Battlespace Visualization:

Programming Theme 1 Experiments 3 & 4 and Programming Theme 5 Experiment 2

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Contract Report

DRDC Toronto CR 2002-204

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December 2002

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Abstract

This report documents software development for contract #W7711-027772/001/TOR with DRDC Toronto. According to experimental designs specified by the scientific authority, software was produced to control the presentation of stimuli and record a participant's behaviour. Theme 1 experiments depicted 2D map and 3D perspective views of geographic terrain, sometimes with dynamic transition between views. The Theme 5 experiment displayed a region of a tactical display around the observer's point of gaze whose size was varied trial to trial to assess visual span. This report describes the software developed for each experiment. Information on installing and using the software is provided along with an overview of program structure.

Résumé

Le présent rapport documente le développement de qui font faisant l'objet du contrat n° W7711-027772/001/TOR passé avec RDDC Toronto. Conformément aux conceptions précisées par le responsable scientifique, les logiciels ont été développés pour contrôler la présentation des stimulus et enregistrer le comportement d'un participant. Les expériences du Thème 1 illustraient les vues perspectives 2D et 3D d'un terrain géographique avec, parfois, une transition dynamique entre les vues. L'expérience du Thème 5 visualisait un endroit d'un affichage tactique entourant le point de vue de l'observateur, dont on variait la taille d'une expérience à l'autre afin de mesurer la portée visuelle. Ce rapport décrit le logiciel développé pour chaque expérience. Les informations sur l'installation et l'exploitation des logiciels sont fournies ainsi qu'un aperçu de la structure du programme.

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Executive summary

There are three projects completed in this contract.

Project Exper_3_ver3 is designed to display 3D terrains and 2D topographic maps and record users' responses to different tasks according to the design of Theme 1 experiment 3.

Project Exper_4_ver3 is designed to display 3D terrains and 2D topographic maps and record users' responses to different tasks according to the design of Theme 1 experiment 4.

Project Theme_5_2 is designed to display bitmaps consisting of Symbicon and 2525B symbols, to change the sizes of gaze-contingent window and to record users' responses and eye movements in a search task.

This report gives program description for all above projects. Information on installing and using the software is also provided along with an overview of program structure.

Jiang, H. 2002. Battlespace Visualization: Programming Theme 1 Experiments 3 & 4 and Programming Theme 5 Experiment 2. DRDC Toronto CR 2002-204. Defence R & D Canada - Toronto.

Sommaire

Trois projets ont été réalisés en vertu de ce contrat.

Le projet Exper_3_ver3 conçu pour afficher des terrains 3D et des cartes topographiques 2D et enregistrer les réactions des utilisateurs à des tâches différentes selon la conception de l'expérience 3 du Thème 1.

Le projet Exper_4_ver3 est conçu pour afficher des terrains 3D et des cartes topographiques 2D et enregistrer les reactions des utilisateurs à l'expérience 3 du Thème 1.

Le projet Theme_5_2 est conçu pour afficher des graphiques en mode point comprenant des symboles Symbicon et 2525B, pour changer l'ouverture de la fenêtre qui dépend du regard et enregistrer les réactions des utilisateurs et les mouvements des yeux lors d'une tâche de recherche.

Ce rapport donne une description de tous le projets décrits ci-dessus. Les informations sur l'installation et l'utilisation des logiciels ainsi qu'un aperçu de la structure du programme sont également fournis.

Jiang, H. 2002. Battlespace Visualization: Programming Theme 1 Experiments 3 & 4 and Programming Theme 5 Experiment 2. DRDC Toronto CR 2002-204. Defence R & D Canada - Toronto.

Table of contents

List of figures

List of tables

Program Description

There are three projects completed for this contract:

Exper_3_ver3

Exper_4_ver3

Theme_5_2

In the following sections, the detail description will be given for each project.

1.1 Description for project Exper_3_ver3

Project Exper_3_ver3 consists of four files:

1) Exper_3_ver3.h

2) Exper_3_ver3.cpp

3) Display3_ver3.h

4) Display3_ver3.cpp

File exper_3_ver3.h declares all structure types used in this program. File exper_3_ver3.cpp contains the main function that sets the order for the displays and writes the results to an output file. File display3_ver3.h declares the functions that are in the file display3_ver3.cpp. File display3_ver3.cpp contains the functions that display 3D terrains, 2D topographic maps, dots and labels; make 3D terrain one translation and two rotations; and gradually fade out the old and fade in the new map view.

1.1.1 Design for displaying 3D terrain and 2D topographic map

There are one translation and two rotations for the transition between 3D terrain and 2D topographic map. One translation is the movement along the x axis. One rotation is around z axis and the other is around x axis. For the transition from the 3D to 2D, the translation on x axis occurs first, then the rotation around z axis occurs, and the rotation around x axis occurs last. For the transition from 2D to 3D, the order is reversed.

