Manufacturing Systems Engineering,
Iowa State University , Ames , Iowa US 50011
E-mail:rstone@iastate.edu

Research Program: Simulation and Visualization

Introduction

This paper discusses development of a new bimanual interface configuration for virtual assembly. Using the developed configuration, user can interact with the virtual environment with a kinesthetic haptic device at one hand and a 6DOF tracking device at the other hand. Two interaction methods are developed combining the input from both devices.

Several definitions of virtual assembly have been theorized by researchers over the years. Jayram et al. [4] defined virtual assembly as "The use of computer tools to make or ''assist with'' assembly-related engineering decisions through analysis, predictive models, visualization, and presentation of data without physical realization of the product or supporting processes" Seth et al. [11] define virtual assembly as "the capability to assemble virtual representations of physical models through simulating realistic environment behavior and part interaction to reduce the need for physical assembly prototyping resulting in the ability to make more encompassing design/assembly decisions in an immersive computer-generated environment".

Although several researchers have implemented interactive virtual environments for virtual assembly, the research is far from reaching the point of realistic interaction. In this research the focus is on bimanual interaction. Asymmetry in the context of human bimanual action was first characterized by Yves Guiard [2]. His proposal was to characterize human bimanual action as a functional kinematic chain between the two hands. Interaction in this research builds on this insight.
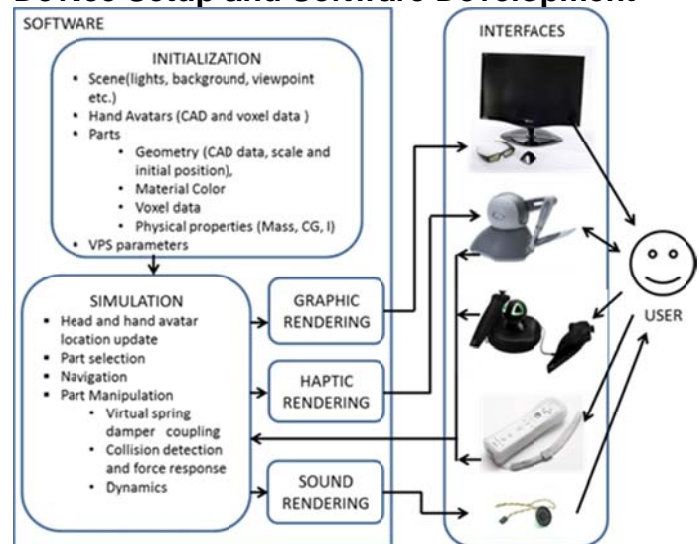
Device Setup and Software Development

Fig 1: Device Setup and Software Architecture

The device setup for this research consists of a 6 degree of freedom magnetically tracked device (Hydra gaming controller from Razer™) and a kinesthetic haptic device (PHANTOM OMNI® from Sensable). An active stereo vision setup consisting of a ViewSonic 3D vision monitor, NVIDIA Quadro FX 4800 graphics card and NVIDIA 3D vision kit all connected /installed on a Windows® 7 64 bit desktop with Intel® Core™ 2 extreme CPU 3.0GHz, with 4GB RAM. Head tracking with a wiimote controller is implemented[7][12]. The application is built using Visual C++ 8 on VRJugglar 2.1 framework with OpenSceneGraph 2.8.2 for graphics

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*Presenting author: Vikram S. Vyawahare

rendering. Voxmap PointShell (VPS)[9] software development toolkit is used for time critical collision detection using a voxelization based approach. VPS physically based modeling library is used for physics calculations for haptic rendering. Application development for this research builds on the knowledge of previous virtual assembly implementations [3][5][6][10] by several researchers at the Virtual Reality applications center at the Iowa State University.

One Hand One Object Manipulation

Once the hand avatar is intersected with a virtual object, the user has to provide a grasp command to initiate the grasp. After the grasp is initiated; the user hand pose is coupled with the virtual object through a virtual spring damper system using an impedance approach. This provides for the stability of rendering for the haptic device.

