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Integrated Computer-Enhanced Remote Viewing System

Quarterly Report Number 6
for
January - March 1994

JUN 10 1994

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April 25, 1994

Work Performed under
Contract No.: DE-AC21-92MC29113

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1. Introduction

The Interactive, Computer-Enhanced, Remote Viewing System (ICERVS) is a system designed to provide a reliable geometric description of a robotic task space in a fashion that enables robotic remediation to be carried out more efficiently and economically than with present systems. The key elements are a faithful way to store empirical data and a friendly user interface that provides an operator with timely access to all that is known about a scene.

ICERVS will help an operator to analyze a scene and generate additional geometric data for automating significant portions of the remediation activity. Features that enable this include the following:

- Storage and display of empirical sensor data,
- Ability to update segments of the geometric description of the task space,
- Side-by-side comparisons of a live TV scene and a computer generated view of the same scene,
- Ability to create and display computer models of perceived objects in the task space, together with textual comments, and
- Easy export of data to robotic world models for robot guidance.

The development of ICERVS is to occur in three phases.

- Phase 1 will focus on the development of the Data Library, which contains the geometric data about the task space and the objects in it, and the Toolkit, which includes the mechanisms for manipulating and displaying both empirical and model data.
- Phase 2 will concentrate on integrating these subsystems with a sensor subsystem into one working system. Some additional functionality will be incorporated in the Data Library and Toolkit subsystems.
- Phase 3 will expand the configuration to meet the needs of a full scale demonstration of the interactive mapping of some waste site to be identified.

The Phase 1 activities ended in June and the Phase 2 contract modification was authorized on September 24, 1993. Work on Phase 2 was unofficially begun in August, when the intent to proceed to Phase 2 was clear. This was

done in order to meet the schedule of the Buried Waste Integrated Demonstration to be carried out at the Idaho National Engineering Laboratory (INEL) in the fourth quarter of FY94.

This report covers the technical effort carried out during the quarter consisting of January, February, and March 1994.

2. Summary of Progress to Date

The second Phase of the ICERVS project consists of nine tasks which are described in Attachment A. This listing includes the eight tasks originally proposed together with an additional task to supply a working copy of ICERVS to INEL for use with the Buried Waste Integrated Demonstration (BWID).

Tasks 1, 3, and 4 were previously completed. Tasks 2, 5, and 8 are in progress.

Significant efforts were devoted to Task 2 (Sensor Subsystems) This effort had been running in parallel with an internal effort to complete the CRADA development of the structured light sensor system, which was demonstrated on February 15-16, 1994. The integrated CRADA software package has become the basis of the ICERVS mapping sensor. The design of the Common Interface for Sensors has been completed and is documented in the Phase II Subsystem Design Report, which has been included in this report as Attachment B. Implementation of the software for Task 2 is just beginning.

The majority of the effort during the past quarter was directed at Task 5 (Analysis Software implementation). Most of the Volumetric Data Subsystem main menu functions are implemented as are about half of the VDS view window and its menu functions. Significant progress has been made at implementing an interface to the TrueSolid package.

Some initial efforts were directed at starting Task 8 (Buried Waste). The new requirements placed upon ICERVS by Task 8 have been identified and incorporated into the Subsystem Design Report. Property data provided by INEL has been used to explore data interpolation, special visualization requirements, data storage needs, etc.

3. Progress Report

3.1 Task 2 — Sensor Subsystem

The sensor subsystem is the major addition to the scope of the Phase 1 system. The sensor subsystem represents the source of all input data and,

for Phase 2, contains a structured light mapping sensor, a laser range finder mapping sensor, and a collection of sensors that measure physical properties of the material (e.g., temperature, conductivity, radiation level) whose data will be provided to ICERVS through the MiniLab subsystem being developed by Sandia National Laboratory (SNL). Architectural data about a plant or factory will also enter ICERVS through the software mechanism associated with the sensor subsystem.

3.1.1 Structured Light Sensor Development

The structured light sensor system under development by MTI as part of a CRADA with both SNL and Oak Ridge National Laboratory (ORNL) was demonstrated on February 15-16, 1994. The CRADA effort is now concluded and the integrated CRADA software package (ORNL user interface and MTI sensor controller) has become the basis of the ICERVS mapping sensor. MTI will make this sensor system available to the project to carry out the ICERVS Phase II development.

3.1.2 Sensors Manager Subsystem CSCI Detailed Design

Detailed design of the interface between ICERVS and the structured light mapping sensor is completed. The Laser Range Finder and MiniLab emulation interfaces are modeled on the structured light sensor interface. Documentation of the design was added to the Subsystem Design Report as sections 8.0 through 12.0.

