1-1-1994

Project 2851 1994 SIF I/ITSEC Data And SIF Api Toolkit

University of Central Florida Institute for Simulation and Training

INSTITUTE FOR SIMULATION AND TRAINING

I/ITSEC 1994 DEMONSTRATION

Project 2851 1994 SIF I/ITSEC Data and SIF API Toolkit

UCF/IST
Visual Systems
Laboratory

Institute for Simulation & Training
Visual Systems Lab
3280 Progress Drive
Orlando, FL 32826-0544
407-658-5000

May 31, 1994

ATTN: I/ITSEC 1994 Demonstration Participant

Subject: Project 2851 1994 SIF I/ITSEC Data and SIF API Toolkit

Dear Participant:

To support the 1994 I/ITSEC Interoperability Demonstration, the Institute for Simulation and Training (IST) is distributing the SIF/HDI Ft. Hunter-Liggett terrain database and the SIF/API Toolkit for PRC, Inc. - Project 2851. Please note that the terrain database and the SIF/API Toolkit are exactly the same as those distributed by PRC, Inc. - Project 2851 for the 1993 I/ITSEC demonstration.

Please find enclosed one high density 1/4" cartridge containing the first issue of the 1993 SIF/HDI Hunter Liggett 2D data, the SIF/HDI Hunter Liggett 3D data, and the SIF/API Toolkit, per your request. Enclosure 2 provides information about the organization of the data on the tape cartridge. Enclosures 3 and 4 are the SIF transmittal forms for the 2D and 3D SIF/HDI data sets, respectively, in accordance with the SIF Military Standard. Enclosure 5 is a Project 2851 "Data Base Problem Report" form.

Jeff Swauger is the IST point of contact for coordinating questions concerning the 1994 I/ITSEC SIF/HDI data and SIF/API Toolkit. If you have questions or problems with the enclosed data or software, please contact Jeff. Please note that IST will only be able to provide limited technical support and will likely refer detailed questions to appropriate parties.

Enclosures:
1. 1994 SIF/HDI 2D & 3D data, and SIF/API Toolkit (media is a 1/4", high density UNIX tape cartridge - SGI UNIX tar format).
2. Description of tape cartridge archive
3. SIF/HDI 2D transmittal form
4. SIF/HDI 3D transmittal form
5. Data Base Problem Report form

Enclosure 1
Physical Organization of 1994 I/ITSEC
SIF Data
Release 1.0 - May 31, 1994

IST is distributing the 1994 SIF/HDI data on 1/4" SGI high density data cartridges in UNIX tar format. The organization of the data is described below:

HIGH DENSITY

High density 1/4" tape cartridges have sufficient capacity to hold all of the 1994 I/ITSEC SIF data and the SIF/API toolkit on a single tape cartridge. Therefore, high density tape cartridges were created by using the Silicon Graphics Unix tar command to make a single archive file that contains the Hunter Liggett 2D data, the Hunter Liggett 3D data, and the SIF/API toolkit. Figure 1 illustrates the creation of the 1994 I/ITSEC high density tapes.

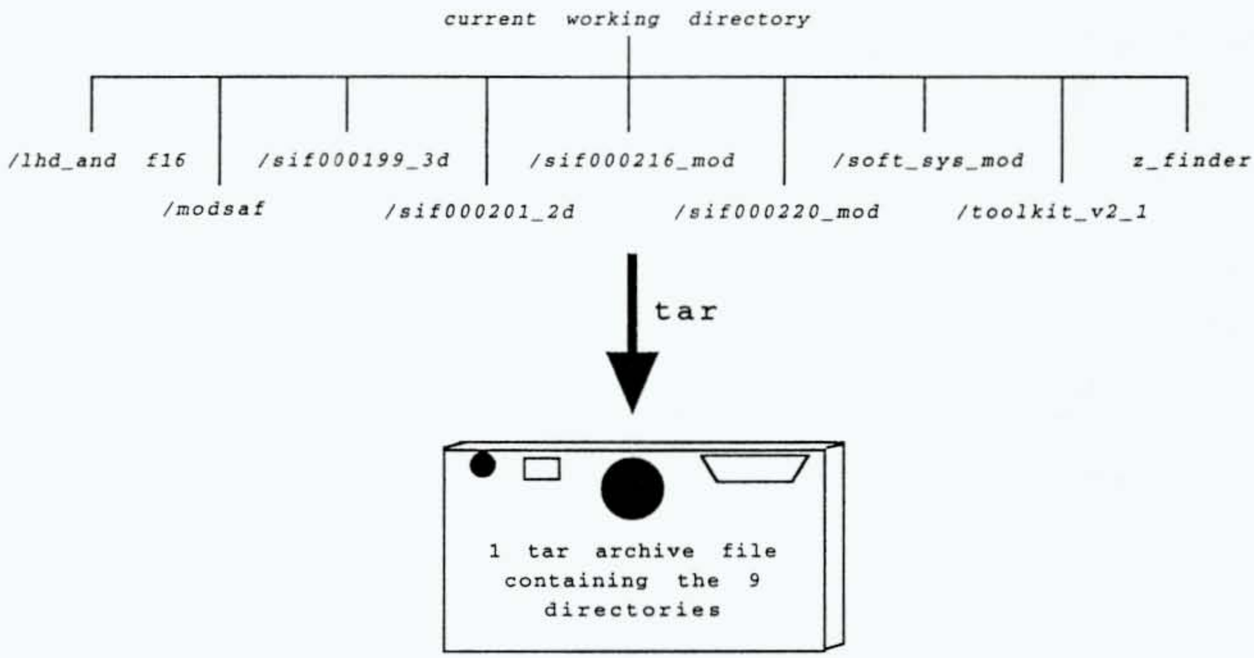

Figure 1.
High Density Tape Creation

To access the I/ITSEC data and toolkit software stored on a high density cartridge, you should use the Unix tar command to extract the archive to a suitable directory on your computing system. The tar extract will recreate the nine subdirectories shown above in Figure 1. On an SGI, the following tar command should allow extraction of the tar files:

tar xvf [1/4" tape drive device path/name]

For example, on our SGI's, the following command worked (note that the default 1/4" tape drive device path/name is /dev/tape):

tar xv

- or (same as) -

tar xvf /dev/tape

The contents of each tar directory follows. In cases where a tar directory contained a SIF/HDI database, the contents of that database will be elaborated via a dump of the SIF/HDI Data Base Header Record.

/lhd_and_f16:

```
********** SIF/HDI DATA BASE HEADER **********
Transmittal Description Record
        SIF Format: SIF/HDI
        Originator: S1000 Format Models converted to SIF/HDI Format, by
                    LNK Corporation, Inc.
        Recipient: P2851 (c/o PRC, Inc.), and the Simulator Industry.
        Transmittal ID: 9310010001
        Creation Date: 931001
        Source Agency/Project: L N K Corp., In
        Database Name: S1000 3D Dynamic Models, for use in the I/ITSEC
                       93, Converted by LNK on 10/01/93
        Data On This Volume Flag: TRUE
        Security Classification: UNCLASSIFIED
        Control and Handling:
        Releasing Instructions:
        Classification Authority:
        Security Control Number:
        Security Downgrade:
        Downgrading Event:
        SIF Version Number: 00002
Data Directory Record
        Number of 2D Static Models: 0
        Number of 3D Static Models: 0
        Number of 3D Dynamic Models: 2
        Number of Culture Tiles: 1
        Number of Terrain Tiles: 0
        Number of Generic Textures: 0
        Number of Stage 3 Specific Model Textures: 0
        Number of Stage 2 Specific Model Textures: 0
        Number of Stage 1 Specific Model Textures: 0
        Number of Stage 3 Specific Areal Textures: 0
        Number of Stage 2 Specific Areal Textures: 0
        Number of Stage 1 Specific Areal Textures: 0
        Number of SMC/FDC Textures: 0
```

```
        Merged or Layered Culture: MERGED
        Database SW Corner: N3500000000 W12200000000
        Database NE Corner: N3600000000 W12100000000
********** End of SIF/HDI DATA BASE HEADER **********
```

