SOFTWARE DEVALOPMENT FOR GRAVITY MODELLING

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ABSTRACT

This project was related to development of a usable software for gravity modeling. It explores the application of C language graphic routines for scientific purposes. Tilvani's method of gravity modeling has been applied for the development of software because of its flaxibility and easy programability. This program consists of two parts. One is the mathematical routine that calculates the gravity effect of the polygonal structures modeled for original gravity values. The second part consists of the graphic routines that are used in order to design the polygon and also to display the comparison of the true and simulated gravity effects.

CHAPTER 1

INTRODUCTION

The computers are used in two ways to calculate the gravity anomalies. One way is the use of computers for the contouring of the gravity values recorded from the field for the manual calculation of the gravity anomalies. The other is the direct application in the computation of the gravitational effect of bodies of arbitrary shape, by developing the expressions for attraction as recursive formulae that are conveniently handled by the computers. These bodies are either of regular geometrical shape or of irregular shape. This project involves the development of a software for the modeling of irregularly shaped bodies to determine the subsurface geological structure using gravity survey.

1.1 OBJECTIVE:

Objective of this project is to learn about various aspects of programming in C-Language and in doing so develop a usable software for geophysical applications.

1.2 METHOD FOR CALCULATION OF GRAVITY EFFECT:

The method used for the calculation of the gravity effect in this software is generally known as Tilwani's method as it was developed by Manik Tilwani in 1965. It involves the treatment of the subsurface structure as a n-sided two dimensional polygon and the integrated gravity effect of this n-sided polygon is taken as an approximation to the gravity effect of the subsurface structure. The calculation involves long formulations that contain log and trigonometric functions that are very difficult to solve without the help of computers.

1.3 C-LANGUAGE:

C-Language was used in this project for the devalopment of the software. It is a programming language developed at AT&T Bell Laboratories of USA in 1972. In the late seventies C started becoming more and more popular as it is reliable simple and easy to use. It provided replacement for mostly used languages of that time PL/I, ALGOL because it meant to be friendly capable and reliable (Lafore, 1990).

The reason of selecting C-language for the present project apart from it's being easy to handle was that it provides batter machine efficiency like machine oriented languages and also gives batter programming efficiency of high level languages. Another important advantage of C-language is it's great variety of functions that makes it more flexible than other programming languages. It has also got a large graphic library that makes graphics much easier to handle while working with C-language. It's facility of pointers has also made passing of values between functions and working with arrays much easier.

CHAPTER 2

GRAVITY MODELING

2.1 GRAVITY EFFECT OF THE EARTH:

According to the Newton all the material bodies in the universe attract each other with a certain force known as gravitational force. Gravitational force although a weak force is the fundamental force in the universe. All the heavenly bodies in the universe are held together by this force in the form of solar systems and galaxies.

A region in which a body exerts gravitational force is called gravitational field of that body. Our earth also has its own gravitational field which attracts the bodies present around it towards its center. The gravitational field of the earth is almost constant at any point on the earth ,with a small but regular increase in the gravity value from the equator to the polls due to the ellipsoidal shape of the earth.

2.2 GRAVITY SURVEY:

Apart from the overall regular variation of the gravitational field of the earth there is some regional variation in the field. This variation is due to the change in the subsurface geological features on a local scale. In order top investigate in the geology of an area on the basis of this variation gravity survey is conducted . This variation arises mainly due to the density contrast of a causative body, which is a rock unit, from the surroundings. A causative body represents a subsurface zone of anomalous mass and causes a localized perturbation in the gravitational field known as gravity anomaly. A very wide range of geological situations give rise to the zones of anomalous mass that produces significant gravity anomalies. On a small scale, buried relief of a bedrock surface, such as a buried valley can give rise to a measurable anomaly. On a large scale, small negative anomalies are associated with salt domes. On amore larger scale, major gravity anomalies are created by granite plutons or sedimentary basins. Interpretation of the these gravity anomalies is done to have an assessment of the probable depth and shape of the causative body (Kearey, 1984).

2.3 GRAVITY MODELING:

The interpretation of the gravity anomalies is generally done through the simulation of the causative body by a model and whose theoretical anomaly can be computed. The shape of the model is altered till the computed anomaly closely matches the gravitational effect caused by the anomalous body. This procedure is much easier if the subsurface anomalous body is of regular shape whose size, position, form and density contrast can be altered to have the best fit. but it becomes quite difficult if it has a irregular shape. Our project is mainly concerned with the calculation of the gravity effect of irregularly shaped bodies.

2.4 GRAVITY EFFECT OF THE IRREGULARLY SHAPED BODIES:

Irregularly shaped bodies can be analyzed in two ways. One way is to divide the irregularly shaped body into a number of regularly shaped bodies and then sum up the gravitational effect of all these regularly shaped bodies to find the approximate gravitational effect of the irregular shaped bodies. The second method is to change the three dimensional body into a two dimensional irregular shaped body and then approximate this two dimensional body with a 'n' sided polygon and find its gravitational effect.

Many people since 1934 have tried to find the solution of this 'n' sided polygon. The work was started by Ovening Meinz in 1934. Hubard in 1948 showed that the gravitational attraction due to a two dimensional body can be expressed in terms of line integral around its boundary as

$$g_z^{n\text{-}poly} = 2\Delta\sigma G \int z\,d\theta \text{ ------- } (1)$$

Where $g_z^{n\text{-}poly}$ is the gravitational effect of the n -sided polygon, $\Delta\sigma$ is the density contrast and G is the universal gravitational constant.

Tilvani in 1965 considered the case of 'n' sided polygon and divided the line integral into 'n' contributions. According to him for a point P(z, θ) which lies on side AB of the polygon ABCD....A (fig 2.1) (Tilwani, 1965)

$$z = (x_{i+1}(z_{i+1}-z_i)-z_{i+1}(x_{i+1}-x_i))/(\cot\theta(z_{i+1}-z_i)-(x_{i+1}-x_i)\text{---------}(2)$$

Substituting this value of 'z' and carrying out the intigrtation and summing similar terms for gravity effect of bodies of triangular crosections OBC, OCD, etc., we can obtaain the gravity effect of the body with the crossection ABCD....A as