To make the terrain rotate around x axis, the following methods– forward rotation and backward rotation are used:

1) Forward rotation: At the start position, the observer is positioned south of the terrain map so that the entire terrain is visible, maintaining a 45-degree angle between ground level and the line of sight with respect to the centre of the terrain (St. John et al., 2000) (see figure 2). As the observer moves to the north while maintaining same altitude, this angle gradually changes from 45 to 90 degrees in 1 degree increments. The observer keeps moving forward to the north until attaining a position directly above the centre of terrain.

2) Backward rotation: At the start position, the observer is directly above the centre of the terrain – high enough to view the entire terrain, maintaining a 90-degree angle between ground level and the line of sight to the centre of the terrain (St. John et al., 2000). As the observer moves to the south while maintaining same altitude, this angle gradually changes from 90 to 45 degrees in 1

degree decrements. The observer keeps moving backward to the south until attaining the start position for the forward rotation.

The actual physical area covered by both 3D terrain and 2D topographic map is 10'6" x 6'6" (latitude, longitude), which translates into 13351.33 meters x 11288.04 meters. The origin of coordinate is at the centre of the 3D terrain or 2D topographic map. The average altitude of 2872 meters (the mean of the highest level and lowest level) is used to represent the altitude of the terrain.

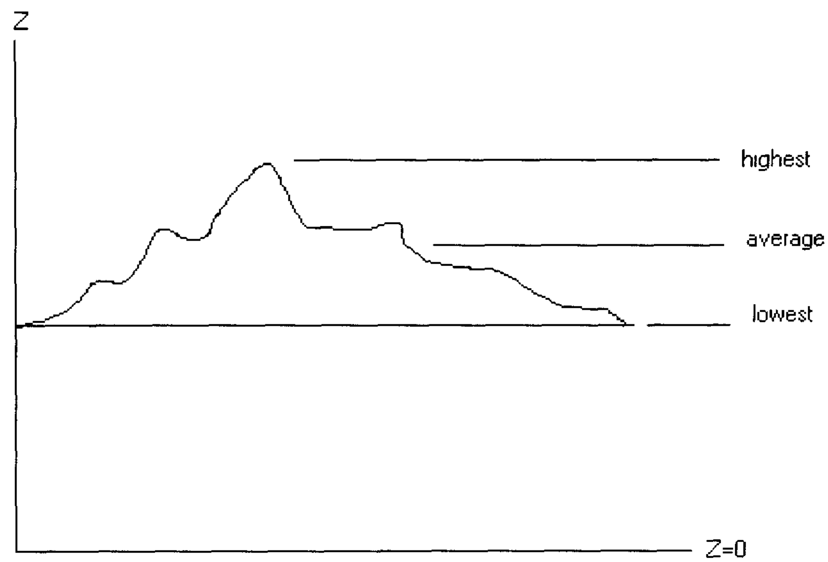


Figure 1. The average altitude of 3D terrains and 2D topographic maps

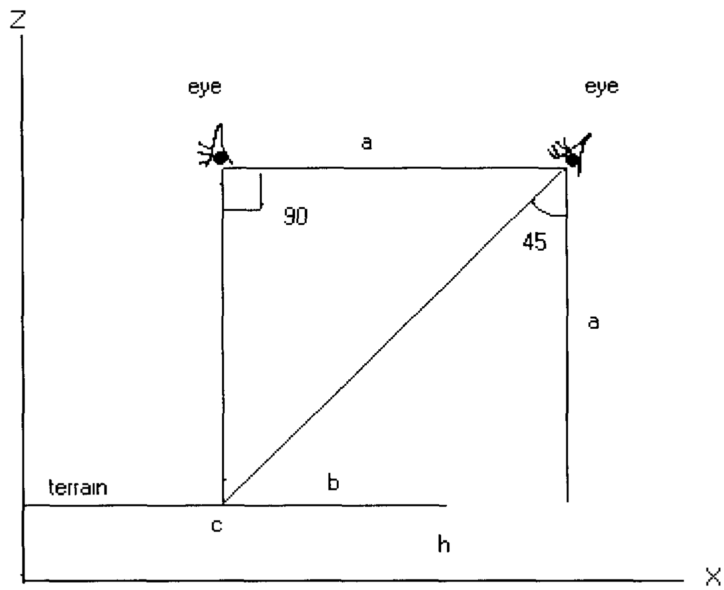


Figure 2. The positions of the eyes of observer and the terrain

a represents the distance between the observer's eyes and the average altitude of the terrain(a = 10600 meters). b represents half of the width of the terrain (b = 5644.02 meters). c represents the width of the terrain (c = 11288.04 meters). h represents an average altitude of the terrain above the zero plane of z axis (h = 2872 meters).