An object-oriented design methodology was used to design this CSCI. After defining the problem domain, the key problem domain component (PDC) classes were identified, including logical sensor, physical sensor, processing agenda, sensor dataset and processed dataset. The relationships, interactions, and associations among these classes were examined and an OOA diagram developed for the CSCI. Each CSC was then addressed separately. An OOA diagram, software classes, OOD diagrams, and major function descriptions were developed for each CSC. The design of the Sensors Manager Subsystem CSCI is detailed in section 8.0 of the ICERVS Phase 2 Subsystem Design Report. Sections 9.0 through 12.0 detail the design of the sensor subsystems that will be part of ICERVS Phase II.

3.1.3 Sensors Manager Subsystem Software Implementation

The implementation of the Sensors Manager Subsystem (SMS) software is just beginning. The corresponding elements from the VDS client-server interface have been copied, renamed, and partially updated to generate the SMS equivalents. The low level UNIX socket support interface used in VDS has been augmented to provide the additional functionality needed by SMS. Implementation of the CLogicalSensor and CPhysicalSensor classes has started.

3.2 Task 5 -- Analysis Software Code / Test

The major effort during the quarter centered around the implementation of the Analysis Software. Progress for the four major sub-areas is described in the subsequent paragraphs.

3.2.1 Client-Server Communications Software

The general implementation approach calls for initially using the CRADA developed communications software and possibly migrating to the ISOE and GENISAS packages by the end of Phase 3. Details of the design of the client-server communications are contained in section 5.0 of the ICERVS Phase 2 Subsystem Design Report.

The CRADA communications software was copied to ICERVS and augmented for use with the Volumetric Data Subsystem (VDS). The command encoding protocol described in the Subsystem Design Report (section 5.0) has been implemented as class CServerCommand. The classes CServer and CClient have been implemented. Simple versions of the VDS classes CVolumetricDataServer and CVolumetricDataClient were implemented to test the client-server communications enhancements. These two classes were then more fully implemented along with CVolumetricDataUser to complete the VdsServer software. All of the VDS commands defined in the Subsystem Design Report (section 7.0) are supported. About half of the commands are fully implemented. The other half will be implemented as the VDS Spatial Data Engine CSC implementation proceeds.

As the Sensors Manager Subsystem detailed design progressed, new requirements for the client-server communications emerged. The ability for a server to connect with other servers was added. The transmission of commands and the receipt of replies were changed to become independent events rather than a two-part single event. Other modifications to improve efficiency and to facilitate software development were also made. Simple versions of the SMS classes CSensorsManagerServer and CSensorsManagerClient were implemented to test the client-server communications enhancements. A few of the SMS commands defined in the Subsystem Design Report (section 8.0) were also implemented to assist with the testing.

3.2.2 Demonstration Application CSCI Software

The ICERVS Phase 2 Demonstration CSCI is the topmost application process and contains the high-level operator interface to demonstrate the functions and features of the ICERVS Phase II system. This CSCI is representative of a user application and may be used as a template for creating user

applications. The details of the design of this CSCI are contained in section 6.0 of the ICERVS Phase 2 Subsystem Design Report.

Most the software development for this CSCI occurred during the October-December 1993 quarter. However, repeated use of the implemented software as a test platform for implementing and testing other software elements uncovered a few errors in the code. These bug fixes together with minor upgrades in the look and feel of the GUI interface constitute the effort for this CSCI during the last quarter.

Now that the SMS design has been completed, the sensor related elements of the Demonstration Application CSCI user interface will need to be reviewed for consistency and possible upgrades. This work will be performed during the coming quarter.

3.2.3 Volumetric Data CSCI Software

The Volumetric Data CSCI encapsulates the storage, retrieval, manipulation, and visualization of spatial, property and geometric object data. The details of the design of this CSCI are contained in section 7.0 of the ICERVS Phase 2 Subsystem Design Report.

The bulk of the software effort during the quarter was concentrated on this CSCI. Progress in the four major development area is summarized below.

3.2.3.1 VDS Main Window Functions

Most the main window functions have been implemented including New, Open, Combine, Close, and Delete. Implementation of the Save and Save As are partly done. All functions for the View menu (Create, Close, CloseAll, Save, SaveAll, Restore, DefaultOptions, and DefaultColors) have been implemented. The Cutplanes menu functions (Edit) have been implemented. The Input and Analyze menu functions remain to be implemented.

The implemented software elements have been partially integrated with the software test platform (vdsmainu) and are being used to facilitate the remainder of the VDS software implementation.

3.2.3.2 VDS View Window Functions

Many of the VDS view window functions have been implemented or are in the process of being implemented.