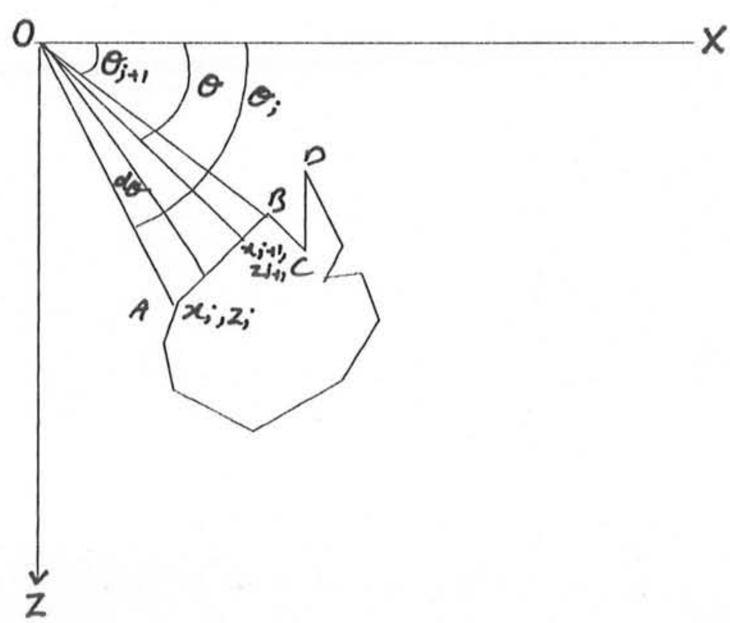

Fig 2.1

$$g_z^{n\text{-}poly} = 2\Delta\sigma G\Sigma Z_i \text{ ------- } (3)$$

where Z_i is the line integral along the ith side of the polygon. Tilwani derived the expression for Z_i by making intensive reference to trigonometric functions as

$$Z_i = a_i\sin\phi_i\cos\phi_i[(\theta_i-\theta_{i+1})+\tan\phi_i\ln((\cos\theta_i(\tan\theta_i-\tan\phi_i))/((\cos\theta_{i+1}(\tan\theta_{i+1}-\tan\phi_i)))]$$

where

$\theta_i = \tan^{-1} z_i/x_i$

$\theta_{i+1} = \tan^{-1} z_{i+1}/x_{i+1}$

$a_i = x_{i+1} + z_{i+1}((x_{i+1}-x_i)/(z_{i+1}-z_i))$

(x_i , z_i) is the ith coordinates of the n-sided polygon.

The origin has to be shifted to the point of observation in order to apply the Tilwani's formula. When this translation of axis takes place several situations arise some of witch are given below

CASE-1:

If $x_i = 0$

$$Z_i = -a_i\sin\phi_i\cos\phi_i[\theta_{i+1}-\pi/2+\tan\phi_i\ln((\cos\theta_{i+1}(\tan\theta_{i+1}-\tan\phi_i)))]$$

CASE-2:

If $x_{i+1}=0$

$$Z_i = a_i \sin\phi_i \cos\phi_i[\theta_{i+1} - \pi/2 + \tan\phi_i \ln((\cos\theta_i(\tan\theta_i - \tan\phi_i)))]$$

CASE-3

If $z_i = z_{i+1} = z$

$$Z_i = z_i(\theta_{i+1} - \theta_i)$$

CASE-4

If $x_i = x_{i+1} = x$

$$Z_i = x_i \ln(\cos\theta_i / \cos\theta_{i+1})$$

CASE-5

If $\theta_i = \theta_{i+1}$

$$Z_i = 0$$

CASE-6:

If $x_i = z_i = 0$

$$Z_i = 0$$

CASE-7:

If $x_{i+1} = z_{i+1} = 0$

$$Z_i = 0$$

CHAPTER 3

SOFTWARE DEVELOPMENT

3.1 INTRODUCTION:

The software mainly consists of two main parts. One is the editor used for the entry of the observed data, other is the graphic part which is used to display the observed data plot , edit and display the polygon and display the calculated effect of the polygon. The calculations are made with a separate routine which involves Tilwani's formula for the determination of the gravity effect of the polygon. These subroutines are linked with by the main routine.

3.2 THE MAIN ROUTINE:

The main routine is allowed to work in the graphic mode. It consists of two parts. The first part displays the name of the program in graphic mode in defined size and text. In the lower portion effect of earth's crossection is displayed.