/sif000199_3d:

```
********** SIF/HDI DATA BASE HEADER **********
Transmittal Description Record
        SIF Format: SIF/HDI
        Originator: Ft Hunter-Liggett SIMNET TDB converted from S1000
                    DBGS format, by LNK Corp., Inc
        Recipient: P2851 (c/o PRC, Inc.), and the Simulator Industry.
        Transmittal ID: 9309240001
        Creation Date: 930924
        Source Agency/Project: L N K Corp., In
        Database Name: Ft Hunter-Liggett SIMNET TDB (High Detail Area),
                       Enhanced by LNK as of 06/12/92.
        Data On This Volume Flag: TRUE
        Security Classification: UNCLASSIFIED
        Control and Handling:
        Releasing Instructions:
        Classification Authority:
        Security Control Number:
        Security Downgrade:
        Downgrading Event:
        SIF Version Number: 00002
Data Directory Record
        Number of 2D Static Models: 0
        Number of 3D Static Models: 0
        Number of 3D Dynamic Models: 0
        Number of Culture Tiles: 1
        Number of Terrain Tiles: 0
        Number of Generic Textures: 22
        Number of Stage 3 Specific Model Textures: 0
        Number of Stage 2 Specific Model Textures: 0
        Number of Stage 1 Specific Model Textures: 0
        Number of Stage 3 Specific Areal Textures: 0
        Number of Stage 2 Specific Areal Textures: 0
        Number of Stage 1 Specific Areal Textures: 0
        Number of SMC/FDC Textures: 0
        Merged or Layered Culture: MERGED
        Database SW Corner: N3500000000 W12200000000
        Database NE Corner: N3600000000 W12100000000
********** End of SIF/HDI DATA BASE HEADER **********
```

/sif000201_2d:

```
********** SIF/HDI DATA BASE HEADER **********
Transmittal Description Record
        SIF Format: SIF/HDI
        Originator: PRC Project 2851
        Recipient: I/ITSEC Participants
        Transmittal ID: 9307260001
        Creation Date: 930723
        Source Agency/Project: PRC
        Database Name: Hunter Liggett
        Data On This Volume Flag: TRUE
        Security Classification: UNCLASSIFIED
        Control and Handling:
```

```
        Releasing Instructions:
        Classification Authority:
        Security Control Number:
        Security Downgrade:
        Downgrading Event:
        SIF Version Number: 00002
Data Directory Record
        Number of 2D Static Models: 0
        Number of 3D Static Models: 14
        Number of 3D Dynamic Models: 65
        Number of Culture Tiles: 1
        Number of Terrain Tiles: 1
        Number of Generic Textures: 22
        Number of Stage 3 Specific Model Textures: 0
        Number of Stage 2 Specific Model Textures: 0
        Number of Stage 1 Specific Model Textures: 0
        Number of Stage 3 Specific Areal Textures: 0
        Number of Stage 2 Specific Areal Textures: 0
        Number of Stage 1 Specific Areal Textures: 0
        Number of SMC/FDC Textures: 0
        Merged or Layered Culture: MERGED
        Database SW Corner: N3500000000 W12300000000
        Database NE Corner: N3700000000 W12000000000
********** End of SIF/HDI DATA BASE HEADER **********
```

/sif000216_mod:

```
********** SIF/HDI DATA BASE HEADER **********
Transmittal Description Record
        SIF Format: SIF/HDI
        Originator: S1000 Format Models converted to SIF/HDI Format, by
                    LNK Corporation, Inc.
        Recipient: P2851 (c/o PRC, Inc.), and the Simulator Industry.
        Transmittal ID: 9309290001
        Creation Date: 930929
        Source Agency/Project: L N K Corp., In
        Database Name: S1000 3D Dynamic Models, for use in the I/ITSEC
                       93, Converted by LNK on 09/28/93
        Data On This Volume Flag: TRUE
        Security Classification: UNCLASSIFIED
        Control and Handling:
        Releasing Instructions:
        Classification Authority:
        Security Control Number:
        Security Downgrade:
        Downgrading Event:
        SIF Version Number: 00002
Data Directory Record
        Number of 2D Static Models: 0
        Number of 3D Static Models: 0
        Number of 3D Dynamic Models: 72
        Number of Culture Tiles: 1
        Number of Terrain Tiles: 0
        Number of Generic Textures: 22
        Number of Stage 3 Specific Model Textures: 0
        Number of Stage 2 Specific Model Textures: 0
        Number of Stage 1 Specific Model Textures: 0
        Number of Stage 3 Specific Areal Textures: 0
        Number of Stage 2 Specific Areal Textures: 0
        Number of Stage 1 Specific Areal Textures: 0
```

```
        Number of SMC/FDC Textures: 0
        Merged or Layered Culture: MERGED
        Database SW Corner: N3500000000 W12200000000
        Database NE Corner: N3600000000 W12100000000
********** End of SIF/HDI DATA BASE HEADER **********
```

/sif000220_mod:

```
********** SIF/HDI DATA BASE HEADER **********
Transmittal Description Record
        SIF Format: SIF/HDI
        Originator: 1993 DIS I/ITSEC
        Recipient: Project 2851
        Transmittal ID: 9309300008
        Creation Date: 930930
        Source Agency/Project: Project 2851
        Database Name: other models
        Data On This Volume Flag: TRUE
        Security Classification: UNCLASSIFIED
        Control and Handling:
        Releasing Instructions:
        Classification Authority:
        Security Control Number:
        Security Downgrade:
        Downgrading Event:
        SIF Version Number: 00002
Data Directory Record
        Number of 2D Static Models: 0
        Number of 3D Static Models: 0
        Number of 3D Dynamic Models: 6
        Number of Culture Tiles: 0
        Number of Terrain Tiles: 0
        Number of Generic Textures: 0
        Number of Stage 3 Specific Model Textures: 0
        Number of Stage 2 Specific Model Textures: 0
        Number of Stage 1 Specific Model Textures: 0
        Number of Stage 3 Specific Areal Textures: 0
        Number of Stage 2 Specific Areal Textures: 0
        Number of Stage 1 Specific Areal Textures: 0
        Number of SMC/FDC Textures: 0
        Merged or Layered Culture: MERGED
        Database SW Corner:
        Database NE Corner:
********** End of SIF/HDI DATA BASE HEADER **********
```

/modsaf:

This directory contains two files: COORD.README and COORD.TAR. The contents of the COORD.README file is:

```
        Instructions for Installing the ModSAF libcoordinates Library    --------
-------------------------------------------------------
September 9, 19930) These instructions assume you are installing the libraries o
n a Unix    system.  These instructions are in the file coord.README.1) Copy the
 file "coord.tar" into the directory where you want to build  the package and t
ype:    tar xvf coord.tar 2) cd to dis_test, which contains a number of "tools.<
platform type>"   directories.  Create a link to the tools.<platform type> for t
he   platform you are using by typing:  ln -s tools.<your type> tools    where <y
```

our type> is one of sgi, mips, sun, aix, hpux. This will create a tools directory for the makes to use.3) Run make-all. This will compile all the libraries and test programs.4) The program `test` will now exist in libsrc/libcoordinates, which you can use to verify the build.5) The source code is in: libsrc/libcoordinates libsrc/libvecmat libsrc/libreader include/global

The COORD.TAR file contained the following archived files:

```
rwxrwxr-x 11349/100 dir     Sep  9 11:31 1993 dis_test/
--------- 11349/100       0 Sep  7 12:44 1993 dis_test/common symbolic link to .
rw-rw-r-- 11349/100     692 Sep  9 11:31 1993 dis_test/coord.README
```

Unfortunately, whoever created the tar file did not use a tar option to follow the symbolic link, so there is no libcoordinates library code. Please note that IST simply made a tape duplicate of a Master Copy tape provided by PRC, Inc. - Project 2851. Please contact Loral for this coordinate conversion software.