The cutplane manipulation control panel (the "C" button) is in progress and is about half completed. A "T" button was added to the view window to provide a more convenient means to activate the view transform control panel. The functionality of this button is identical to the Display-Transform

menu function. The view rotation control panel (the "R" button) has not been started yet.

The Display-Transform menu function dialog panel is implemented but not full integrated with the view window. The Display-Options and Display-Colors menu functions and their dialogs are nearing completion. The Display-Refresh and Display-ID functions remain to be implemented. The Object menu functions (Show, Editing, Functions) user interface elements are implemented but not fully integrated with the view window. The Options and Output menu functions remain to be implemented.

3.2.3.3 TrueSolid Interface

The TrueSolid library functions have been encapsulated by a C++ class. This class isolates TrueSolid from the rest of the ICERVS software. The methods for this class implement the higher level functionality that ICERVS needs from TrueSolid, including:

- Creation and initialization of new octrees
- Reading of existing octrees into memory
- Display of the octree data in an X-Window
- Rotation of a displayed octree
- Translation of a displayed octree
- Scaling of a display octree
- Interpolation of octree data
- Traversal of the octree and creation of an ASCII file of data points
- Creation of a Postscript file for a displayed octree

At present, these functions are implemented in a standalone software program. Integration of these functions with the ICERVS view window will begin in May.

Bruce Edwards of Octree Corporation visited MTI in early April to assist with the development of the TrueSolid interface. The insights and guidance provided by Bruce was very instructive and has helped clarify many cloudy issues with the interface between ICERVS and TrueSolid.

3.2.3.4 Geometric Object Editing and Display

Geometric object display using TrueSolid has been prototyped for both wireframe and solid objects. The algorithms for converting geometric objects into TrueSolid CSGs will be added to the TrueSolid interface package during the coming quarter.

The integration of Rogue Wave's RWCanvas facility and the ICERVS view window is in progress. Display of 2D and 3D wireframe and solid geometric objects using RWCanvas has been implemented. Reshaping the faces of

prismoid objects has also been implemented. Implementation of software for translation, scaling and rotation of geometric objects and their faces is in progress.

3.3 Task 8 – Buried Waste Task

The buried waste pit application adds many new requirements to ICERVS, including:

- Display multiple datasets (dig faces) in a single view
- Define and manipulate a corner cutplane (cuts away a corner of data)
- Define derived property types
- Combine property data using Boolean operations
- Color the displayed data by property value
- Interpolation of property data

During the execution of Task 1 (Intermediate System Design) and Task 4 (Analysis Software Detailed Design), many of these new requirements were identified and incorporated into the ICERVS design.

During the last quarter, efforts have been directed toward investigating the approaches to be used to implement the new capabilities. The data received from INEL in November 1993 has been used to test various interpolation, visualization, and data interpretation concepts relating to property data. Much of the effort in this area has been performed with the standalone version of TrueSolid. The approaches developed have then been incorporated into the ICERVS TrueSolid interface (paragraph 3.2.3.3). With the exception of combining property data, preliminary approaches for almost all of the new capabilities have been worked out. Implementation of the software will begin in April.

4. Plans for Future Activity

The work on Task 2: Sensor Subsystem is continuing and will be completed before the end of the next quarter. The detailed design is completed and the software implementation has begun. Software completion is expected by the end of May. Integration into the ICERVS package (Task 6) will begin in June.

Analysis Software Code / Test (Task 5) will continue throughout most of the next quarter. It is expected that most of the software will be implemented by the end of May. Integration (Task 6) of the various software modules will begin in June.

Task 8 (Buried Waste) will become a dominant factor in the next quarter. The enhancements and special features required for buried waste pits will be added to the ICERVS software.

As the three major software elements (Tasks 2, 5 and 8) near completion integration activities will be started (sometime in mid-June). Integration is expected to complete by mid-August.

5. Assessment of Prospects

The results after the third quarter of activity continue to be quite encouraging. Discussions with end users at various remediation sites reveal ongoing and increasing interest in ICERVS. This Phase will address the needs of the Buried Waste Integrated Demonstration (BWID), while a joint effort with another PRDA project in robotics will begin to explore the utility of ICERVS in the D&D application.

6. Appendices

A. Task Descriptions

B. Draft of Subsystem Design Report

Appendix A. ICERVS Task Description

ATTACHMENT A

ICERVS Task Description

The nine tasks in Phase II are described below.

Task 1: Intermediate System Design

Based on the results from Phase I, MTI will review and update the requirements for the ICERVS, including an evaluation of the "TrueSolid" software and alternative data formats to IGES. The result will be a modified set of requirements for integrating the various subsystems. MTI will complete and initial draft of the ICERVS generic sensor interface. MTI will also establish user focus groups in the DOE end-user community.