MAIN SCREEN

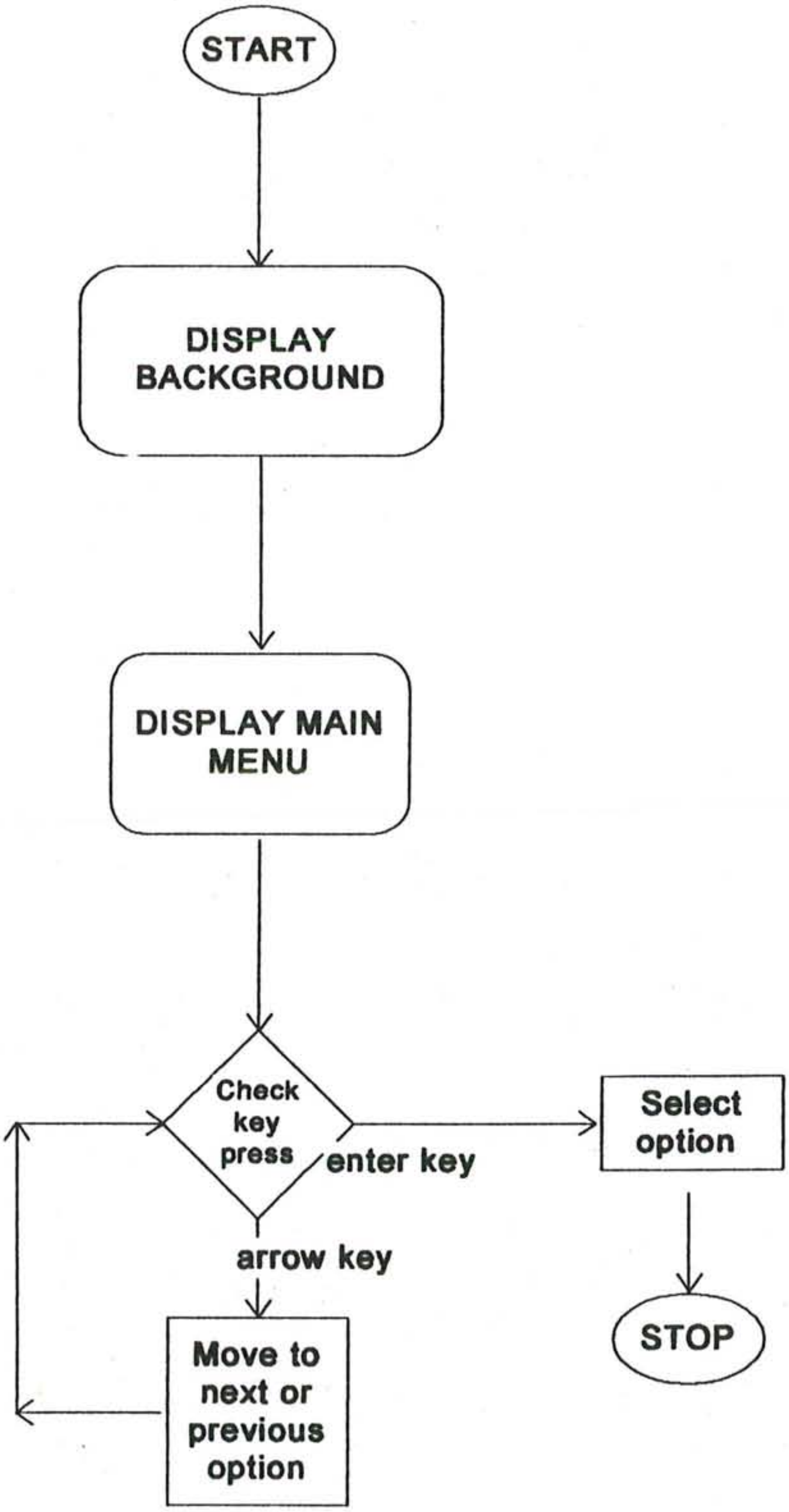

Fig 3.1

The second part of the main routine consists of the main menu which is controllable through arrow keys and control is shifted to the selected routine when return key is pressed. The main logic used in the almost all the menu routines applied in this software is given in fig 3.1.

The code for the right and left arrow keys is used to add or subtract one respectively from a variable whose value varies between 0 and the number of options in the menu routine. Using the resultant value of the variable the control is transferred to the instruction set that hilightens a options on the main option bar and then a key has to be pressed again for further instructions. The next or previous option is highlighted if right or left arrow key is pressed respectively. Otherwise if return key is pressed control is transferred to the selected routine.

3.2.1 ekbc( ) FUNCTION:

This function is extensively used in this program to get the code for the keyboard keys. These codes are either single byte keys such as numeric and alphabetic keys or they are two byte keys. In the present case the right arrow and left arrow keys are two byte keys. First byte is a zero byte while the second byte contains the code of the key called extended keyboard code. This function is used to identify the key pressed and return only it's extended keyboard code eliminating the zero byte from it. It checks whether the first byte of the key pressed is zero or not. If it is zero then it checks for the second byte and returns it's value to the calling routine else it returns the first byte to the calling routine (fig 3.2).

3.3 editor( ) FUNCTION:

It is another major function of the program. It's purpose is to edit the observed gravity data file (fig 3.3). Editor( ) function has two main parts. One is it's menu which has the same logic as for the menu in the main routine with only difference that it is in text mode. The second part is a spread sheet used for the editing of data. It has four columns and 1000 rows. First column is a counter that displays the row number. The other three columns are for station number, distance and gravity value. All the entries in the spread sheet are of type character. The distance and gravity values are converted into type float at the