/toolkit_v2_1:

This directory contains the PRC, Inc. - Project 2851 SIF/API Toolkit. It includes the following subdirectories:

```
/sif
/sif/bin
/sif/data
/sif/inc
/sif/lib
/sif/manuals
/sif/src
```

Please refer to the SIF API Toolkit documentation (in /toolkit_v2_1/sif/manuals) for a description of the contents of each of these directories.

/z_finder:

This directory contains the PRC, Inc. - Project 2851 "Z_Finder" software utility, which is well described by its "README" file:

```
--------------------------------------------------------------------------
-
-    Filename:   "Z_Finder.README"
-
-      Purpose:  This file documents the compilation, linking, and use of the
-                standalone utility "Z_Finder" which can be used to extract
-                terrain elevation(s) from a SIF/HDI format (3-D) Culture tile,
-                given a list of input X-Y coordinates in geodetic format.
-
-                This utility has some limitations with respect to the contents
-                of the SIF/HDI Culture tile, which will be explained below.
-                In addition, it expects the input X-Y coordinates to be in a
-                specified format, which will also be explained below.
-
--------------------------------------------------------------------------
-
-  Limitations:
```

```
-
-               1)  The Utility requires three (3) data files to be present
-               in the directory it is called from:
-
-                 1 - "CUL[tile-identifier].FTR"  ,
-                 2 - "CUL[tile-identifier].SEG"  ,
-                 3 - "CUL[tile-identifier].3DC"  .
-
-               where [tile-identifier] is a valid tile specification (as
-               defined in the SIF MIL-STD-1821, 17 June 1993), such as:
-
-                  "M00002" - merged culture data, tile number 2,
-               or "400001" - tile number 1 of Level-Of-Detail 4.
-
-               When calling Z_Finder, you may (optionally) specify the
-               tile-identifier as the first (and only) argument passed
-               to the utility, for example:
-
-               user-prompt >> Z_Finder 400002<CR>
-
-               If no [tile-identifier] is specified "M00001" is used.
-
-
-               2)  The utility checks only SIF/HDI Areal features, whose
-               terrain_feature_identifier_fld = "POLY".
-
-
-               3)  The features to be checked (to determine Z value) may
-               have only three (3) or four (4) segments, each of which must
-               have exactly two (2) vertices, and the segments of the feature
-               must be arranged in counter-clockwise order.  The vertices of
-               each segment may be in clockwise or counter-clockwise order,
-               with the Segment Direction Field of the Culture Segment
-               Pointer Record (Feature File) set appropriately.
-
--------------------------------------------------------------------------------
-
-  Compilation and Linking:
-
-               To generate the "Z_Finder" executable, simply change directory
-               to the "z_finder" sub-directory, and execute the command:
-
-                 "make -f Z_Finder.mak<CR>"
-
-               This should cause the program to be both compiled and linked
-               if it is out of date with respect to any of its dependencies.
-
--------------------------------------------------------------------------------
-
-  Format of (any line of) Input X-Y Coordinate File ("lat_long.lis"):
-
-fld#:  1   | 2  | 3   |  4   |  5   |  6   |  7   |  8   | 9
--------------------------------------------------------------------
        1     N    35.0    45.0    0.00     E     238.0   45.00   0.00
--------------------------------------------------------------------
-
-  Explanation of fields:
-
-  1)  Number of Input Coordinate (in file, 1 - NUMBER_OF_INPUT_COORDINATES,
-      defined in "z_finder.h");
```

```
-
-  2)  Latitude Hemisphere specification - "N" or "S";
-
-  3)  Degrees of Latitude (floating point);
-
-  4)  Minutes of Latitude (floating point);
-
-  5)  Seconds of Latitude (floating point);
-
-  6)  Longitude Hemisphere specification - "E" or "W";
-
-  7)  Degrees of Longitude (floating point - values >= 0.0, and < 360.0
-      allowed);
-
-  8)  Minutes of Longitude (floating point);
-
-  9)  Seconds of Longitude (floating point);
-
--------------------------------------------------------------------------------
-
-  Output:
-
-         "Z_Finder" outputs a file called "x_y_z.lis" in which it copies the
-     input lines, and then adds several spaces and the extracted Z value:
-
-  1   | 2 | 3   |  4   |  5   |  6   |  7   |  8   | 9 |    10
--------------------------------------------------------------------------------
   1      N    35.0    45.0    0.00     E     238.0  45.00   0.00   642.3921
--------------------------------------------------------------------------------
-
-  10)  The Z value extracted from the 3-D terrain polygon.  If this value is
-       specified as "-999999.9999", then "Z_Finder" did NOT find a 3-D "POLY"
-       (terrain feature identifier) areal feature within which the input (2-D)
-       coordinate was located (meaning that either the input coordinate lies
-       OUTSIDE of the real area of coverage, or that there are missing terrain
-       "POLY"(gons) WITHIN the area of coverage).
-
--------------------------------------------------------------------------------
-  End of file "Z_Finder.README"
--------------------------------------------------------------------------------
```

SIF TRANSMITTAL FORM

SIF FORMAT Check The One That Applies: [X] SIF/HDI MERGED [ ] SIF/DP [ ] SIF/HDI LAYERED	
SIF VERSION NUMBER: 00002 (June 1993)	SIF CATALOG ID NUMBER: 201
TRANSMITTAL ID: 9307260001	
DATA BASE TITLE: Hunter Liggett	
ORIGINATOR'S NAME: PRC, Inc.	ORIGINATOR'S ADDRESS: 1500 PRC Dr. McLean, Va 22102
RECIPIENT'S NAME: I/ITSEC Participant	RECIPIENT'S ADDRESS: N/A
MAXIMUM BLOCK SIZE: 512 bytes per block	
DATA TYPES PROVIDED Check All That Apply: [X] Models [X] Culture [X] Terrain [X] Texture	
1° x 1° Cells Included/Requested for Culture, Terrain, or Texture Area of coverage starts at a southwest corner of 35° N 123° W and extends to a northeast corner of 37° N 120° W.	
Non-Referenced Models Included/Requested: None	
NUMBER OF TAPE VOLUMES: 1	
FIRST VOLUME CONTENTS Check The One That Applies: [ ] Data Base Header File Only [X] Data Base Header File Plus Additional Data	
VOLUME IDs (IN ORDER): Volume 1 of 1	
RELEASABILITY RESTRICTIONS: None	

SIF TRANSMITTAL FORM

SIF FORMAT Check The One That Applies: ☒ SIF/HDI MERGED ☐ SIF/DP ☐ SIF/HDI LAYERED	
SIF VERSION NUMBER: 00002	SIF DATA ID NUMBER: 199
TRANSMITTAL ID: 930714LN01	
DATA BASE TITLE: Ft. Hunter-Liggett SIMNET TDB, Enhanced by LNK Corp. as of 06/12/92.	
ORIGINATOR'S NAME: LNK Corporation, Inc.	ORIGINATOR'S ADDRESS: 6811 Kenilworth Ave., Suite 306 Riverdale, MD 20737
RECIPIENT'S NAME: PRC, Inc. (and I/ITSEC '93 Participants)	RECIPIENT'S ADDRESS: 1500 PRC Drive McLean, VA 22102
MAXIMUM BLOCK SIZE: 512 bytes per block	
DATA TYPES PROVIDED Check All That Apply: ☐ Models ☒ Culture ☐ Terrain ☒ Texture	
$1^{\circ} \times 1^{\circ}$ Cell Included/Requested for Culture or Texture Area of coverage starts at a southwest corner of 35° N 122° W and extends to a northeast corner of 36° N 121° W (Background feature). Data coverage (High Density 3D) extends from a (UTM) southwest corner of 650,000 (Easting) 3,975,000 (Northing), to a northeast corner of 680,000 (Easting) 3,985,000 (Northing), making up a 10 X 30 (N-S X E-W) kilometer area. The (SIF) data was converted from UTM (zone 10, datum = WGS84) to relative geodetic coordinates as the MIL-STD requires.	
Non-Referenced Models Included/Requested: None	
NUMBER OF TAPE VOLUMES: 1	
FIRST VOLUME CONTENTS Check The One That Applies: ☐ Data Base Header File Only ☒ Data Base Header File Plus Additional Data	
VOLUME IDs (IN ORDER): Volume 1 of 1	
RELEASABILITY RESTRICTIONS: None	