To make the terrain rotate around z axis, the terrain is rotated clockwise or counter clockwise around the z axis which is at the center of the terrain. The line AB will end up at the position which is vertical to the x axis and the dot labeled as A is always close to the observer in the 3D image. For saving the time for the rotation, the smallest rotation angle will be chosen between the clockwise rotation and counter clockwise rotation. The degree for rotation is calculated by the following way.

If yb = ya,

{

If xa < xb,

the terrain will be rotated a1 = 90 degrees.

Else if xa > xb,

the terrain will be rotated a2 = -90 degrees.

}

See figure 3.

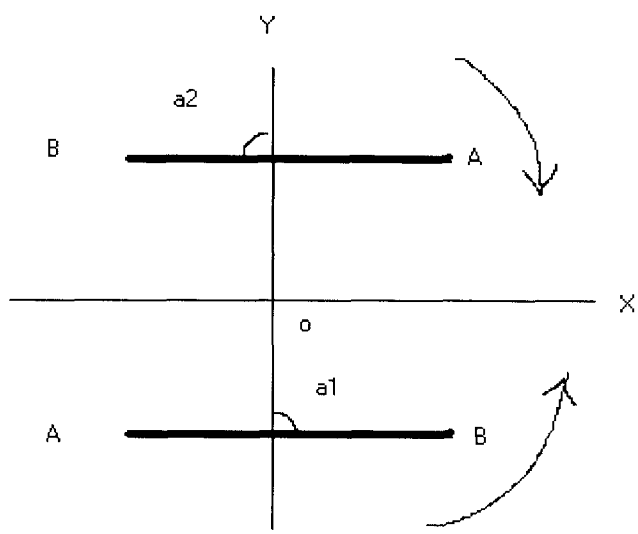


Figure 3. The terrain will be rotated 90 degrees to make both points A and B are aligned with viewer's line of sight.

Else if yb > ya,

{

If xa > xb,

The terrain will be rotated a1 = –(90 – atan (fabs (ya – yb) / fabs (xa – xb))*180/3.1416) deg.

Else if xa < xb,

The terrain will be rotated a2 = (90 – atan (fabs (ya – yb) / fabs (xa – xb)) *180/3.1416) deg.

Else if xa = xb,

No rotation.

}

See figure 4.

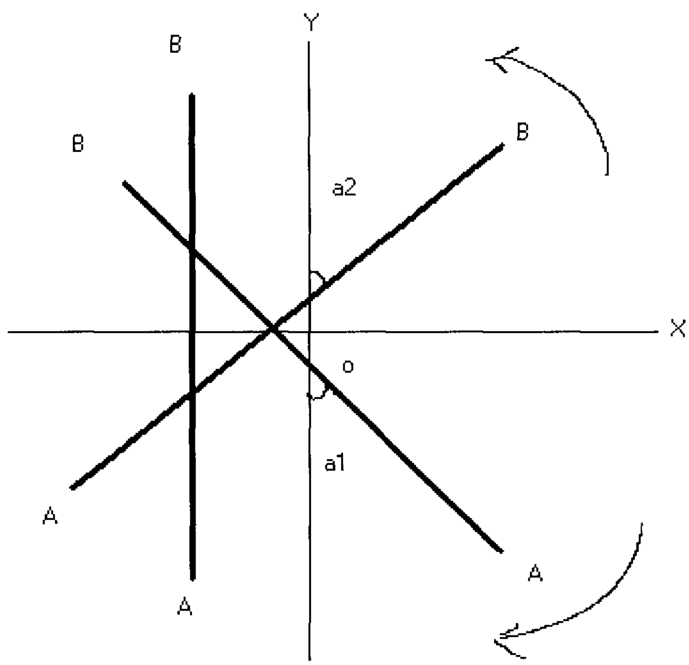


Figure 4. The terrain will be rotated a1 or a2 to make both points A and B are aligned with viewer's line of sight.

Else if yb < ya,

{

If xa < xb,

The terrain will be rotated a1 = (90 + atan (fabs (ya – yb) / fabs (xa – xb))*180/3.1416) deg.

Else if xa > xb,

The terrain will be rotated a2 = –(90 + atan (fabs (ya – yb) / fabs (xa – xb))*180/3.1416) deg.

Else if xa = xb,

The terrain will be rotated a3 = 180 deg.

}

See figure 5.

