Programs for Grid-Free Object-based Facies Modeling of IHS Sets

Rahman M. Hassanpour and Clayton V. Deutsch

The grid-free object-based facies modeling of IHS sets algorithm has been presented in papers 107 and 203 of this report. Two GSLIB style FORTRAN codes called IHSSIM *and* IHSRAST *are developed to implement this algorithm. This paper explains the workflow and shows examples of the parameters and the required input files.*

1. Introduction

The main idea of the grid free object-based modeling is to store all the geo-objects and geological sequences in the model without relating them to a particular grid system. As mentioned in paper 107 in this report, implementation of grid free object-based modeling involves setting up three main components. For the application of Inclined Heterolithic Stratification (IHS) modeling in the grid free mode, two FORTRAN programs have been developed; IHSSIM, and IHSRAST. IHSSIM is the simulation engine and the IHSRAST is the rasterization engine. Details of these two programs are presented in this paper.

2. IHSSIM Program

IHSSIM program is a GSLIB style program that is developed to generate unconditional IHS facies realizations in a grid-free simulation mode. The program starts with reading the parameter file. If the parameter file does not exist, then a default parameter file is generated automatically.

The default parameter file for IHSSIM in shown in Figure 1. The geological object database file is specified in **line 1**. For this application the geological object database is optional because it has been integrated in the code however, it is included in the parameter file for future applications and developments. The output grid free model is written out to the file that is specified on **line 2** of the parameter file. **Lines 3** to **5** ask for the size of the model in *x*, *y*, and *z* coordinates. The channel source is specified with the mean and standard deviation of x and y coordinates in **line 6**. Mean and standard deviation of channel azimuth is specified in **line 7**. In **line 8** the mean and standard deviation of the meandering wavelength should be specified. **Lines 9** and **10** ask for the ratio of amplitude and width to the half wavelength. Mean and standard deviation of Gaussian distribution for the IHS thickness and dip are specified in **line 11** and **12**. The maximum number of accreationary surfaces is specified in **line 13**. This is required for allocation of dynamic arrays for drapes. Number and elevation of aggradation levels are specified in **line 14**. **Line 15** asks for the number of channels in each aggradation level. The shale drape frequencies in each level are specified in **line 16**. Top shale thickness and the bottom breccias are specified in terms of percentage of total IHS thickness in **line 17** and **18**. The probabilities of appearance for each profile type should be specified in **line 20**. The random number seed and the number of realization to be generated are specified in **line 21** and **22**. See paper 203 of this report for examples of models generated with this program.

The general program workflow is shown in Figure 2. The simulation starts by picking a random location and angle for the channel source and channel azimuth, respectively. Then the geometric parameters of IHS sets are randomly selected from the user specified distributions and the object is located on the channel line. More IHS set will be generated for this channel if the anchor points of new IHS set falls inside the modeling area. In order to maintain the continuity of the channel along the channel line, the channel width, IHs thickness, and IHS dip are assumed to be constant along the channel stream. The amount of shale drapes in the IHS sets are controlled by the shale frequencies. Larger frequency value leads to generation of more shale drapes. Although, the program does not use any vertical trend but the facies proportions can be partially controlled by the number of levels, number of channel and the shale frequencies in each level. The simulation terminated when enough realizations are generated.

The output file of the IHSSIM program is an ASCII file format. Figure 3 shows an example of the IHSSIM output file. The first five lines in the output file are the header. The first line of header is a description. Lines 2 to 4 are showing the size of model and the fifth line indicates the number of

realizations in the output file. There are different keywords that are used in the output file. These keywords are used by the rasterization program to generate gridded model. Table 1 provides a brief description of the keywords.

Table 1: Descriptions of Keywords in `IHSSIM` output file.

Keyword	# of Variables	Description
REALIZATION	3	Identifies the realization number, number of IHS objects in this realization, and maximum number of shale drapes in this realization
IHS_SET	1	Indicates the IHS object number
{	0	Indicates the start of parameters block
}	0	Indicates the end of parameters block
IHS_BODY	12	Shows (x,y) coordinates of top six points of IHS body
BOX	6	Indicates the IHS bounding box in the format of xmn xmx ymn ymx zmn zmx
ANCHOR	4	Indicates the anchor points coordinates in the format of xm ym ztop zbot
PROFILE	2	Shows the slope on top and bottom
CHANNEL	2	Indicates channel width and channel thalweg
TOP_SHALE	1	Indicates the top shale thickness
BRECCIA	1	Indicates the breccias thickness
DRAPE	10	Indicates (x,y) coordinates of top four points of shale drape, thickness at top, and the vertical length

3. `IHSRAST` Program

`IHSRAST` is the rasterization engine that has been developed to generate the gridded facies model of IHS sets. The model from `IHSSIM` need not be rasterized in a grid free modeling framework; however, there are currently insufficient programs and tools to be able to model properties grid free. While these tools are being developed, IHSTAST can be used to populate a regular grid with the desired facies codes and proportions.

