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TELEROBOTIC GROUND-REMOTE OPERATIONS

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TELEROBOTIC GROUND-REMOTE OPERATIONS

The Telerobotic Ground-Remote Operations task consists of development of a demonstration local-site operator control station that includes a graphical user interface (GUI) for control of a remote robot, and development of operator-assisted perception algorithms and software that will provide flexible and accurate world modeling capabilities.

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TELEROBOTIC GROUND-REMOTE OPERATIONS

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- Local Site Development
- Operator-Assisted Perception

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LOCAL SITE DEVELOPMENT CONFIGURATION

The local-site hardware consists of a Silicon Graphics Incorporated (SGI) workstation with advanced graphics capabilities. It includes hardware for stereo display using special viewing glasses, video input displayable in stereo, and a "spaceball" for 6-axis control of object poses and graphics viewpoint. The cpu is a MIPS 3000 providing approximately 50 times the raw processing power of a MicroVAX II. Ethernet with TCP/IP is used for communications with the remote site.

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LOCAL SITE DEVELOPMENT CONFIGURATION

SGI Workstation with:

- Advanced graphics capabilities
- Stereo display for depth perception
- Video input, displayable in stereo
- Spaceball -- 6 axis operator input
- MIPS cpu for mini-supercomputer machine vision performance
- Ethernet/TCP/IP for communications

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SYSTEM DESIGN

Implementation Decisions:

- SGI Graphics Library -- chosen for speed, power and support; also has some measure of portability
- X window system, Motif, Widget Creation Library for graphical user interface -- chosen for capabilities for rapid prototyping of a powerful graphical user interface and for portability to other platforms
- Communications via Distributed Communication System (DCS) -- chosen for compatibility with other systems being developed at JPL (code sharing, etc.), and for ease of use and a good match with our requirements

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SYSTEM DESIGN

Implementation Decisions:

- SGI Graphics Library
- X window system, Motif, Widget Creation Library for graphical user interface (GUI)
- Communications via Distributed Communication System

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SYSTEM DESIGN

The main program is an infinite loop that calls other modules to check for and service events. There are modules for network communications, operator interface, knowledge base, video/graphics, operator-assisted graphics and operator-assisted manipulation.

The Graphical User Interface (GUI) Module presents a high-level, easy-to-use interface to the operator and responds to window/mouse-generated events.

The Operator-Assisted Perception Module interacts with the operator, the knowledge base module and the video/graphics module to provide the system with information on the poses and geometries of objects. Machine vision, embedded within this module, refines objects poses and geometries for increased accuracy.

The Operator-Supervised Manipulation Module interacts with the operator and the Knowledge Base Module to control remote manipulation activities.

The Video/Graphics Module controls all video and graphics display activities, as well as the spaceball. There is a single stereo window in which all video and graphics are displayed.

The Network Communications Module uses DCS to receive and process incoming messages. Outgoing messages do not generate events and originate with the appropriate other module.

The Knowledge Base Module contains data structures for object models, the world model tree, camera models, etc., and provides functions for easily accessing all information.

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SYSTEM DESIGN

Major modules:

- Main program: infinite loop, calls other modules to service events
- Graphical User Interface: X windows, Mac-like GUI
- Operator-Assisted Perception
- Operator-Supervised Manipulation
- Video/Graphics Module: all display of video images and graphics overlays, spaceball handling
- Network Communications: receive data from remote site
- Knowledge Base: object models, world model, camera models, etc.

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OPERATOR CONTROL STATION (I.E. LOCAL SITE)

SOFTWARE BLOCK DIAGRAM

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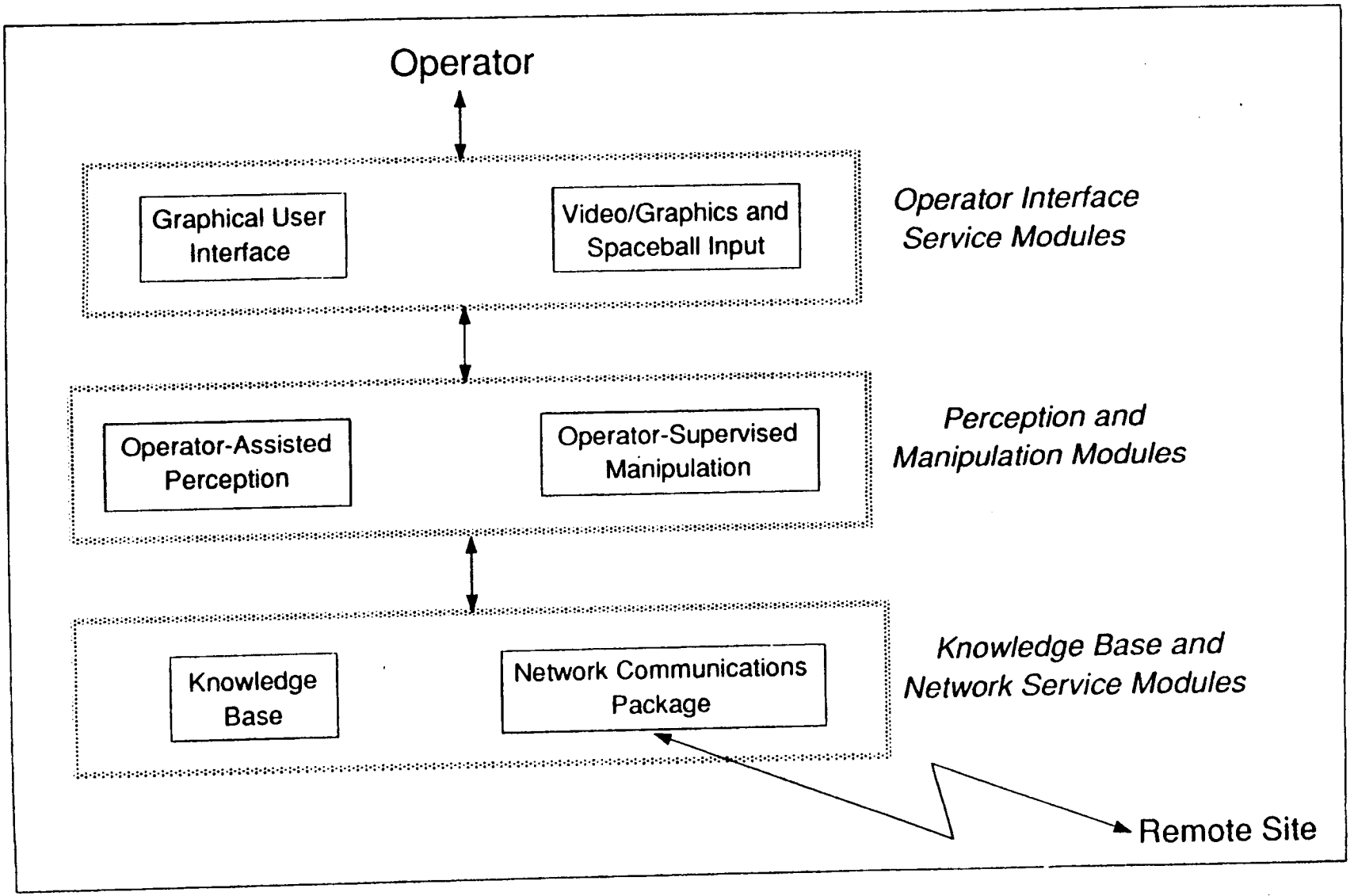
TELEROBOTIC GROUND-REMOTE OPERATIONS