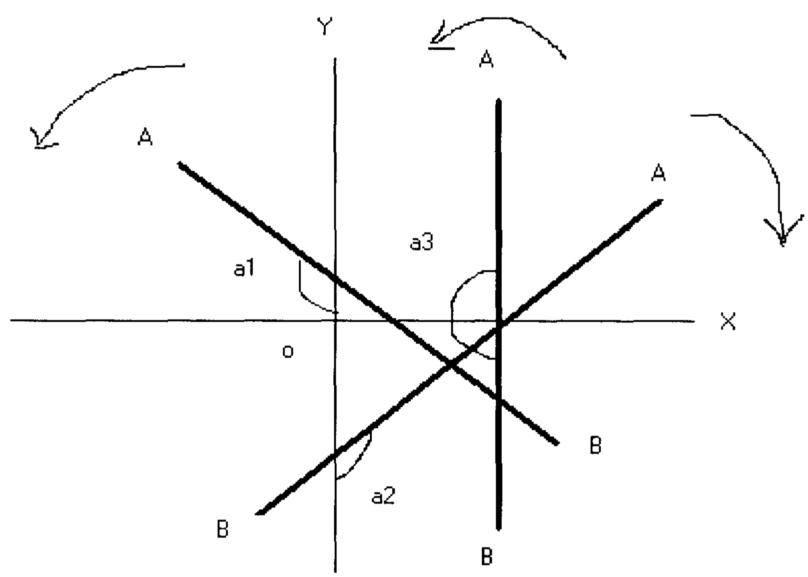


Figure 5. The terrain will be rotated a1 or a2 or a3 to make both points A and B are aligned with viewer's line of sight.

To make the terrain move along the x axis, the observer will be moved along the x axis. This movement makes the line AB always in the middle of the screen. That is, this line AB also aligns with the observer. The distance for movement is the distance from the origin of coordinate to the line AB. The distance is calculated by following formula:

Distance = fabs ((xb – xa) * ya – (yb – ya) * xa) / sqrt ((yb – ya) * (yb – ya) + (xb – xa) * (xb – xa))

The direction of movement depends on the sign of the distance. If the distance is positive, the movement is to the positive direction along x axis. If the distance is negative, the movement is to the negative direction along x axis.

Under the following conditions, the distance is positive:

1) ya = yb and xa < xb and ya < 0

2) ya = yb and xa > xb and ya > 0

See figure 6.

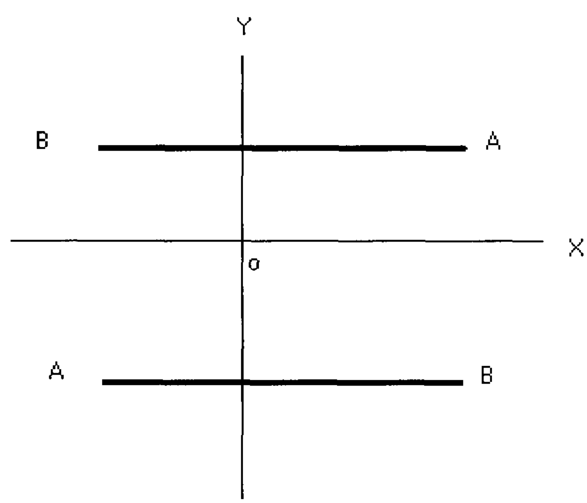


Figure 6. In condition 1 or 2, the observer will be moved to the right to align with line AB since line AB will be in the right after the terrain is rotated.

3) xa = xb and yb > ya and xa > 0

4) xa = xb and yb < ya and xa < 0

See figure 7.

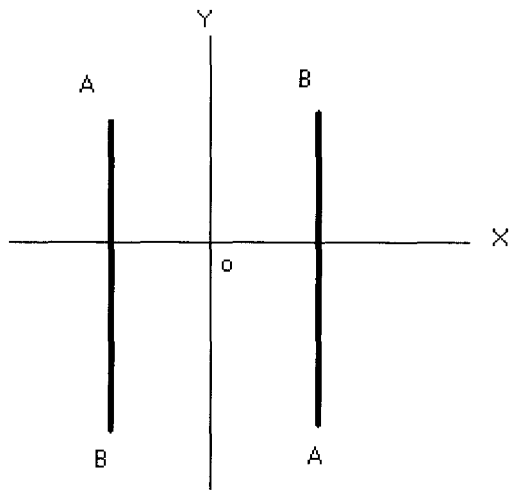


Figure 7. In condition 3 or 4, the observer will be moved to the right to align with line AB since line AB will be in the right after the terrain is rotated.

5) yb > ya and (xb – xa) * (xa / (xb – xa) – ya / (yb – ya)) > 0

6) yb < ya and (xb – xa) * (xa / (xb – xa) – ya / (yb – ya)) < 0

See figure 8.

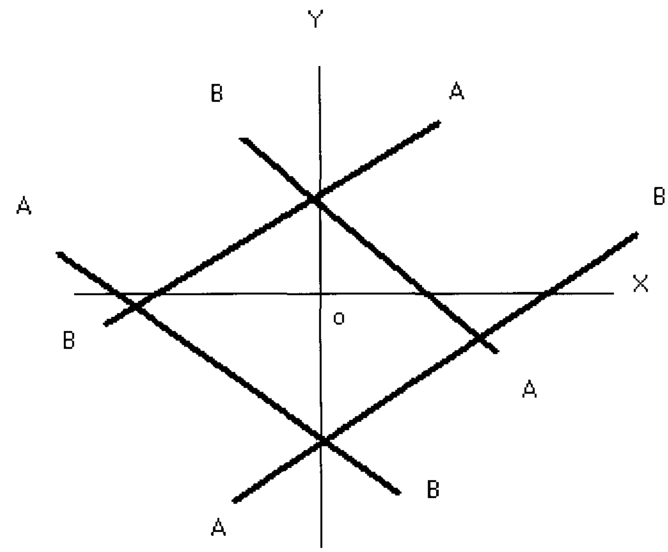


Figure 8. In condition 5 or 6, the observer will be moved to the right to align with line AB since line AB will be in the right after the terrain is rotated.