ekbc() FUNCTION

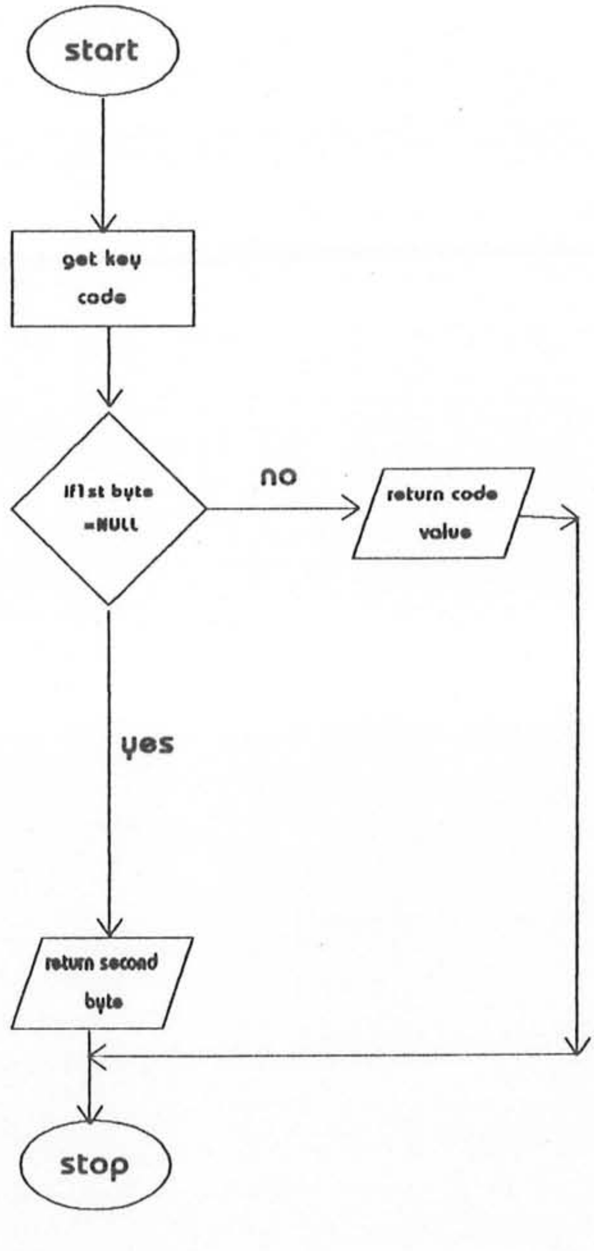

Fig 3.2

editor( ) FUNCTION

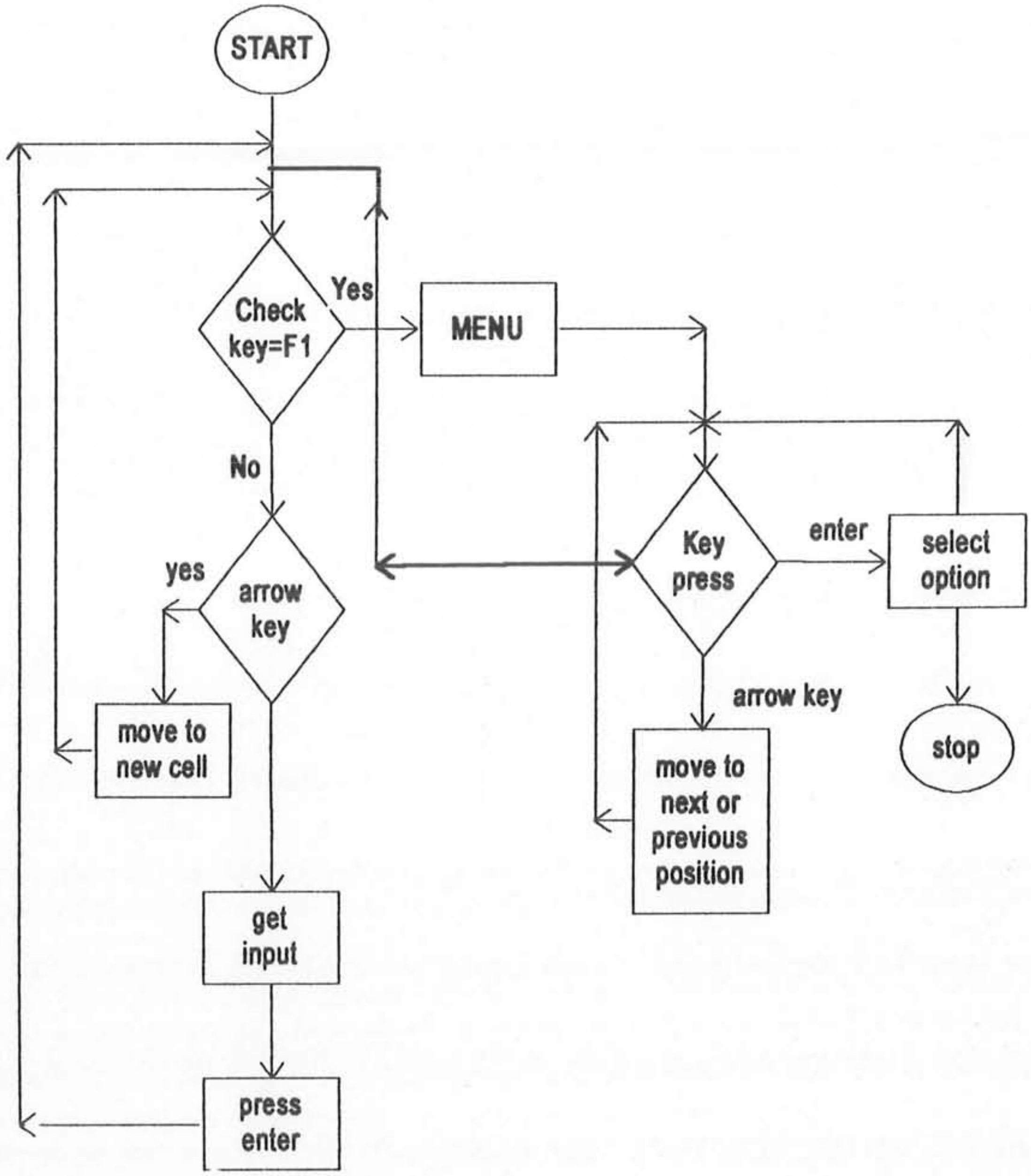

Fig 3.3

time of saving the data. Likewise they are converted back to type character when an existing data file is opened. When a new file has to be created the existing values in the arrays are made equal to zero.

The value on the spread sheet are entered in the cell displayed on the screen. The cell is empty if the value at the cell location is zero otherwise previous value is displayed in the cell that can be changed. First character of the input string is fetched separate from the rest of the string. This is done in order to distinguish the function keys from the character keys. If the key pressed is a function key such as up arrow, down arrow etc., then the computer performs the function instructions as according to the program else it gets rest of the string. 'F1' function key is used to access the editor menu from where the data entered can be saved giving the file name without any extension. All the observed data files are saved with a file extension of 'obs' by the editor( ) function. It is done by adding four characters '.', 'o', 'b', and 's' at the end of the file name. Also when a file is opened the program searches for the file after adding 'obs' extension to it's name.

3.4 polygon( ) FUNCTION:

This is fully graphical function used to display the graph of observed data, draw polygon and compare the gravity effect of the polygon with the observed gravity effect (fig 3.4). It consists of four major parts

3.4.1 grpmnu( ) FUNCTION:

This is a general use menu function that works under graphic mode (fig 3.5). It gets it's x and y coordinates, text of options to be displayed and the number of options from the calling function. It then vertically divides the polygon formed by the input coordinates into the number of parts equal to the number of options. Then it displays the text of the options in each part. A switch statement is used to move between option in order to select the desired one. When an option is selected and return key is pressed it returns the option number to the calling function that can be used with the help of a switch statement to perform the task. The cases of this switch statement are assigned the option number of the task it has to perform and control is transferred to it whenever that particular option is selected. It is quite flexible