Task 2: Sensor Subsystem

MTI will make available a sensor subsystem developed under a CRADA with two national laboratories. This sensor subsystem has two instrument stations. Each station consists of a solid-state camera and a laser projector. Each station will also include the appropriate suspension and positioning hardware for investigating a simulated single shell tank and will provide for yaw and pitch motions.

MTI will upgrade the software in the structured light sensor to operate as an ICERVS sensor subsystem. This will involve defining a remote interface (in accordance with the ICERVS generic sensor interface) and developing the necessary hardware and software for integration with the analysis subsystem. MTI will also define appropriate interfaces for a laser range finder and Minilab. In the absence of empirical sensor data from such sensors, MTI will create simple simulators to test these interfaces.

Task 3: Computer Upgrade

MTI will upgrade the computing platform to enhance the functionality of the overall system. MTI will include, at least: a color TV video monitor, an upgraded central processing unit, and if necessary, additional internal memory. The Octree Corporation's "TrueSolid" software module (or equivalent) to facilitate the Octree engine shall also be included.

Task 4: Analysis Software Design

MTI will review and modify the analysis software requirements as identified in Task 1, Phase II. MTI will design software modules which implement a generic sensor interface, integrate the "TrueSolid" package, and which enhance the capabilities to include, but not be limited to: the ability to accept and store real empirical data (to encompass material properties); the ability to store and merge object models alongside the data they represent; the ability to convert data into a suitable format, such as IGES or STEP, to facilitate interaction with robotic controls. MTI will also design two sets of graphics tools. The first shall enhance the system's display capabilities, and the second shall improve the system's ability to build three-dimensional geometric models.

Task 5: Analysis Software Code and Unit Test

MTI will code, test, and integrate the new analysis software and test it in a stand-alone mode to verify functionality. The new analysis software will incorporate data library functions, interface to "TrueSolid", generic sensor interface, and data output in IGES or an alternative format.

Task 6: System Integration

MTI will integrate, install, and operate data library and toolkit analysis software in an interactive mode to ensure compatibility and interoperability.

MTI will design the software elements needed to ensure effective communication between the sensor subsystems and computing platform. MTI will write, test, and integrate the necessary computer codes required for data acquisition and interactive viewing.

MTI will design an operator interface which provides effective control of the structured light sensor subsystem (i.e. cameras, lights, and positioning systems). MTI will prepare a computer code which allows the operator to control the video camera view selection and simultaneously display a matching computer image.

MTI will interconnect all system components and verify their joint functionality. A simulated, single-shell tank shall also be prepared for demonstrating the subscale ICERVS.

Task 7: Demonstration

MTI will demonstrate and verify, at least, the following components: a sensor subsystem which automatically and interactively maps the surface and walls of a simulated single-shell tank; a sensor interface to a laser range finder; a sensor interface to a minilab subsystem; library analysis software which properly creates and manipulates an equivalent world model in a form compatible with the needs of a robotic controller; analysis software which also demonstrates enhanced viewing and model-building tools; and an ICERVS which demonstrates the ability to match scenes from live TV and the world model as the operator pans the camera.

Task 8: Buried Waste Application

Subtask 8.1: System Design Modifications

MTI will finalize the features and performance needed for the buried waste application through discussions with INEL personnel. MTI will perform design modifications of the ICERVS architecture and algorithms as needed.

Subtask 8.2: Detailed Design

MTI will design the analysis software elements to support the buried waste application, including: enhanced user interface, means for storage and display of

multiple material properties, updating of data from excavation activities, tools for registering data from different sensors, interpolation of material properties for analysis and display, and combination of multiple property data via boolean operations.

Subtask 8.3: Code and Unit Test

MTI will generate the necessary software to implement the features to support the buried waste application. Each element of code shall be unit tested and then tested again at the various levels of integration.

Subtask 8.4: Demonstration, Installation, and Training

MTI will incorporate the buried waste features as part of the ICERVS Phase II demonstration. MTI will install a copy of the ICERVS executable software on an INEL-supplied workstation, provide a user's guide, and supply a one-week level of effort for informal training at INEL.

Task 9: Topical Report and Decision Point

MTI will submit a topical report within sixty (60) days prior to completion of Phase II detailing the work completed to date and including the results of the Task 8 Buried Waste Application. Within thirty (30) days after submittal, the COR shall accept the draft topical report or recommend changes.

Within (3) days after submittal of the topical report, the contracting officer shall decide whether to proceed to the next phase. If the contracting officer decides NOT to continue to the next phase, MTI will submit a camera-ready final copy of the topical report within two weeks of this notification from the contracting officer. This report shall be used in lieu of a final report.

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