The part of (xb – xa) * (xa / (xb – xa) – ya / (yb – ya)) is the distance on the x axis when the line AB intersects the x axis. Please see Annex A for details.

Except the above conditions, the distance is set to be negative under other conditions. That is, the observer needs to be moved left to align with the line AB.

The 2D topographic map is made from the corresponding 3D terrain. The multi-coloured contour lines are put on the 3D terrain as a texture. By changing the lighting and taking out the shading, the 3D multi-coloured contour map becomes a 2D topographic map.

There is a transition between 3D terrain and 2D topographic map. The transition is accomplished by gradually fading-out the old and fading-in the new map view, and by changing the argument of the near (Vega property) to make the object invisible and visible.

1.1.2 Arrangement of trial pairs

In every 3D terrain and 2D topographic map, there are two dots that are called A and B. The experimental tasks are based on judgments about altitude of these two points. The total of 4 pairs of A_B points are used in 32 trials. Among those 4 pairs of points, 2 pairs of points have the attributes that A can see B and other 2 pairs of points have the attributes that A can't see B. Among the 2 pairs of points that A can see B, there are 1 pair of points have the attributes that A is higher than B and 1 pair of points that A is not higher than B. Among the 2 pairs of points that A can't see B, there are also 1 pair of points that A is higher than B and 1 pair of points that A is not higher than B. The table 1 describes those attributes.

Table 1. The attributes of 4 pairs of A_B points

Pair of A_B points	Can A see B	Is A higher than B
P1	Yes	Yes
P3	Yes	No
P5	No	Yes
P7	No	No

Those 4 pairs of points are displayed in 32 trials. Each pair is repeatedly used for 8 times. The pairs of points are at same locations across trial 1 and trial 2 and the tasks are different. The trial pairs and their attributes are arranged as follows:

Table 2. The arrangement of trial pairs for the experiment 3.

trial pair	pair of A_B points	trial 1	attribute 1	trial 2	attribute 2
1	P1	2D A-see-B	Y	3D A-hi-B	Y
2	P3	2D A-see-B	Y	3D A-hi-B	N
3	P5	2D A-see-B	N	3D A-hi-B	Y
4	P7	2D A-see-B	N	3D A-hi-B	N
5	P1	2D A-hi-B	Y	3D A-see-B	Y
6	P3	2D A-hi-B	N	3D A-see-B	Y
7	P5	2D A-hi-B	Y	3D A-see-B	N
8	P7	2D A-hi-B	N	3D A-see-B	N
9	P1	3D A-hi-B	Y	2D A-see-B	Y
10	P3	3D A-hi-B	N	2D A-see-B	Y
11	P5	3D A-hi-B	Y	2D A-see-B	N
12	P7	3D A-hi-B	N	2D A-see-B	N
13	P1	3D A-see-B	Y	2D A-hi-B	Y
14	P3	3D A-see-B	Y	2D A-hi-B	N
15	P5	3D A-see-B	N	2D A-hi-B	Y
16	P7	3D A-see-B	N	2D A-hi-B	N

The total trial pairs in this table are 16. To avoid the trial pair with same pair of A_B points to be adjacent, the same pairs of A_B points are grouped together and table 2 is rearranged to table 3 as follows:

Table 3. The rearrangement of trial pairs for experiment 3.

group	trial_pair_No	pair of A_B points	trial 1	attribute 1	trial 2	attribute 2
1	1	P1	2D A-see-B	Y	3D A-hi-B	Y
1	2	P1	2D A-hi-B	Y	3D A-see-B	Y
1	3	P1	3D A-hi-B	Y	2D A-see-B	Y
1	4	P1	3D A-see-B	Y	2D A-hi-B	Y
2	5	P3	2D A-see-B	Y	3D A-hi-B	N
2	6	P3	2D A-hi-B	N	3D A-see-B	Y
2	7	P3	3D A-hi-B	N	2D A-see-B	Y
2	8	P3	3D A-see-B	Y	2D A-hi-B	N
3	9	P5	2D A-see-B	N	3D A-hi-B	Y
3	10	P5	2D A-hi-B	Y	3D A-see-B	N
3	11	P5	3D A-hi-B	Y	2D A-see-B	N
3	12	P5	3D A-see-B	N	2D A-hi-B	Y
4	13	P7	2D A-see-B	N	3D A-hi-B	N
4	14	P7	2D A-hi-B	N	3D A-see-B	N
4	15	P7	3D A-hi-B	N	2D A-see-B	N
4	16	P7	3D A-see-B	N	2D A-hi-B	N

The program first randomizes the trial_pair_No within each group. Then each time the program picks up 4 numbers from 4 groups respectively to form 1 block. The order of group for picking up is also at random.