Project 2851

Data Base Problem Report

Project 2851

ORIGINATOR/ACTIONEE/CM

1. Originator	2. Telephone	3. Date	P2851 Use Only **DBPR No.**
4. Problem Short Title			**Status**

5. Hardware/Image Generator System Configuration *(Describe)*

6. Problem Priority *(1=Critical... 5=Low)*	7. Affected SIF or GTDB No. *(Enter SIF Tranmittal No. or GTDB Gnnnnn No.)*	8. SIF or GTDB Transmittal Date *(mm/dd/yy)*
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5	SIF ________________ GTDB ________________	

9. Affected Features and/or Models *(List coordinates or feature numbers, if known. List model description and numbers, if known.)*

10. Problem Description *(Provide as much detail as possible. Continue on separate sheet, if necessary.)*

P2851 PCP

11. Disposition *(Accepted, Rejected)*	12. Date *(mm/dd/yy)*	13. Authorized No. Hours
14. Chairperson		15. OPR

PROGRAMMER/OPR

16. Problem Resolution	17. Affected Documents
	18. Actual No. Hours

PCP

	19. Closed By	20. Date *(mm/dd/yy)*

Version 2.1 27 July 93

The tapes have been Fed Expressed to the following addresses, and charged to account number 64-13-303:

OIC
Naval Warfare Assessment Center
Code SE-10
Attn: Dr. Dennis Jackson
2300 5th Street
Norco, CA 91760-1915

Division, Inc.
431 W. Franklin Street
Chapel Hill, NC 27516
Attn: Craig Ramsdell

Kary Ball
Phone: (407) 722-2506
Fax: (407) 676-1628
SAIC
700 S. Babcock Suite 300
Melbourne, Fl 32901

>Harris Corporation ISD
>505 John Rodes Blvd.
>Bldg. R-3
>Attn: Bruce McQueary
>Bldg. W-3 7759; Phone 984-5964
>W. Melbourne, FL 32935

WL/AAAS-2
2185 Avionics Circle
Wright-Patterson AFB OH 45433-7301
ATTN: John Woodyard
(513) 255-4827.

Douglas Reif
>Amherst Systems, Inc.
>30 Wilson Road
>Buffalo, NY 14221
>Phone: 716-631-0610

/* KCH - 8/15/94 - Gave dist. tape to Ron */

/* Moore (E&S) when he visited */

Donald Shillcutt
Greystone Technology, Inc.
15010 Avenue of Science, Ste. 200
San Diego, CA 92128
(619) 675-7800
email: dshillcutt@gstone.com

Mr. Carl Suttle
MultiGen Inc.
1884 The Alameda
San Jose, CA 95125
(408) 247-4326
email: multigen!carl@uunet.uu.net

Mr. Andy Bushnell
Coryphaeus Software
985 University Avenue, Ste 31
Los Gatos, CA 95030
(408) 395-4537

Mel Davey
Code 60, New London Detatchment
NUWC
39 Smith St., New London, CT 06320-5594

Statistical Certification of Terrain Databases

Dr. Guy A. Schiavone, Russell S. Nelson and Brian Goldiez
Institute for Simulation and Training
3280 Progress Drive
Orlando, FL 32826

Abstract

Consistency in terrain representations between run-time databases is a prerequisite for interoperability in Distributed Interactive Simulation (DIS). It has been suggested in previous research that one hundred percent alignment of databases will never occur in a simulation that utilizes distributed geometric databases. However, statistical certification of terrain database elevations offers a means of ensuring the degree of consistency necessary for interoperability. In this paper we define a statistical metric for terrain database certification. Starting with a review of the existing work on quantitative terrain database metrics, we examine a basis for specification and statistical certification of terrain elevation data. Using classical acceptance sampling, hypothesis testing will be introduced as a method by which a terrain database (TDB) is certified. A method for determining the critical error value for the desired accuracy proportion and consumers risk (Type II error) will be discussed. From these results the producers risk associated with the test is evaluated for several different accuracy proportions. Using data collected at the 1992 I/ITSEC as a basis for comparison, the utility of acceptance sampling is demonstrated using data collected at the 1994 I/ITSEC. A distinction is drawn between tests designed for TDB certification and tests with inherent diagnostic capability. As an example of the latter, the use of the cross-correlation metric is introduced for the purpose of detecting linear shifts between the terrain skins of a baseline database and a trial database. Using a portion of the Hunter-Liggett high definition area, an example of linear shift detection is provided for the case of a shift by an integer number of samples.

About the Authors

Dr. Guy A. Schiavone is a Visual Systems Scientist at the Institute for Simulation and Training. He holds a Bachelor of Engineering from Youngstown State University, and the Ph. D. in Engineering Science from Dartmouth College, Thayer School of Engineering. His current interests include spatial error in terrain databases, 2-D signal processing, image processing, scattering from random surfaces, and propagation through random media.

Russell S. Nelson is an Assistant Engineer at the Institute for Simulation and Training. He holds a Bachelor of Science in Electrical Engineering and a Master of Science in Electrical Engineering, both from the University of Central Florida. Currently, Mr. Nelson is a member of the Visual Systems Laboratory R & D of Terrain Databases for DIS project. Prior to joining the VSL, Mr. Nelson was a Graduate Research Assistant with the Distributed Interactive Simulation Lab at IST.

Brian Goldiez is the Director of Research and Development at the Institute for Simulation and Training. Mr. Goldiez's professional interests are in aerodynamic modeling, visual systems, systems design, and testing. Mr. Goldiez directed IST's efforts in the first large scale design, test, and demonstration of Distributed Interactive Simulation at I/ITSEC 1992. He has been in simulator research and development for over 15 years as an employee of the US DoD, industry, and academia. Mr. Goldiez has Bachelor of Science in Aerospace Engineering and a Master of Science in Computer Engineering.

Statistical Certification of Terrain Databases

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Introduction

In recent years, the effectiveness and relative low cost of applications utilizing Distributed Interactive Simulation (DIS) has made the development of DIS a focus of the US military for the purpose of training and other applications requiring real-time interactive simulation. DIS is defined as a time and space coherent synthetic representation of world environments designed for linking the interactive, free play activities of people in operational exercises [1]. Each simulator on a DIS network maintains its own representation of the world. While current technology has provided visual systems with the capability of displaying high fidelity representations of a given synthetic environment, the failure to define and properly certify an agreed-upon synthetic environment before the start of a simulation exercise can lead to significant inconsistencies between world views of individual entities. Also, while members of the simulator industry compete to simulate operational systems at minimum cost to users, there are often times when proprietary "black-box" implementations lead to interoperability problems between networked simulators. It is well known that a consistent playing field between all networked simulators is essential to a successful training mission or evaluation of a new weapon system. As recently noted by Woodard [2], a fundamental first step in addressing this problem is the establishment of a common database format and content. In order to ensure that the content remains unaltered in the transformation between source database and runtime database, it follows that the content of the individual run-time databases should be tested and certified as a necessary step to guarantee a successful simulation exercise.