For the non-haptic hand, the virtual spring damper is a one way (from user hand to the object only) as force rendering back from the object to the user hand is not possible. Due to the spring damper there is relative motion of the hand avatar with respect to the manipulated object during part to part collision which also aids in visuo-haptic perception of collision.

Bimanual Single Object Manipulation

In real world it would be natural for the user to use both hands for object manipulation. This is necessary to overcome the limitations of human wrist motion. A new scheme decoupling the positioning and orientation is developed in this research. In this scheme positioning is to be dictated by the left hand location, whereas orientation is a function of relative location of the right hand with respect to left hand. Only 3DOF position input from the two devices is considered and the orientation of individual hands is disregarded. The conceptual dynamics of the manipulated object in this scheme is as shown in Fig. 2. The virtual spring damper system is attached between the haptic handle avatar and the manipulated object. The motion of the non–haptic hand with respect to the haptic hand provides the angular inputs for determining torques acting on the virtual object. A dotted link between the non-haptic avatar and the object point of grasp represent this connection.

Increasing the distance between the two hands will generate larger radius of rotation, thus sufficiently large motion of the right hand can be used by the user for generating smaller torques resulting in smaller rotations giving the user finer control over the orientation task.
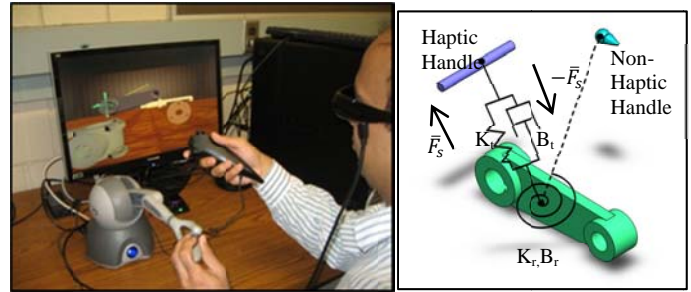

Fig 2: Conceptual Dynamics During Bimanual Single Object Manipulation

Bimanual Haptic Workspace Expansion

Kinesthetic haptic devices typically have a small workspace as compared to the virtual environments. The design criteria that "free space must feel free" [8] creates stringent requirements on back drive friction and inertia thereby limiting the size of devices. A new method to expand the haptic device workspace is developed in this research. In this scheme the distance between the two hands is used as a control of rate of scene motion and the direction from the left hand to the right hand as a control for direction of scene motion. The central region of the haptic device workspace is rendered for user reference.
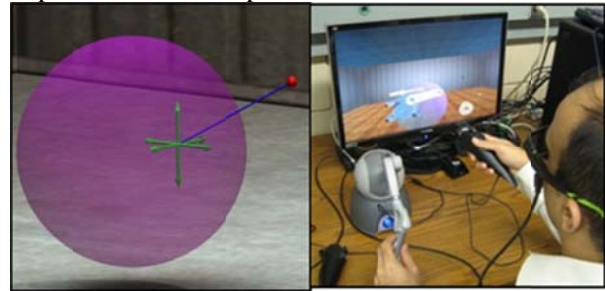

Fig 3 : Bimanual Haptic Workspace Expansion

There are several advantages of this technique as compared to techniques like the bubble technique[1], especially for virtual assembly.

Results and Discussion

For one hand one object interactions this device configuration offers advantages of increased manipulation workspace and provides a tradeoff between the cost effectiveness and mode of feedback. For bimanual single object manipulation an interaction method developed using this device configuration improves the realism and facilitates variation in precision of task of bimanual single object orientation. Furthermore a method to expand the haptic device workspace by controlling its mapping developed in this research helps in overcoming the haptic workspace size limitation and has advantages for use in virtual assembly.

*Presenting author: Vikram S. Vyawahare

Acknowledgements

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