1.2 Description for project Exper_4_ver3

Project Exper_4_ver3 consists of four files as follows:

1) Exper_4_ver3.h

2) Exper_4_ver3.cpp

3) Display4_ver3.h

4) Display4_ver3.cpp

File exper_4_ver3.h declares all structure types used in this program. File exper_4_ver3.cpp contains the main function that sets the order for the displays and writes the results to an output file. File display4_ver3.h declares the Draw function. File display4_ver3.cpp contains the Draw function that displays 3D terrains, 2D topographic maps, dots and labels. The Draw function also controls the time for the transition between 3D and 2D.

1.2.1 Design for displaying 3D terrain and 2D topographic map

For the most part, the design of this experiment is the same as the design of Exper_2_ver2. However, there are only 4 pairs of A_B points (there are 8 pairs of A_B points in the Exper_2_ver2). The important change in this project is that there is no blank between the 3D display and the 2D display. After the subject presses the response button, the 3D (or 2D) display will stay for half of the gap time, then the 2D (or 3D) display will appear but the reminder will not appear until the gap time has elapsed.

1.2.2 Arrangement of trial pairs

This section is same as section 1.1.2.

1.3 Description for project Theme_5_2

Project Theme_5_2 consists of eleven files:

1) more.h

2) w32_bitmap_sppt.c

3) w32_bmp_bitmap.c

4) w32_demo_main.c

5) w32_demo_window.c

6) w32_gcwindow_trial.c

7) w32_gcwindow_trials.c

8) w32_ellip_gcwindow.c

9) w32_text_bitmap.c

10) w32_text_support.c

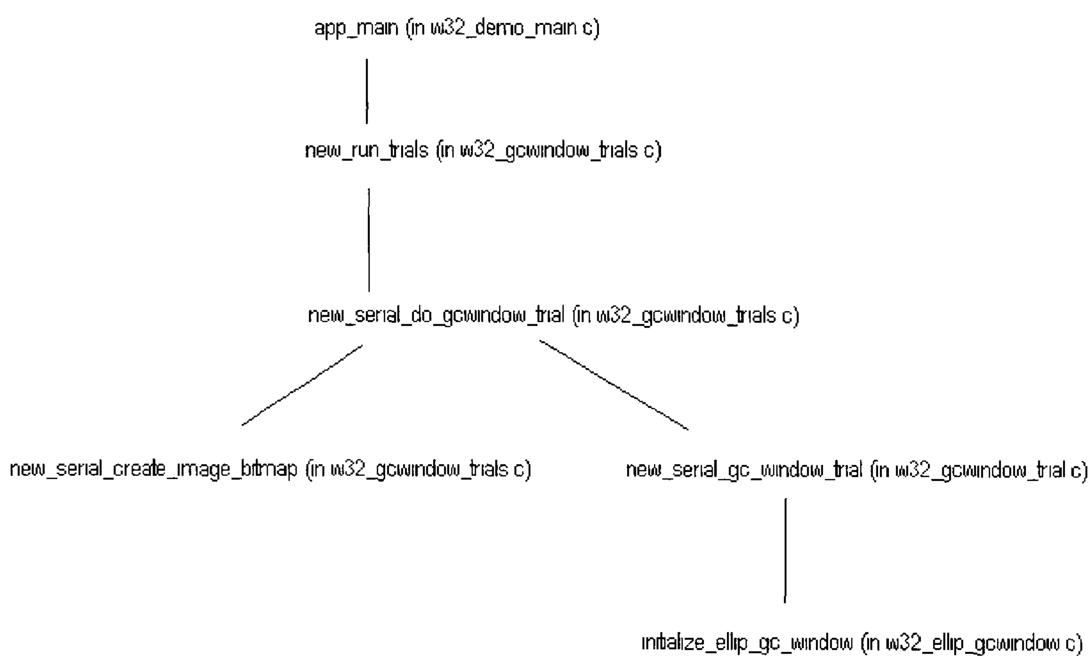
11) eyelink_exptkit.lib

The project also needs some header files and external dependencies:

1) eye_data.h
2) eyelink.h
3) eyelink.ico
4) eyetypes.h
5) w32_demo.h
6) w32_exptsppt.h