polygon() FUNCTION

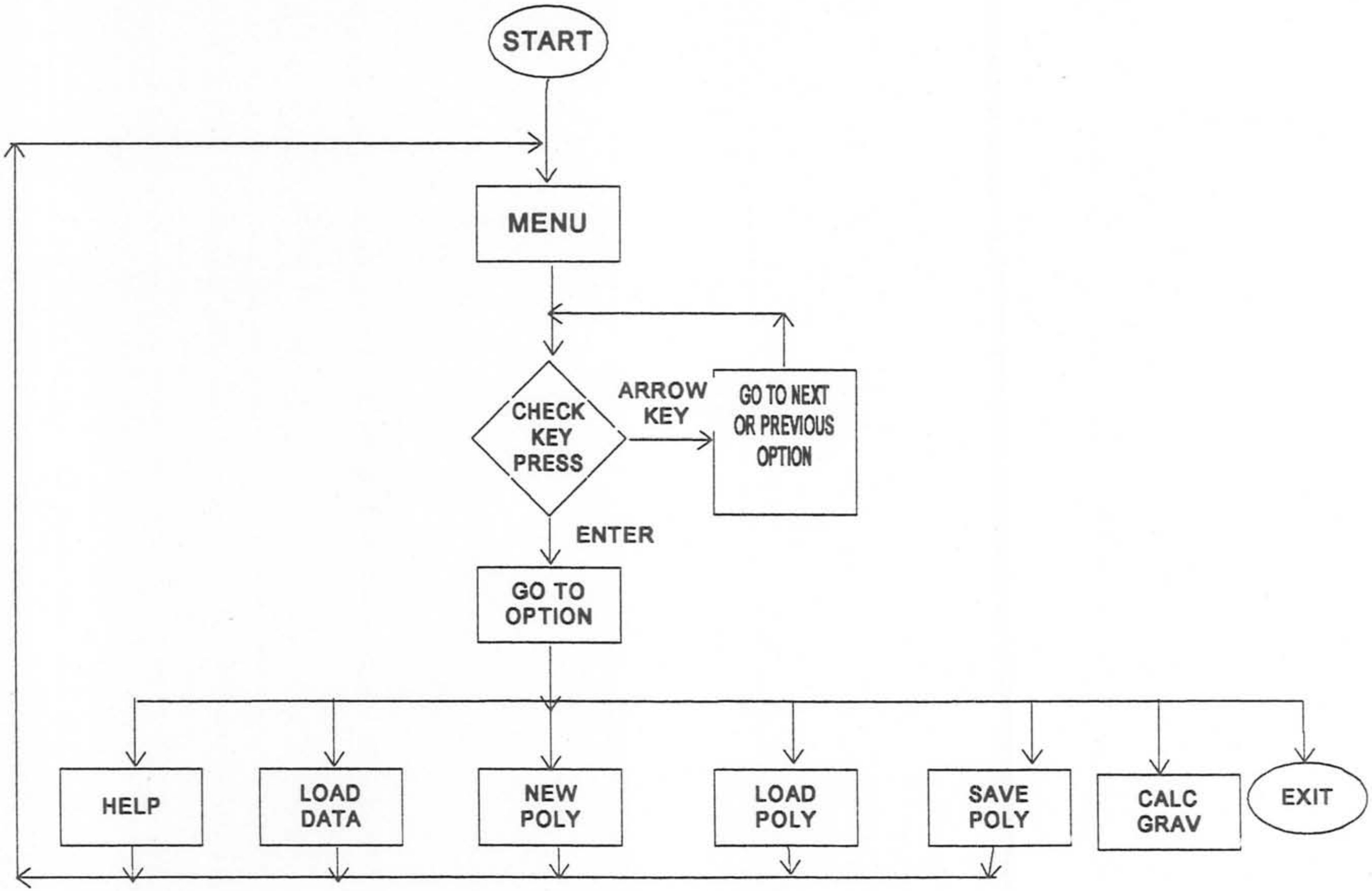

Fig 3.4

GRPMNU() FUNCTION

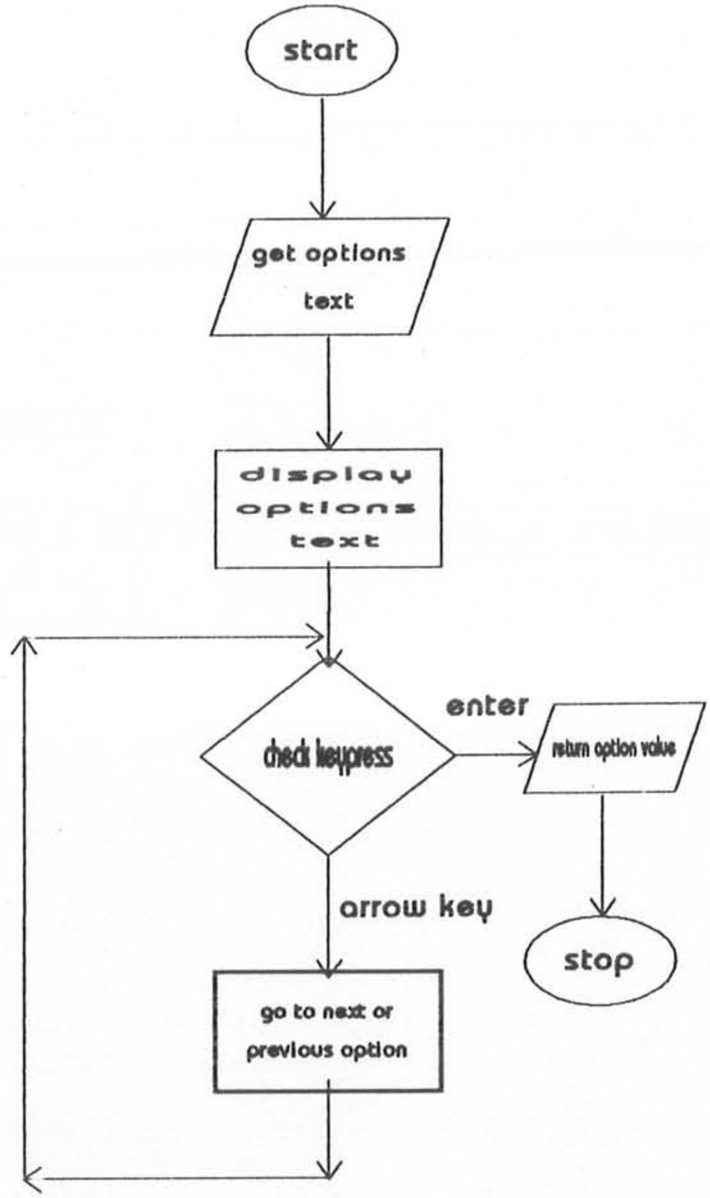

Fig 3.5

routine and any number of options can be assigned to it according to requirement.

In the polygon( ) function the grpmnu( ) function was used to form it's menu. This menu has the options of displaying help, loading observed data, opening and saving polygons etc.

3.4.2 DRAWING GRAPH OF OBSERVED AND CALCULATED GRAVITY EFFECT:

Second major function of polygon( ) is to display and compare the graphs of the observed data and the calculated effect of the drawn polygon. The scale of the graphs is set separately according to the maximum and minimum values present in the observed and calculated gravity effects. The minimum gravity value is set to zero if the minimum gravity value is positive. If the data contains any negative value then the graph space is divided into positive and negative portion according to the ratio between the maximum positive and negative values and a zero line is placed according to the division. Whenever the control is transferred to this case it redraws the observed and calculated values to show the changes in the gravity effect by the change in the polygon coordinates. The size of the window in which the graphs are displayed can also be changed by the arrow keys and the graph is readjusted in the new window as it is drawn with respect to the window coordinates.

3.4.3 DRAWING POLYGON:

The third part of the polygon( ) function is to draw a polygon for the calculation of the gravity effect through Tilwani's formula. The polygon is drawn in the lower part of the screen by shifting the zero position to the lower part. The cursor control keys are used to adjust the position of the polygon coordinates. Cursor position is changed a line moves with it with it's starting point at the zero position at the initial stage and the last point at the current cursor position. A polygon coordinate is selected by pressing 'enter' key. This way line is drawn from the starting polygon position to the current cursor position and other from the current cursor position to the last polygon coordinate position selected. As the cursor position is changed the line showing the cursor position is moved to the new location and the old line is overwritten by a line of the having same color as that of the background. Various hot keys with different functions are provided to edit the polygon. By pressing a particular hot key the control is transferred to the instruction set to perform the desired process and the user can thus make changes in the polygon. These hot keys provide the following functions.

Move to the previous position:

This allows the cursor control to move to the immediate previous selected polygon coordinate. This is done by loading the coordinates of the previous position in the current position coordinates.

Insert a new line:

In order to insert a new line in the drawn polygon the coordinate array is shifted forward up to the point of insertion and the new coordinate value is written at the old coordinate value position of the array.

Deleting a coordinate:

The array of the polygon coordinates is shifted backwards to delete a selected coordinate from the polygon and the coordinate next to the selected coordinate is overwritten on the selected coordinate.

At the bottom of the display screen the three values are displayed.

One is the density contrast whose value is entered from the keyboard and can be changed when needed. The other two values are the real-time x and z coordinates depending upon the maximum distance and depth values.

The polygon coordinates can be saved and also retrieved through the menu in the polygon( ) function.