There is an industry consensus that the most common sources of spatial error between virtual environment representations in networked simulators include inaccurate coordinate transforms, TDB preprocessing by graphics systems, differences between rendering algorithms, and inconsistent source TDBs [3]. As an example, data and analysis recently presented by Economy, et. al. showed inaccurate coordinate transformations to be a leading source of positional error between simulators in end to end system tests [4]. Although progress is being made to improve the quality and consistency of rendered images through improvements in hardware technology, it has been suggested that resolution of interoperability problems by hardware improvements alone is not in the foreseeable future. However, in simulation environments consistency checks can be applied between TDBs as well as between displays. Thus, there exists an avenue on which the problem may be approached, and that is by way of certification testing of runtime terrain databases. Although, in this paper the authors concentrate on terrain skin only, the environment includes space, atmosphere, earth and sea; features and attributes as well as elevations. Ultimately, spatial coherence metrics for all features of the synthetic environment must be developed. Goldiez, et. al. have mentioned that a spatially coherent environment is an essential element to achieving non-biased simulator interaction [5]. Furthermore, any interaction that takes place in an environment that is spatially incoherent would be accidental and probably meaningless. It is understood that one hundred percent coherence between runtime TDBs is not currently feasible due to performance differences and other causes, and this suggests that applications-based acceptance criteria for runtime TDBs must be defined.

Although much attention has been recently given to the issue of interconsistency between terrain databases in the DIS world, terrain database "correlation" has been recognized as a problem in the real-time simulation community since at least 1977 [6] . Since that time many qualitative evaluations and discussions of the problem have appeared in the literature (for example, [7-12]). Other references can be found in a survey conducted by Zvolanek and Dillard [13]. Unfortunately, proposals for attacking the problem on a sound quantitative footing have been infrequent. Zvolanek and Dillard [14] evaluate terrain elevation "correlation" by calculating the statistical mean, standard deviation, and range of the elevation differences. Feature "correlation" is defined as the percentage of misclassified pixels. Dunn-Roberts et. al. propose a line-of-sight (LOS) intervisibility metric to measure differences in intervisibility between two TDBs [15]. A LOS comparison metric was also used by Fatale et. al. [16] in a study comparing DTED levels 1 and 2. Ellis [17]

recommends measuring off-line elevation errors by the statistical mean and the 90% or 99% maximum error, per unit of standard roughness.

Even though the quantitative methods outlined above represent the current state of the art in terrain database spatial error metrics, they all suffer from various shortcomings. There exists no criteria or guidelines to determine an acceptable level of error for a given application, or how to use the results of the tests. The statistical metrics mentioned above do not allow for control or estimate of producers and consumers risk. The simple statistical measures yield no information on error locality, beyond human-in-the -loop visualization of difference maps. The LOS methods may require a large number of calculations since, in order to obtain a unique error mapping, intervisibility must be calculated from every point in each TDB to every other point in the TDB. None of the metrics mentioned thus far are diagnostic in the sense that they are able to detect shifts, rotations, warps, or other spatial or temporal characteristics of the error. Moreover, there has been limited attention given to identifying the source of the error between a source TDB and a subject TDB. A preliminary investigation of some TDB metrics that overcome some of these shortcoming was undertaken by Kilby et. al. [18]. Currently, IST is involved with a STRICOM funded project to define and quantify interoperability in the DIS paradigm. It is the intention of this paper to present a solid mathematical approach to quantifying differences between TDBs. Acceptance sampling techniques will be applied to the elevation differences between two TDBs. Thus, an accuracy proportion with an associated confidence level can be determined and used to establish the degree of error of the subject TDB. Examples of acceptance sampling will be given using data collected at the 1993 I/ITSEC. Moreover, the use of the cross-correlation for the purpose of linear shift detection between TDBs will be investigated.

ACCEPTANCE SAMPLING THEORY

Acceptance sampling is the branch of statistical quality control that is concerned with calculating the risks associated with accepting or rejecting product lots based on information provided by a sample of the lot. Originally developed for industrial purposes, acceptance sampling was first used for map accuracy certification by Ginevan in 1979 [19]. As a background to testing for TDB elevation accuracy using acceptance sampling, we begin by examining a sample of terrain skin sample points and calculating the elevation differences Δz_i between the source database and the runtime database under test. The sample elevation differences are then compared to a given maximum elevation error criteria Δz_0. For example, denoting $\Delta z_1 \ldots \Delta z_N$ as our elevation samples, and choosing $\Delta z_0 = 0.5$ meters as our maximum allowable elevation error, we conduct a Bernoulli trial for each sample elevation difference Δz_i, $i = 1, \ldots, N$, where the trial is counted as a success if $\Delta z_i < \Delta z_0$, and otherwise is counted as a failure. The N Bernoulli trials form a binomial probability distribution, where the binomial probability density function is given by

$$f(Y;N,Q) = \frac{N!}{Y!(N-Y)!} Q^{N-Y}(1-Q)^Y \qquad (1)$$

where Q is the accuracy proportion, N is the total number of elevation difference samples, and Y is the number of failures.

A hypothesis testing criteria will be used in this statistical approach in which the null hypothesis H_0 states that the actual accuracy proportion of the TDB Q_a under test is less than the desired accuracy proportion Q. The possible outcomes of such a hypothesis test are listed below in Table 1.

Hypothesis Ho: $Q > Q_a$ Test Conclusions	Ho is TRUE	Ho is FALSE
Do not reject Ho (Do not certify TDB)	Correct	Type II Error
Reject Ho (Certify the TDB)	Type I Error	Correct

Table 1 Hypothesis Test Outcomes

As Table 1 shows,. the test yields correct results either if H_0 is true and the test rejects the database or if H_0 is false and the test certifies the database. Type I error occurs if the test certifies an unacceptable database. This is known as the consumers risk, which occurs with a probability β. Alternately, Type II error occurs when a good database is rejected by the test. This second type of error is known as the producers risk, and occurs with a probability α.

To apply acceptance sampling for TDB accuracy certification β and Q_L are chosen, where Q_L is a low accuracy proportion that will be rejected with a probability $(1-\beta)$. Note that $Q_L = Q$ in Table 1. After determining an appropriate sample size N, find the largest value X such that

$$\beta \geq \sum_{Y=0}^{X} \frac{N!}{Y!(N-Y)!} Q_L^{N-Y}(1-Q_L)^Y \qquad (2)$$

For a given N and β, the resulting value of X is known as the critical value. By ordering our elevation difference samples Δz in decreasing order, and counting down to the X^{th} sample, we determine our maximum error criterion $\Delta z(X)$ for which we may make the statement that the trial TDB agrees with the source TDB to within an error of $\Delta z(X)$ with an accuracy proportion of Q_L and a confidence of (1-β). For example, choosing N=2000, Q_L=0.95 and β=0.05, we find that X=83. In this case we will count down to the 83rd largest error $\Delta z(83)$. If we find that, say, $\Delta z(83)$=0.5 meters, then we may say with 95% confidence that 95% of the trial TDB agrees with the source TDB to within 0.5 meters.

Once the critical value X has been determined, the producers risk a can be determined for various high accuracy proportions Q_H from the relationship

$$\alpha = \sum_{Y=X+1}^{N} \frac{N!}{Y!(N-Y)!} Q_H^{N-Y}(1-Q_H)^Y \qquad (3)$$

Terrain skin elevation tests conducted by IST at the 1993 I/ITSEC utilized a sample size of 2000. To maintain continuity with last years test, participants in the 1994 I/ITSEC demonstrations were also asked to supply a sample of N=2000 elevations points from their run-time databases. Using Eqn. 2, the critical values associated with sample sizes ranging from 1897 to 2093 were calculated for a nominal β=0.05 and a low accuracy proportion Q_L=0.95, and are shown in Table 2, below.

Sample Size N	Critical Value X	Consumers Risk β
1897	79	0.0500
1919	80	0.0498
1941	81	0.0498
1963	82	0.0496
1984	83	0.0500
2006	84	0.0499
2028	85	0.0497
2050	86	0.0497
2071	87	0.0500
2093	88	0.0499

Table 2. Optimum sample sizes N for given critical values of X and a nominal β=0.05, with the low accuracy proportion Q_L set to Q_L=0.95

Using Eqn 3 and the sample sizes and critical values shown in Table 2, we may then calculate our producers risk a for some relevant values of Q_H, as shown in Table 3.