The source codes of project Theme_5_2 originally come with SMI EyeLink eye-tracking software and are modified for the Theme 5 experiment 2. Head file more.h is added to the project to define some constants and declare one structure and some functions. File w32_bitmap_sppt.c is a module for displaying entire bitmap, displaying part of the bitmap and creating blank bitmap. File w32_bmp_bitmap.c loads BMP file and creates the bitmap. File w32_demo_main.c displays the window that prompts the user to input the file name, the section number and subject number, and writes the results to the output files. File w32_demo_window.c creates a full screen window, ensuring the window is closed before exiting, clearing the window background and handling all messages for full-screen experiment window. File w32_gcwindow_trials.c controls trial set-up and running, and the change in window size. File w32_gcwindow_trial.c performs one experimental trial and records the reaction time. File w32_ellip_gcwindow sets up an elliptical gaze-contingent window. File w32_text_bitmap.c draws formatted text and creates bitmap with formatted text. File w32_text_support.c supports Windows fonts. File eyelink_exptkit.lib is a binary library file.

The hierarchy of important function calls is as follows:



The functions of program theme_5_2 are: to read in the file names of the display from a list (a file includes BMP file names); to load all BMP files for display; to display target instructions and symbol pictures in a random order seeded by subject number; to change the size of the gaze-contingent window; to record reaction times and write them to the output file; and to record eye movements and write the data to the EDF file.

The following procedure is currently set for the experiment by using program Theme_5_2:

1. Display 5 practice trials before each block.
2. Display 32 baseline trials to follow practice trials before each block.
3. Calculate 3rd quartile of baseline reaction time (RT) distribution.
4. Display the block of 96 trials started with the window size of 8 degrees of visual angle.
5. Measure median RT every 32 trials, 3 times total within a block.

   e.g. Median RT = (16th RT + 17th RT) / 2
6. Compare this Median RT to the baseline RT for the block. If this Median RT is greater than 102% baseline RT, the window size is increased. If this Median RT is less than 98% baseline RT, the window size is decreased. In other conditions, the window size remains same.
7. In each block, adjust window size to increase/decrease of 1.28°, and successively adjust to be 9% smaller than on the preceding trial.

   e.g. The window size is as follows :

5 practice	32 baseline	32 experiment	32 experiment	32 experiment
no window	no window	8 deg	8 ±1.28 deg	(8±1.28)±91%*1.28

Installation and Use

Installing the Software

Projects Exper_3_ver3 and Exper_4_ver3 were developed under Microsoft Visual C++ (version 6). The Vega (MP NT 3.7, MultiGen-paradigm product) library was also used. Project Theme_5_2 was developed under Microsoft Visual C++ (version 6). The EyeLink library (SensoMotoric Instruments product) was also used. These projects are delivered on a CD-ROM. To install the software, load the CD and open it with Windows Explorer. Copy the whole directory of the project that you want (e.g. Exper_3_ver3) to your hard disk.

Running the Program

To run the programs Exper_3_ver3 and Exper_4_ver3, you first need to have Vega software installed and licensed in your computer. Then make sure the paths for the FLT files are right in the application definition files setting.adf and setting1.adf. Then you double click on Exper_3_ver3.exe or Exper_4_ver3.exe and the program will automatically start. You will be asked to give the file name for output file, subject number and the section number as follows:

Please enter file name (e.g. Smith_2001_12_01):

(your response:) James_2001_12_02 (press the Enter key)

Please enter subject number (1-80):

(your response:) 21 (press the Enter key)

Please enter section number (0 – discrete, 1- continuous):

(your response:) 0 (press the enter key)

After the program gets your input, it will start to display the 2D topographic maps and 3D terrains. Follow the instructions, you can get different 2D topographic maps and 3D terrains to be displayed.

To run Theme_5_2, you first need to put files that list all names of BMP files and all BMP files in the directory that the application file gcwindow.exe exists. Then double click on gcwindow.exe and the program will automatically start. You will be asked to give the file name for EDF file, to choose the section to display Symbicon or 2525B symbols and to give subject number. After the program gets your input, it will: display target instructions and symbol pictures in random order seeded by subject number; change the size of the gaze-contingent window; record reaction times and write them to the output file; and record eye movements and write the data to the EDF file.