3.4.4 grvcalc( ) FUNCTION:

gravcalc( ) function is defined to calculate the gravity effect of the polygon drawn in the polygon( ) function. This function gets value of x and z coordinates and density from the calling function and returns the calculated gravity value to the calling function which is then drawn on the graph for the comparison with the real gravity values. In the grvcalc( ) function the gravity value for each coordinate value is calculated and is summed up to calculate the gravity effect of the whole polygon for each observation point of the observed gravity effect after shifting origin to the observation point for which the gravity effect has to be calculated.

CHAPTER 4

USER GUIDE

4.1 INTRODUCTION:

The "GRAVITY WORLD" software is fully menu driven software and is very user friendly. Its purpose is to allow the students and professionals in the field of geophysics, with a minimal computer knowledge to use this software for gravity calculation. It is mainly applied to simulate earth's internal structure using Tilwani's method, that generates gravity effect near to the observed gravity effect in a certain area. Options are provided to edit observed data, graphically represent the gravity variations, draw and edit a polygon and also to calculate and graphically display the gravity effect of the drawn polygon. The general program flow is shown in the fig4.1.

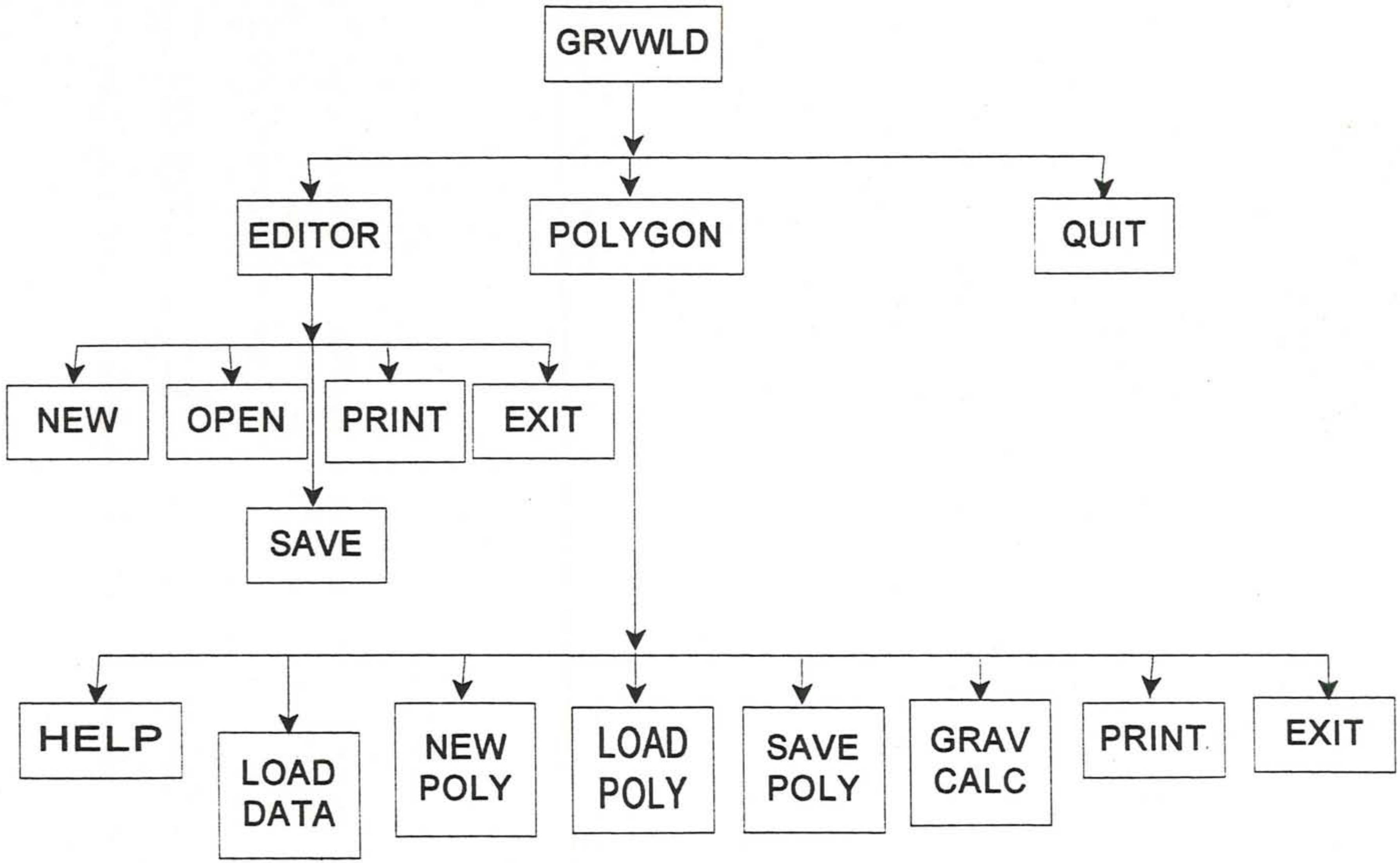
GRVWLD
EDITOR
POLYGON
QUIT
NEW
OPEN
PRINT
EXIT
SAVE
HELP
LOAD DATA
NEW POLY
LOAD POLY
SAVE POLY
GRAV CALC
PRINT
EXIT

FIG 4.1

4.2 STARTING UP:

The program can be executed through "grvwrld.exe" file. At the start of the program it's main menu is displayed on the screen as shown in the fig 4.2. The main menu consists of the following options one of which can be selected using the right and left arrow keys.

4.2.1 EDITOR:

This option is used the activate the editor used to edit the observed gravity values. This is done by pressing the return key after highlighting the option.

4.2.2 POLYGON:

This option activates the graphical part of the software that displays the observed gravity value graph and also used to draw polygon and calculate the gravity effect of the polygon. This option is also activated by pressing "enter" key.

4.2.3 QUIT:

This option is used to end the program and return to the DOS prompt.