Operator Control Station Software Block Diagram



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TGRO-5

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OPERATOR-ASSISTED PERCEPTION

The fundamental principal of operator-assisted perception is to utilize computer power for precision measurement where computational requirements are heavy, and to utilize the capabilities of the operator for recognition, scene segmentation, etc., where reliable and efficient computer algorithms are not available.

To aid human perception, the system provides views from multiple video cameras, as well as graphics-only display from arbitrary viewpoints. Stereo displays allow the operator to use binocular stereo cues for depth perception.

Graphics-overlay models of objects are easily movable by the operator using the spaceball to command both translations and rotations.

Once the operator has achieved reasonable registration of an object model overlay with video images of the object, machine vision can measure its position and orientation accurately.

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OPERATOR-ASSISTED PERCEPTION

Principals:

- Human provides intelligence for recognition, segmentation, etc.
- Computer provides computational power
- System provides multiple views including stereo for depth perception
- Graphics models of objects, movable using spaceball, allow natural data input by operator
- Machine vision for precision geometry measurement

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OPERATOR-ASSISTED PERCEPTION

Operations available:

- Object localization: Computer determines pose (position and orientation) of known objects using a priori pose provided by operator positioning of graphic model overlaid on video images, with machine vision for precision pose estimation using image edge measurements.

- Object creation and editting: Allows operator to designate the positions and relationships of object features in order to create a model of an unknown object, followed by machine vision to determine accurate geometry and pose. May also be used to edit existing object models in order to account for inaccuracies or changes in objects represented.

- Changing world view: Allows operator to select cameras for video image display, stereo pair or monocular views from wing cameras, optionally with graphics overlays representing known objects; or to select arbitrary viewpoints for graphics viewing without video.

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OPERATOR-ASSISTED PERCEPTION

Operations:

- Object localization: determining position and orientation of known objects using operator a priori plus machine vision
- Object creation and editting: allowing operator to create models of unknown objects and to edit existing models, augmented by machine vision to determine accurate geometry and pose
- Changing world view: selecting cameras for video images, optionally with graphics overlays; selecting arbitrary viewpoint for graphics viewing without video

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STATUS

The main program is essentially complete. File input for initialization is complete, and stubs are used for initialization and event servicing of yet-to-be-implemented modules.

The top-level of the GUI, displaying the background window and menu bar, is complete. Most menu items are non-functional, and the GUI is not yet integrated with the main program. The Operator-Assisted Perception Module has not been implemented except for a machine vision algorithm for estimating object geometry from operator and edge-detector measurements. (This algorithm was implemented before SGI development began, in portable C, on a MicroVAX.) The Operator-Supervised Manipulation Module has not been implemented on the SGI workstation. An earlier version was implemented on a Sun workstation and will be ported to the SGI. The Video/Graphics Module is the current focus of development. The framework is in place and stereo display of video images from files is currently available. Graphics overlays are under development, and graphics-only display with operator-controlled viewpoint is planned.

The Network Communications Module consists of a router that performs actual message transmission plus routines to handle incoming messages. The router is complete. Implementation of message handling routines awaits definition of network interfaces.

The core of the Knowledge Base Module, data structures for representing the various forms of knowledge plus routines to read and write files from these data structures, is complete. Routines to access knowledge base data have been defined but not implemented.

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STATUS

- Main program: complete except for minor details
- Graphical User Interface: top-level complete
- Operator-Assisted Perception: machine vision model-fitting complete
- Operator-Supervised Manipulation: not yet ported to SGI
- Video/Graphics Module: stereo video from files displayed, graphics under development
- Network communications: skeleton complete, interface details TBD
- Knowledge Base: file reading/writing and internal data structures complete, most access calls designed but not implemented

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