Sample Size N	Critical Value X	α for QH = 0.925	α for QH = 0.950	α for QH = 0.975
1897	79	1.0000	0.9500	0.0000
1919	80	1.0000	0.9502	0.0000
1941	81	1.0000	0.9502	0.0000
1963	82	1.0000	0.9504	0.0000
1984	83	1.0000	0.9500	0.0000
2006	84	1.0000	0.9501	0.0000
2028	85	1.0000	0.9503	0.0000
2050	86	1.0000	0.9503	0.0000
2071	87	1.0000	0.9500	0.0000
2093	88	1.0000	0.9501	0.0000

Table 3. Values of the producers risk α for various high accuracy proportions Q_H, for the values of β and Q_L used in Table 2.

We note in Table 3 that for these relatively large samples the range of significant producers risk about $Q_L=Q_H$ is very small. In the above table we see that for Q_H = 0.925 < Q_L=0.950 we have α=1.0000, which indicates the near certainty that a TDB with accuracy proportion of 92.5% will be rejected. On the other side, we see that for Q_H=0.975 > QL = 0.950, we get α = 0.0000, which tells us that there is virtually no chance of rejecting a TDB with an accuracy proportion of 97.5%. Finally, we note that when $Q_H=Q_L$, we have the case where $\alpha=1-\beta$.

Since the binomial distribution is discrete, there exists several values of N for each critical value X. Based on our test procedure of the previous year, we have chosen our sample size as N=2000, which falls between N=1984 and N=2006 in Table 2. Our critical value is therefore 83. The results of our application of the acceptance sampling theory to samples obtained from participants in the 1993 I/ITSEC will be detailed in a later section.

At the Interservice and Industry Training, Simulation, and Education Conferences (I/ITSEC)

As a part of the preparation for the 1993 I/ITSEC DIS demonstration, IST generated and distributed 2000 uniform random sample points within a geographic area of Fort Hunter Liggett, CA. This area was designated the "high detail area" because it was the only area in the data base where ground interaction was allowed. The high detail area was 10km X 30km. The latitude and longitude of the sample points were chosen at random using a bivariate uniform random distribution. Sampling of the 1992 Hunter-Liggett high detailed area was done on a grid with a minimal spacing of one arc second between samples. These points were chosen within boundaries that are one arc second toward the inside of the boundaries to avoid the effects of feathering at

the boundaries. As a result of the post 1992 I/ITSEC TDB testing, a discussion on an acceptable TDB metrics followed at the 1993 I/ITSEC planning meetings. It was requested by I/ITSEC planning meeting members that the resolution of the grid from which the random points were chosen have a spacing of 0.01 arc seconds, which results in sampling with a minimum possible spacing of 0.3 meter (approximately one foot).

I/ITSEC 92

As a result of the data gathered from the I/ITSEC '92 demonstration, development of an analysis tool that allows a database engineer to locate regions of spatial error while building a database was indicated. If the differences in elevations between two databases are recursively examined and adjusted while building a database then the error in elevation can be minimized (see Fig. 1).

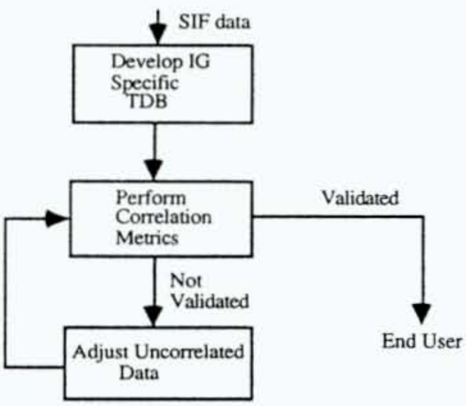

Fig. 1. Reducing Error in TDBs

The area of interest for the terrain correlation study was the high detailed inset area of the Hunter-Liggett database agreed upon for I/ITSEC 92. The area consisted of a patch of land that was bounded by a 30km easting and a 10km northing.

Based upon initial recommendations from the I/ITSEC 93 planning meeting attendees, a maximum desirable variance between a subject database and PRC's database was 0.5 meters. 1992 I/ITSEC data was analyzed to determine the suitability of 0.5m. However, after reviewing the data it became evident that a 0.5 meter error threshold would not allow anyone to participate according to the hypothesis test requirements set for 95% confidence and 95% probability for success. A filtering mechanism was used to find the number and location of the coordinates that exceeded this half-meter threshold. As seen in Table 4 very few of the participants met the 95 percent success rate at 1.25 meters.

The wide variation in 1992 data drove IST to recommend using the mean and standard deviation as criteria for 1993. We did not know at the time that in 1992 participants used gridded data as source material, when polygonal data would have been more appropriate. The polygonized SIF data was used as the standard database for I/ITSEC in 1993. Statistical analysis on the discrepancies between the subject and datum (PRC P-2851) databases showed a mean and standard deviation of the errors, as shown in Table 5.

Company	0.5m	0.75m	1.0m	1.25m
A	1719	1546	1380	1265
B	1012	641	473	340
C	1878	1815	1743	1688
D	811	422	0	0

Table 4 Failure Rate at Various Threshold Levels I/ITSEC '92 Results

Company	Mean (m)	Standard Deviation (m)
A	456	.286
B	.451	.961
C	.632	5.67
D	1.322	14.01

Table 5 Statistics for I/ITSEC '92 Databases

The data that was returned by participating organizations in the 1992 I/ITSEC revealed that the largest errors were found in geographical regions with a large variance of elevation (mountainous regions). The scatter plot of one participant indicating the points filtered from the 2000 random points that exceeded the tolerance level, defining an error, is plotted in Fig. 3. This figure represents the tolerance threshold being set at 10m. Results from other organizations reflected similar error responses.

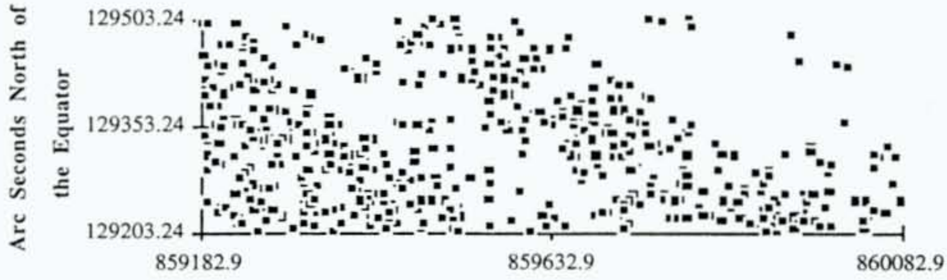

Fig. 3. Tolerance = 10m

I/ITSEC 93

Again, the area of interest for the terrain correlation study for I/ITSEC 93 was the high detailed inset area of the Hunter-Liggett (HL) database agreed upon for I/ITSEC 92. However the boundaries of the database changed from the previous year. The new boundaries were shifted north by 2km from I/ITSEC 92. Again, the area consisted of a patch of land that was bounded by a 30km easting and a 10km northing. The area for I/ITSEC 93 correlation study can be seen on a UTM map projection in Fig. 4. The distribution of the points for I/ITSEC 93 was uniform just as the sample points in 1992. In Fig. 5 notice that the range of values for elevation differences has been reduced drastically from the data collected from I/ITSEC 92, as seen in Tables (4)(5)(6). Thus, most '93 databases contained mean elevation errors on the order of a few centimeters, and errors located in the mountainous regions were greatly reduced as compared to the previous year. After reviewing the results one can note that the sample distributions for I/ITSEC 93 participants indicates that the TDBs were built with more precision than in the previous year. Fig. 5 shows the distribution of the elevation differences between the original SIF 3D