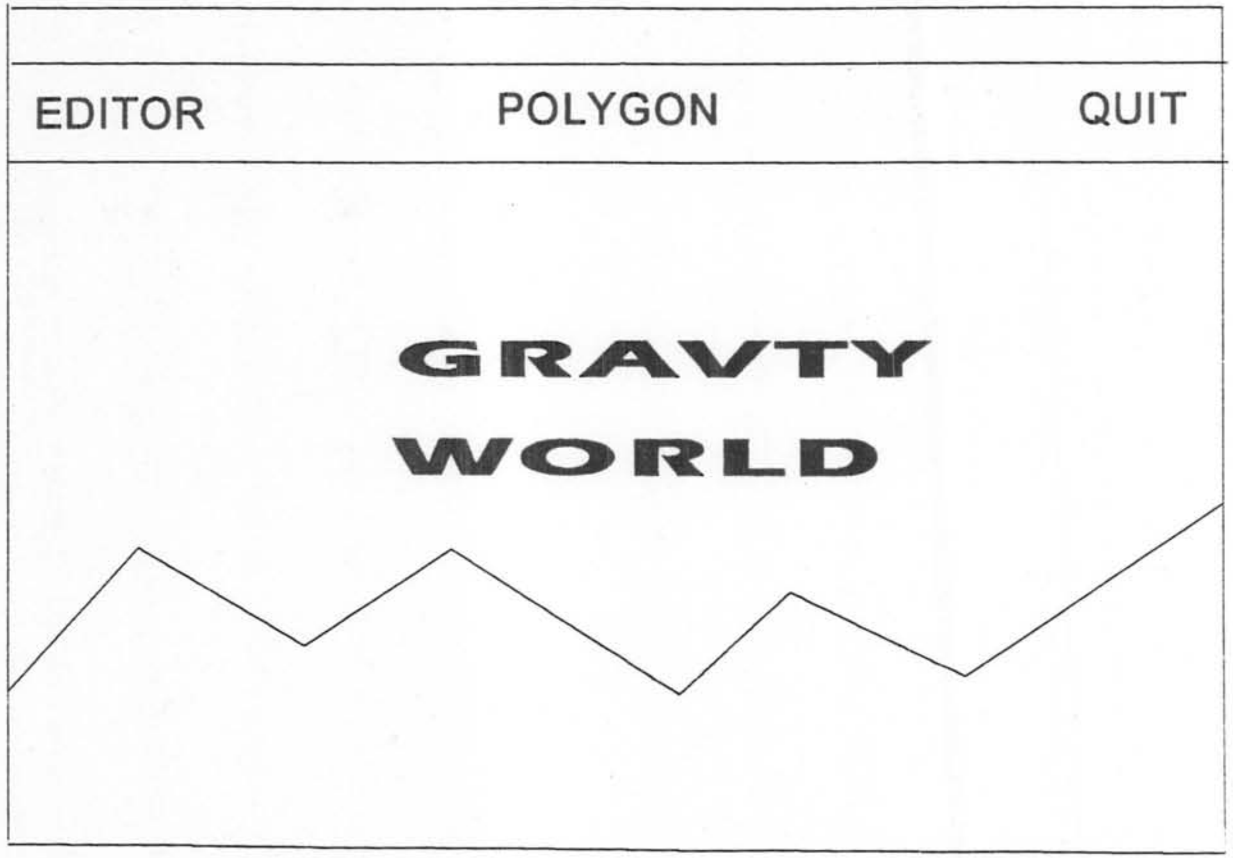

FIG 4.2

4.3 EDITING THE OBSERVED DATA:

This software has provided the facility of editing the gravity data and storing it in the files with a format readable to the software. The editor is in the form of a spread sheet with 4 columns and 1000 rows (fig 4.3).

The first column shows the serial number of the values entered. These serial numbers are internally generated to count rows as we move down the rows. The second column is for the observation points whose values are entered by the user. This column accepts both alphabetic as well as numeric values. The third point is for the distance of the observation point from the base station. This column accepts only numeric values. The forth column is for observed gravity values and it also accepts only numeric values. The values are entered in cells. The cell position can be changed by arrow keys and the value entered can be accepted by pressing the "enter" key. If a value already exists in the selected cell it is deleted on entering a new value. The editor is a is a menu driven program. One can switch to its menu by

PRESS F1 FOR MENU COMMANDS

S.NO.	OBS.PT	DISTANCE(meters)	GRAVITY(mgals)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			

FIG 4.3

pressing 'F1' function key (fig 4.4). The menu has got the following options.

4.3.1 NEW:

This option is used to create a new data file. If a file is already open following message is displayed.

SAVE CURRENT CHANGES(Y/N)

Press 'N/n" to discard the changes.

Press 'Y/y' to save the changes. The computer displays the following message.

SAVE FILE AS "file name"(Y/N)

"file name" is the name of the file already open.

Press 'Y/y' to save the changes in the existing file.

Press 'N/n' to save changes in a new file. The computer will ask the new file name. Enter the name by which the file is to be saved. After saving the file the screen will be cleared to enter new values.

NEW OPEN SAVE PRINT EXIT

S.NO.	OBS.PT	DISTANCE(meters)	GRAVITY(mgals)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			

FIG 4.4

4.3.2 OPEN:

This command allows to open an existing data file. For this purpose select the "OPEN" option and press enter following message will appear on the screen.

ENTER THE NAME OF THE FILE TO OPEN

Enter the name of the existing file which is to be opened and the contents of the files will be displayed on the screen. If a file is already open the program will prompt to save the file before opening an new one following the same procedure as in case of creating a new file.

4.3.3 SAVE:

This option allows to save data with a user defined file name. This option when selected displays the following option if a new file has to be saved.

ENTER THE FILE NAME

Enter the desired file name without any extension as program automatically assigns "obs" extension to the data file.

If changes in an existing file are to be saved following message is displayed.

SAVE FILE AS "file name"(Y/N)

"file name" is the name of the file already open.

Press 'Y/y' to save the changes in the existing file.

Press 'N/n' to save changes in a new file. The computer will ask the new file name. Enter the name by which the file is to be saved.

4.3.4 PRINT:

This option allows the user to produce a hard copy of the observed gravity data entered.

4.3.5 EXIT:

This option closes the editor and shifts the control to the main menu. If a file is already open the program will follow the same procedure as in case of creating a new file, to save the current changes before exiting.

4.4 EDITING POLYGON AND CALCULATING IT'S GRAVITY EFFECTS:

The main function of the "GRAVITY WORLD" software is to provide simulation facility for the earth's internal structure in the form of polygons in order to determine the real earth structure through gravity survey. This part of the program provides this facility of calculating the gravity effect of user defined polygon through Tilwani's formula and compare it with the teal gravity values in the survey area to have a true picture of the earth's internal structure.

The screen for this part is divided into three parts as shown in the fig 4.5. One part displays the gravity observed and calculated gravity values, the second is for editing the polygon and the third is the menu. The menu provides the following options.

