

THE AMES VIRTUAL ENVIRONMENT WORKSTATION: IMPLEMENTATION ISSUES AND REQUIREMENTS

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This presentation describes recent developments in the implementation of a Virtual Environment Workstation in the Aerospace Human Factors Research Division of NASA's Ames Research Center. Introductory discussions are presented on the primary research objectives and applications of the system and on the system's current hardware and software configuration. Principal attention is then focused on unique issues and problems encountered in the workstation's development with emphasis on its ability to meet original design specifications for computational and graphics performance and for associated human factors requirements necessary to provide compelling sense of presence and efficient interaction in the virtual environment.

1. Research Objectives and Applications

In the Aerospace Human Factors Research Division of NASA's Ames Research Center, an interactive Virtual Environment Workstation (VIEW) has been developed to aid in design, simulation and evaluation of advanced data display and management concepts for operator interface design. The VIEW system provides a virtual auditory and stereoscopic image surround that is responsive to inputs from the operator's position, voice and gestures. As a low-cost, multipurpose personal simulation device, this variable interface configuration allows an operator to virtually explore a 360-degree synthesized or remotely sensed environment and viscerally interact with its components.

At present, the major thrust of this research effort centers on the development of guidelines and requirements that are necessary for implementation of virtual environments that are matched as closely as possible to human cognitive and sensory capabilities and that feature transparent, natural system interaction. It is projected that design specifications derived from this prototype system can help define the range of necessary and sufficient hardware and software architectures for future virtual environment systems.

Application areas of the virtual environment research are focused in:

TELEPRESENCE: Development of workstations for complex operational tasks such as telerobotic and telepresence control of remotely operated robotic devices and vehicles that require a sufficient quantity and quality of sensory feedback to approximate actual presence at the task site.

DATASPACE: Development of concepts and guidelines for "portable" multi-modal information management systems such as EVA Spacesuit visor display, with subsequent development of workstations for supervision and management of large-scale integrated information systems in which data manipulation, storage and retrieval, and system monitoring tasks can be spatially organized.

VISUALIZATION: Design and evaluation of virtual environments to facilitate visualization of complex, three-dimensional data structures in areas such as architecture, engineering and computational fluid dynamics, and for interactive training or planning environments such as surgical simulation.

2. VIEW System Configuration: Performance requirements and implementation

The current Virtual Interface Environment Workstation consists of: a wide-angle stereoscopic display unit, glove-like devices for multiple degree-of-freedom tactile input, connected speech recognition technology, gesture tracking devices, 3D auditory display and speech-synthesis technology, and real-time computer graphic and video image generation equipment. This hardware is integrated with a realtime Unix workstation that supports the computations required to drive an external high-performance realtime 3D graphics system, processes input from up to 12 realtime input peripherals (e.g., the trackers and gloves), and provides other realtime task processing. A collection of software called the "simulation framework" has also been developed that consists of a well-documented library of functions to provide access to all of the system peripherals and software services, and of a collection of source files and simulation software that demonstrates the use of the major hardware and software components that make up the VIEW system in order to facilitate system reconfiguration for changing research requirements.

Before the beginning of the implementation phase of the Virtual Environment Workstation, a number of performance requirements and specifications for the major VIEW systems components were determined. These are discussed with respect to attaining an overall performance objective of providing 640x480 pixel resolution imagery at 30 frames per second over dual, independent, synchronized display channels with image viewpoints updated in coordination with head and limb motion.

3. VIEW Implementation: Unique Issues and Problems

The VIEW project attempts to match media and computational technology as closely as possible to the perceptual and cognitive capabilities of the human operator in order to achieve a state of Telepresence in which a sufficient quantity and quality of sensory feedback is presented to the operator to approximate presence at a remote task site or in a synthetic environment. The factors that directly influence and effect the achievement of this display configuration are divided into three main areas and are discussed in detail as examples of problems and challenges for the development of virtual environment systems.

3.1 Computational issues.

- Problems in achieving VIEW objective of 30Hz frame rate:
 - Overall cumulative system transport delay
 - "Realtime" UNIX
 - Communication timing problems and scheduling artifacts
 - Problems with original performance benchmarking
- I/O problems and requirements:
 - RS232 requirements and host modifications
 - Parallel communication between host and graphics system
- Floating point accuracy requirements in database representation.
- System calibration requirements for research applications (tracker, etc.)
- The need for evolution to object-oriented software structure for VIEW.

3.2 Graphics implementation issues:

- Requirements and problems in synching dual channel graphics systems for proper stereoscopic image representation:
 - SGI IRIS graphics
 - HP SRX/TurboSRX graphics
 - ISG graphics
- Differences between human eye and virtual camera image geometry:
 - Viewport specification
 - Perspective transformations (world rotation)
 - Field of View specification
 - Display calibration requirements
- Matrix/Euler/Quaternion representation; difficulties and advantages.
- Graphics language implementations and extensions (GOSAMR)
 - Object editor
 - Problems with animating textures
 - Needed extensions
- Idiosyncrasies of lighting model in VIEW environment.
- Software structure for 3D information windows in VIEW environment: differences between screen space and world space.

3.3 Human Factors issues (Telepresence requirements):

- Guidelines and requirements necessary to provide stereoscopic images that are geometrically correct representations of the depth relationships and perspective of a rendered or captured scene are discussed (orthostereoscopy). For example, in an orthostereoscopic scene, an object in the Virtual Environment would subtend the same angle of visual field as the object it represents in the real world and would also impart correct motion parallax and motion perspective cues in relation to its virtual surroundings as the viewer changes position.

- Differences between human eye and virtual camera image geometry are discussed with reference to view representation, depth of field representation, image separation for stereoscopic fusion, window effect in stereoscopic image fusion, foveal image display, and correct focal length and viewport specification.
- Differences between human eye and virtual camera image QUALITY such as luminance, resolution, color, and texture are discussed as well as differences between human visual system and virtual camera image DYNAMICS such as frame rate and image generation lag, axis of rotation for changing viewpoint (tracker offset), image and spatial distortions from non-parallel optical axes, and infinity optics versus variable accommodation performance.
- Multisensory virtual representations provide an additional dimension to the telepresence experience and are discussed in relation to synchronization with visual imagery, auditory localization and 3D sound cues, tactile feedback, and visceral simulation with motion platforms.

4. References

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