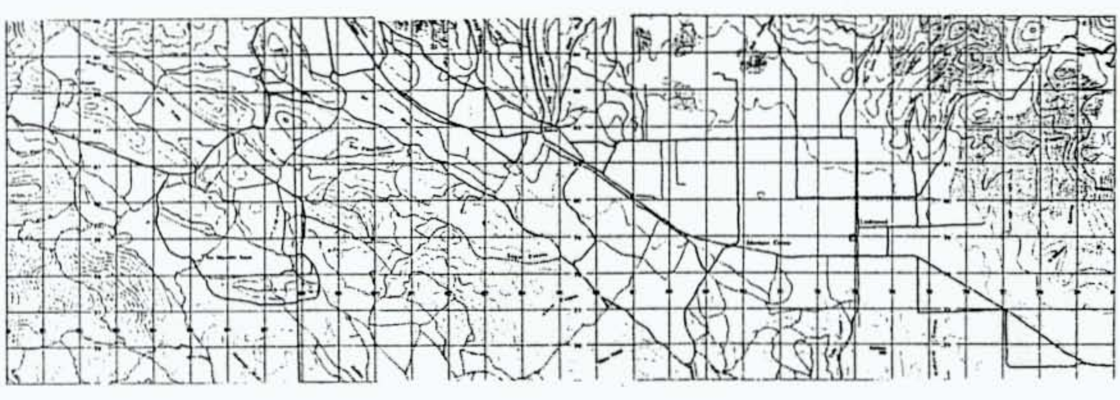

Fig. 4. Hunter-Liggett UTM Map

polygonal terrain database and the subject terrain databases. Table 6 shows the mean elevation differences, elevation difference standard deviations and the critical values. The critical value represents the 83rd largest value after finding the descending rank order of the magnitude of the elevation differences. Referring back to our previous discussion on acceptance sampling (see Table 3), the 83rd value represents the maximum number of errors allowed in a sample size of 2000 for 95% confidence that 95% of the sample points are within some tolerance (in meters) of the source terrain database. For each database the tolerance level will be different. For example, the critical value for company I was 0.162333m and the critical value for company D was 0.000163m. This means that the confidence interval for company I is much smaller than that of company D at any given elevation difference, while assuming 95% probability of correctness. Another interesting result of this experiment shows that although a TDB might have a negligible mean elevation

difference the critical value could remain relatively large. For example, let's consider the results for company F. The mean elevation difference for company F was 0.000097m, where as the corresponding critical value was 0.029338m. Notice that the standard deviation of the elevation differences for company F is relatively large also. This indicates that there are outliers present in the elevation difference distribution.. This is shown in Fig. 5f and Table 6. In one respect, the histograms in Fig. 5 show a high correlated database with a negligible elevation shift. However, the corresponding data in Table 6 indicates that the mean elevation difference for company B was -0.019578, while the histogram in Fig. 5b appears to be shifted to the right of zero. This is caused by outliers that are present but are not within the range of the graph, which probably are indicative of anomalies in the TDB construction such as sliver polygons. Let's now compare elevation difference distributions for companies C and I. Companies C and I have relatively close statistical values (as seen in Table 6), however, the histograms in Fig. 5 show that the error in the company C database is less central than that of company I. Company I could shift the elevation of their entire database by their average Δz to correct the error between their database and the source database. However, since company C's elevation differences are not as central, the correction procedure is not as simple.

Company	Mean Delta-Z (meters)	Std Deviation (meters)	Critical Value (meters)
A	-0.00079	0.029533	0.011836
B	-0.019578	1.382213	0.069666
C	0.022796	0.603328	0.015828
D	-0.000002	0.000212	0.000163
E	-0.000065	0.015944	0.007024
F	0.000097	0.073186	0.029338
G	0.000000	0.004332	0.001501
H	-0.000090	0.009548	0.005330
I	0.487752	0.361715	0.162333