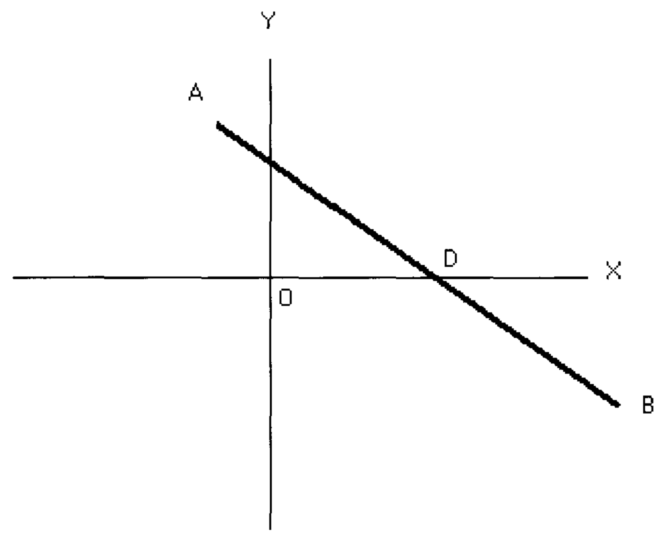
Result Data Format

For programs Exper_3_ver3 and Exper_4_ver3, the subject's responses will be recorded in an output file. The name of the file is given by you at the beginning of the experiment (for example, James_2001_12_02). This file is in the same directory as the executable application file is. The file is an ASCII file. Each row in the file contains the data for one trial.

For program gcwindow.exe, the subject's responses will be recorded in an EDF file that includes the information of events and eye's position, and an output file storing the subject number, the file name for the block, the name of the display, subject's reaction times and the sizes of gaze-contingent window. These files are in the same directory as the executable application file is. The file format for recording reaction time is ASCII. The EDF file also can be transferred to an ASCII file.

Annex A The calculation of the distance on the x axis

To calculate the distance OD on the x axis when the line AB intersects the x axis, the following formula is used:



Let A(xa, ya) and B(xb, yb) be two points on the line AB,

(y – ya) / (yb – ya) = (x – xa) / (xb – xa)

That is,

x / ((xb – xa) (xa / (xb – xa) – ya / (yb – ya)))+ y / ((ya – yb) (xa / (xb – xa) – ya / (yb – ya))) = 1

So the distance OD on the x axis when the line AB intersects the x axis is:

(xb – xa) (xa / (xb – xa) – ya / (yb – ya))

References

1. Hollands, J. G. et al: Ethics Committee Proposal (Protocol #L-329), 2001.

2. Hollands, J. G. et al: Protocol #L-329-AMENDMENT 1 – Visual Momentum in Shape-Perception and Relative-Position Tasks, May 30, 2002.

3. St. John, M et al: Navigating Two-Dimensional and Perspective Views of Terrain (Technical Report 1827), SSC San Diego, CA 92152-5001, July 2000.

DOCUMENT CONTROL DATA SHEET

1a PERFORMING AGENCY Haiying Jiang, 908-90 Atkinson Road, Toronto, Ontario M3J 2S5	2 SECURITY CLASSIFICATION UNCLASSIFIED Unlimited distribution -
1b PUBLISHING AGENCY DRDC Toronto	

3 TITLE

(U) Battlespace visualization: Programming Theme 1 Experiments 3 & 4 and Programming Theme 5 Experiment 2

4 AUTHORS

Hai-Ying Jiang

5 DATE OF PUBLICATION	6 NO OF PAGES
December 1 , 2002	31

7 DESCRIPTIVE NOTES

8 SPONSORING/MONITORING/CONTRACTING/TASKING AGENCY

Sponsoring Agency
Monitoring Agency
Contracting Agency
Tasking Agency

9 ORIGINATORS DOCUMENT NO	10 CONTRACT GRANT AND/OR PROJECT NO	11 OTHER DOCUMENT NOS
Contract Report CR 2002-204	16kd18	

12 DOCUMENT RELEASABILITY

Unlimited distribution

13 DOCUMENT ANNOUNCEMENT

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14 ABSTRACT

(U) This report documents software development for contract #W7711-027772/001/TOR with DRDC Toronto. According to experimental designs specified by the scientific authority, software was produced to control the presentation of stimuli and record a participant's behaviour Theme 1 experiments depicted 2D map and 3D perspective views of geographic terrain, sometimes with dynamic transition between views. The Theme 5 experiment displayed a region of a tactical display around the observer's point of gaze whose size was varied trial to trial to assess visual span. This report describes the software developed for each experiment. Information on installing and using the software is provided along with an overview of program structure.

(U) Le présent rapport documente le développement de qui font faisant l'objet du contrat no W7711-027772/001/TOR passé avec RDDC Toronto. Conformément aux conceptions précisées par le responsable scientifique, les logiciels ont été développés pour contrôler la présentation des stimulus et enregistrer le comportement d'un participant Les expériences du Thème 1 illustraient les vues perspectives 2D et 3D d'un terrain géographique avec, parfois, une transition dynamique entre les vues. L'expérience du Thème 5 visualisait un endroit d'un affichage tactique entourant le point de vue de l'observateur, dont on variait la taille d'une expérience à l'autre afin de mesurer la portée visuelle. Ce rapport décrit le logiciel développé pour chaque expérience. Les informations sur l'installation et l'exploitation des logiciels sont fournies ainsi qu'un aperçu de la structure du programme.

15 KEYWORDS, DESCRIPTORS or IDENTIFIERS

(U) geographic terrain; 2D displays; 3D displays; maps; tactical displays; visual momentum, visual span