4.4.1 HELP:

This part of the program provides help for the hot keys used for editing the polygon coordinates and screen adjustments for the display

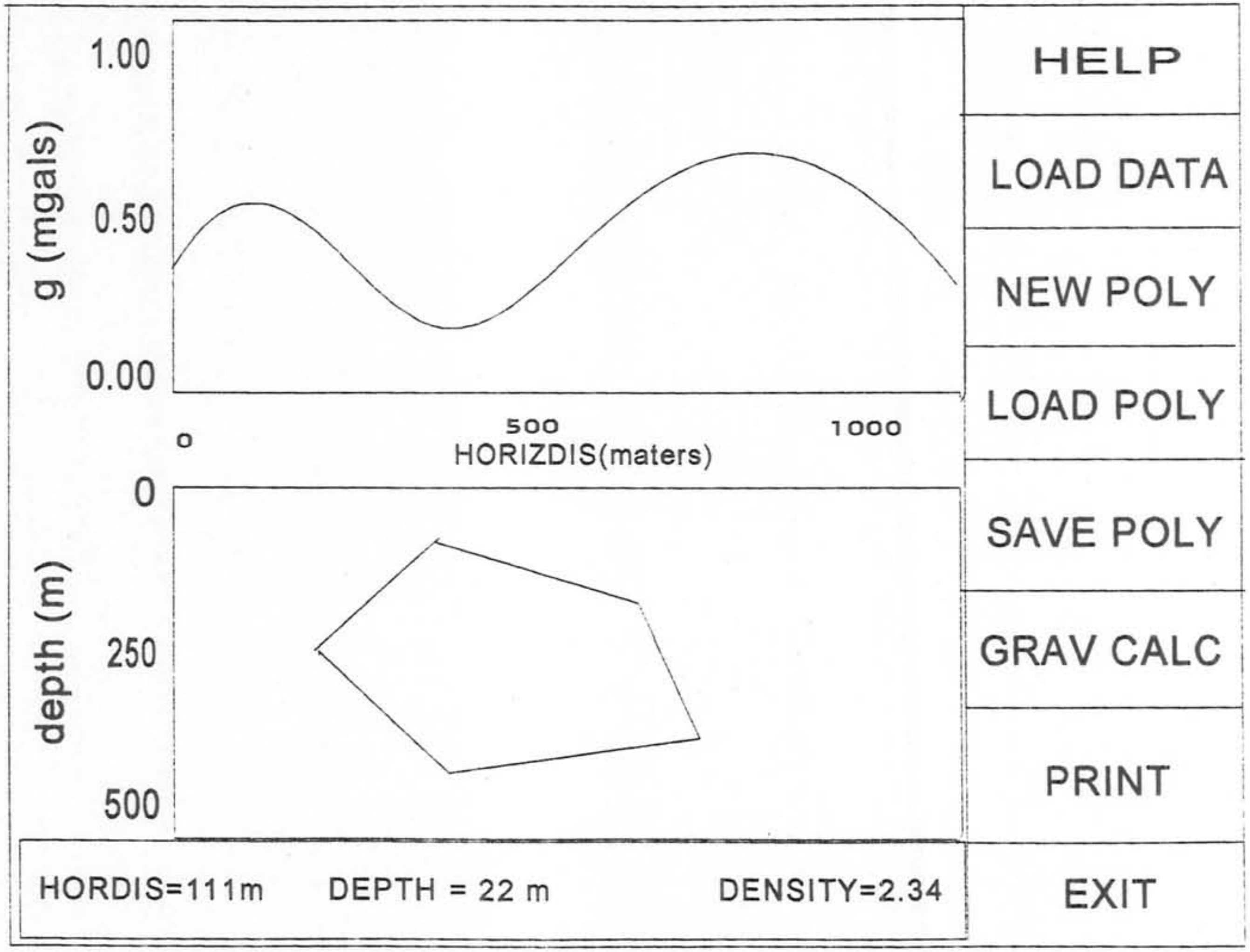
1.00
0.50
0.00
g (mgals)
0
500
1000
HORIZDIS(maters)
0
250
500
depth (m)
HORDIS=111m
DEPTH = 22 m
DENSITY=2.34
HELP
LOAD DATA
NEW POLY
LOAD POLY
SAVE POLY
GRAV CALC
PRINT
EXIT

FIG 4.5

of gravity graphs. Following message is displayed if this option is activated.

For polygon:

^D:Changing density value

^Z: Changing maximum depth

Up Arrow: Moving polygon coordinates upward the screen.

Down arrow: Moving a polygon coordinate downwards the screen.

Right Arrow: Moving the polygon coordinate rightward on the screen.

Left Arrow: Moving the polygon coordinate leftward on the screen.

Insert: Inserting a new coordinate in the polygon.

Del: Deleting a polygon coordinate.

Page Up: Moving to previous polygon coordinate.

Page Down: Moving to next polygon coordinate.

Gravity graph:

Up Arrow: Expanding the graph window vertically.

Down Arrow: Reducing the graph window vertically.

Right Arrow: Expanding the graph window horizontally.

Left Arrow: Reducing the graph window horizontally.

4.4.2 LOAD DATA:

This option allows to load an observed data file. If this option is selected following message is displayed.

ENTER NAME OF THE OBSERVED DATA FILE

Enter the name of the file to be used and the graph of the gravity graph shall be displayed in the gravity graph window.

4.4.3 NEW POLY:

This option allows to draw a new polygon but if a polygon is already drawn on the screen it displays the following message window

SAVE CURRENT POLYGON(Y/N)

Press 'N/n' to discard the current changes.

Press 'Y/y' to save the current changes. In this case the computer will display \the following message if the drawn polygon already has a file name.

SAVE POLYGON AS "file name"(Y/N)

If you want to save the polygon with the existing name press 'Y/y" else press 'N/n' then you will be asked for the new file name by which the polygon has to be saved.

If the polygon does not have any existing file name then this message is displayed if the current polygon is to be saved.

ENTER NEW FILE NAME

After saving the current polygon the screen will be cleared and a new polygon can be drawn.

4.4.4 LOAD POLY:

This option allows the user to load an existing polygon file. If this option is selected computer asks for the file name to be loaded which is to be entered by the user. If a polygon is already loaded the program will follow the same procedure to save current changes before opening a new one.

4.4.5 SAVE POLY:

This option allows the user to save a new polygon or the changes in an existing polygon. If a new polygon has to be saved computer asks the user to enter the file name to save the polygon that should be without any extension as a polygon is always saved with a "ply" extension.

If an existing file has to be saved following message is displayed.

SAVE POLYGON AS "file name"(Y/N)

If you want to save the polygon with the existing name press 'Y/y" else press 'N/n' then you will be asked for the new file name by which the polygon has to be saved.

If the polygon does not have any existing file name then this message is displayed if the current polygon is to be saved.

ENTER NEW FILE NAME

Enter the name by which you want to save the existing file.

4.4.6 GRAV CALC:

When a polygon is completed this option is used to calculate the gravity effect of the polygon end draw it's graph in the gravity graph window. The graph of the calculate gravity effect is updated each time this option is used.

4.4.7 PRINT:

When this command button is pressed it allows to produce a hard copy of the graphs being displayed on the screen.

4.4.8 EXIT:

This option is used to exit from the polygon option to the main menu. Before exiting the program will save the existing polygon following the same procedure as before drawing a new polygon.

REFERENCES

Kearey, P., 1988, An Introduction to Geophysical Exploration, Blackwell Scientific Publications, England.

Lafore, R., 1990, C Programming Using Turbo C++, Macmillian Computer Publishing, Indiana.

Tilwani, M., 1967, Computation of Gravity Anomalies.