Table 6. Statistics for I/ITSEC 93 Databases

Fig. 5b

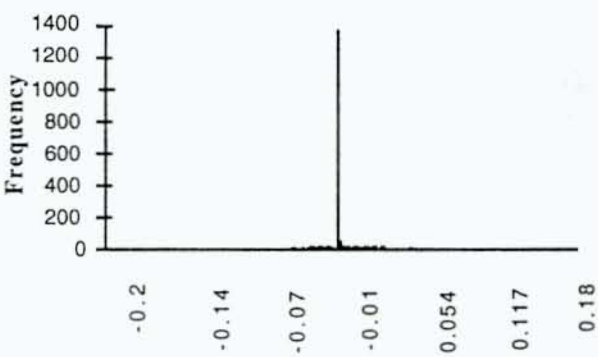

Fig. 5a

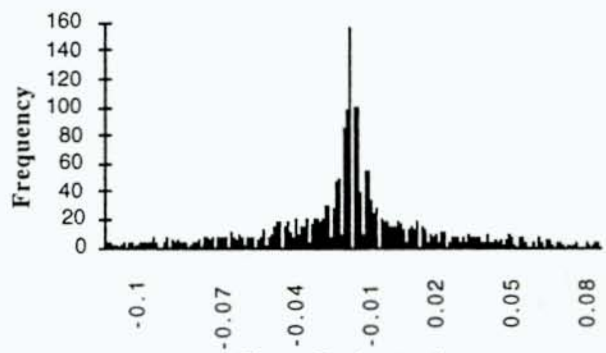

Fig. 5c

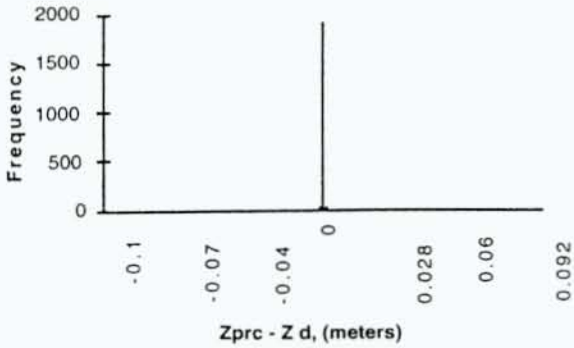

Fig. 5d

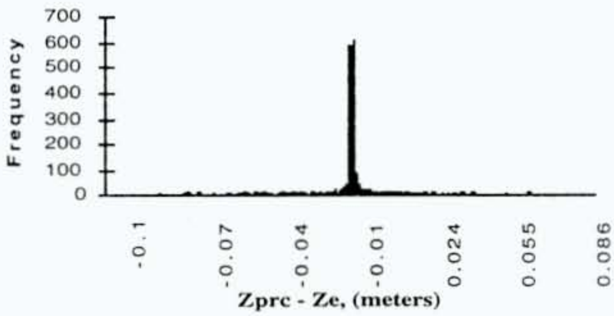

Fig. 5e

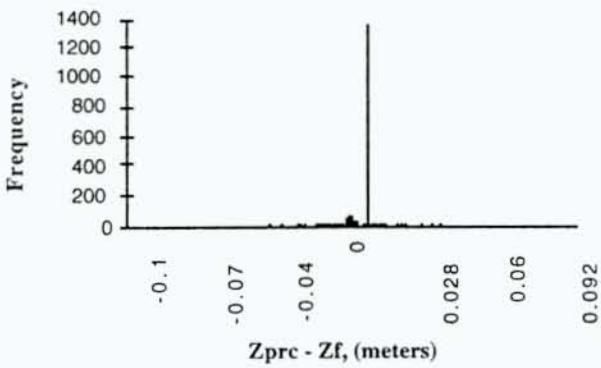

Fig. 5f

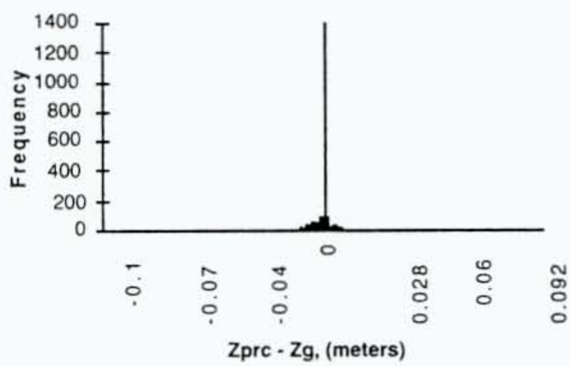

Fig. 5g

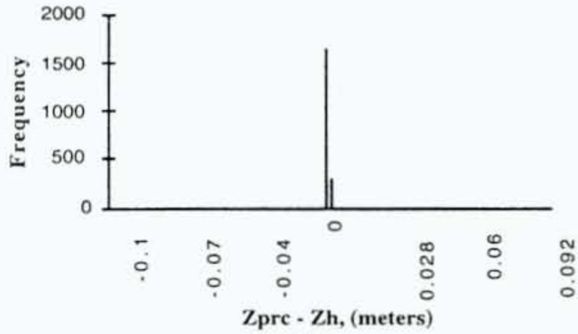

Fig. 5h

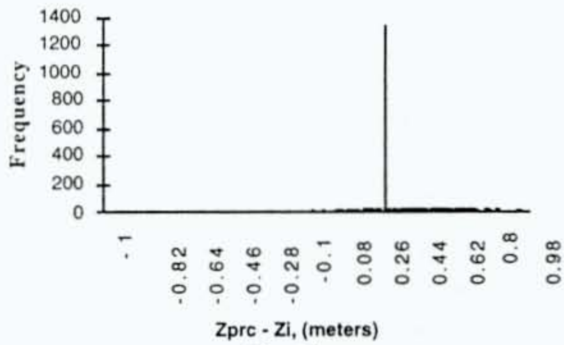

Fig. 5i

CROSS-CORRELATION TESTING

As opposed to the probabilistic statements as to the TDB spatial error made possible by acceptance sampling theory, a diagnostic metric should not only provide a measure of spatial error but should also extract information as to the type of error. Discrepancies specifically mentioned by Kilby [18] are shifts, skews, warping and resampling. Economy [3] observes a linear shift due to a suspect coordinate transformation. The ability to detect, say, the magnitude and direction of a simple linear shift in coordinates may allow one to easily determine the source of the error.

Our initial approach in developing run-time CIG-specific database correlation diagnostics is to consider the full cross-correlation on the gridded elevation data. A requirement of this approach is that a symmetric and uniform grid of elevation values must be extracted from the run-time database. Given G, a K x L set of baseline data, and H, an M x N set of trial data (with M < K and N < L), the normalized correlation of lag (k,ℓ) between G and H is

$$R_{k,\ell}(g,h) = \frac{\sum_{i=1}^{N}\sum_{j=1}^{M}\left(g_{i+k,j+\ell}-\bar{g}\right)\left(h_{i,j}-\bar{h}\right)}{\sqrt{\left(\sum_{i=1}^{N}\sum_{j=1}^{M}\left(g_{i+k,j+\ell}-\bar{g}\right)^2\right)\left(\sum_{i=1}^{N}\sum_{j=1}^{M}\left(h_{i,j}-\bar{h}\right)^2\right)}} \qquad (4)$$

R will range between -1 and 1, with R=1 describing perfect correlation, R=0 describing a complete lack of correlation, and R=-1 describing perfect anticorrelation. The initial approach is to compute R for every possible lag (k,l). The method could possibly be refined by investigating methods of determining the path that leads to the global maximum, without having to compute every possible lag. This form of the correlation will be most useful in determining linear shifts in the xy-plane. Other forms can be developed to measure other types of discrepancies. We expect this method to succeed for any reasonable data sets, although certain special cases can be constructed where, in the absence of special provisions, the method would fail, such as cases where in the windowed region the terrain elevations are doubly periodic or periodic in one dimension and constant in another.

An example of the utility of the cross-correlation metric comes from a preliminary test conducted at IST. Fig. 6a shows a portion of the terrain skin from the 1993 I/ITSEC high-detail source database, slightly upsampled at every 100 meters. The terrain extends 6.4 kilometers north and east from the southwest corner of the Hunter-Liggett database. In the test, the data used as the baseline data was the first 60 by 60 samples, while the trial data used was also a 60 by 60 sample of the terrain skin, but shifted by 400 meters (4 samples) both to the north and to the east. The cross-correlation of these two data sets is shown in Fig. 6b. The maximum value, as given by equation 4, is found as $R_{5,5} = 1.0$. Thus, the correlation returns the exact linear shift for this case involving a shift by an integer number of sample intervals.

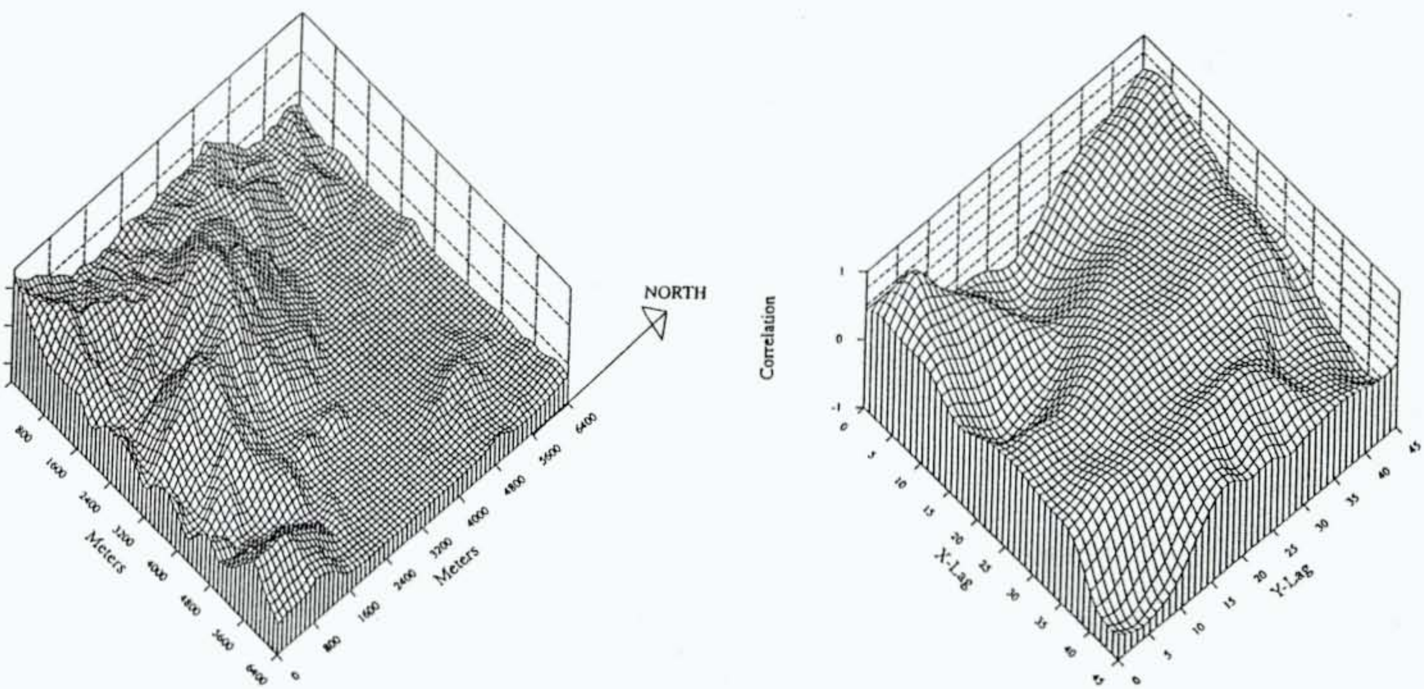

Fig. 6 a) Southwest corner of Hunter-Liggett high-detail area. b) Cross-correlation of two different sample sets from Fig. 6a, with the second set shifted both to the north and east by 400 meters.

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