Figure 4 shows the default parameter file for `IHSRAST`. The geological object database file is specified in **line 1**. For this application the geological object database is optional because it has been integrated in the code however, it is included in the parameter file for future applications and developments. The grid free model file that was generated with the `IHSSIM` program should be specified in **line 2**. **Line 3** asks for the output gridded facies model file name. The grid specifications are specified in **lines 4** and **5**.   The architectural elements facies code can be specified in **line 7**. **Line 8** asks for the realization number to be rasterized. The program allows users to choose from four different rasterization options. The flag code for rasterization engine is defined in **line 9**. If the rasterization option in **line 9** is set to cross section rasterization, then the slice number is specified in **line 10.** If the facies proportions at each grid location are required, then the refinement grid numbers in each coordinate direction have to be specified in **line 10**.

Figure 5 shows the general workflow of `IHSRAST` program. The grid free model generated with the `IHSSIM` program is the input to the rasterization program. Rasterization stars with finding and indexing the objects to be rasterized, if the cross section is selected as a rasterization option, the section plane is compared to all objects boxes and the objects that cross the plane are indexed. For faster rasterization, the program loops over the objects first and then loop over the grids inside the object's bounding box.

4. Considerations and Limitations

The programs explained in this paper, are generated for research purposes. They can be used to generate unconditional realizations of IHS sets in McMurray Formation. The unconditional models can be either used as training images in multiple point simulators or directly as a facies model for testing purposes. The simulation engine program (IHSSIM) is very fast. For example, generating an unconditional grid free model for a 5km by 5km by 50 m model comprising 220 IHS set and about 110,000 shale drapes on a 2.00 GHz dual core machine with 4GB of memory takes only 13 seconds. There is a limitation in the number of grids specified in the IHSRAST program. The maximum number of grids may be different depending on the computer resources. Rasterization of large model with small grids would take hours to be executed. In that case, cross sections can be rasterized instead of the whole 3D model.

References

C.V. Deutsch and A.G. Journel. *GSLIB: Geostatistical Software Library and User's Guide*. Oxford University Press, New York, 2nd edition, 1998.

Line	START OF PARAMETERS:	
	Parameters for IHSSIM	
	********************	
1	estuarine.dbs	-file for Geo-object database
2	ihssim.gfm	-file for output grid-free model
3	0.0 5000.0	-xmn, xmx
4	0.0 5000.0	-ymn, ymx
5	0.0 50.0	-zmn, zmx
6	2500 100 0 10	-channel line source: mx, stdevx, my, stdevy
7	0 30	-channel line azimuth angle: m, stdev
8	1400 50	-meander wavelength: m, stdev
9	0.55 0.05	-meander amplitude to wavelength ratio: m, stdev
10	0.55 0.05	-IHS width to wavelength ratio: m,stdev
11	20 5	-IHS thickness: m, stdev
12	10 2	-IHS dip: m, stdev
13	2000	-max. number of accreationary surfaces
14	4 15 25 35 45	-number of levels, level elevations
15	5 7 5 10	-number of channel in each level
16	0.1 0.2 0.3 0.4	-shale drape frequency in each level
17	10 5	-top shale thickness(% of thickness): m, stdev
18	10 5	-breccia thickness(% of thickness): m, stdev
19	0.4 0.1	-channel thalweg: m, stdev
20	0.6 0.3 0.1	-profile probability for:sigmoidal,convex-up,concave-up
21	75079	-random number seed
22	1	-number of realization to generate

Figure 1: Parameter file for the IHSSIM.

Program Start

Parameter file exist?

No

Create par. File

Read Parameters

Loop over realizations

Yes

Last realization?

No

Loop over levels

Yes

Last level?

No

Loop over channels

Yes

Last channel?

No

Pick geometric parameters for IHS set and place it on channel line

Write the grid-free model to the output

Program End

More IHS set fo this channel?
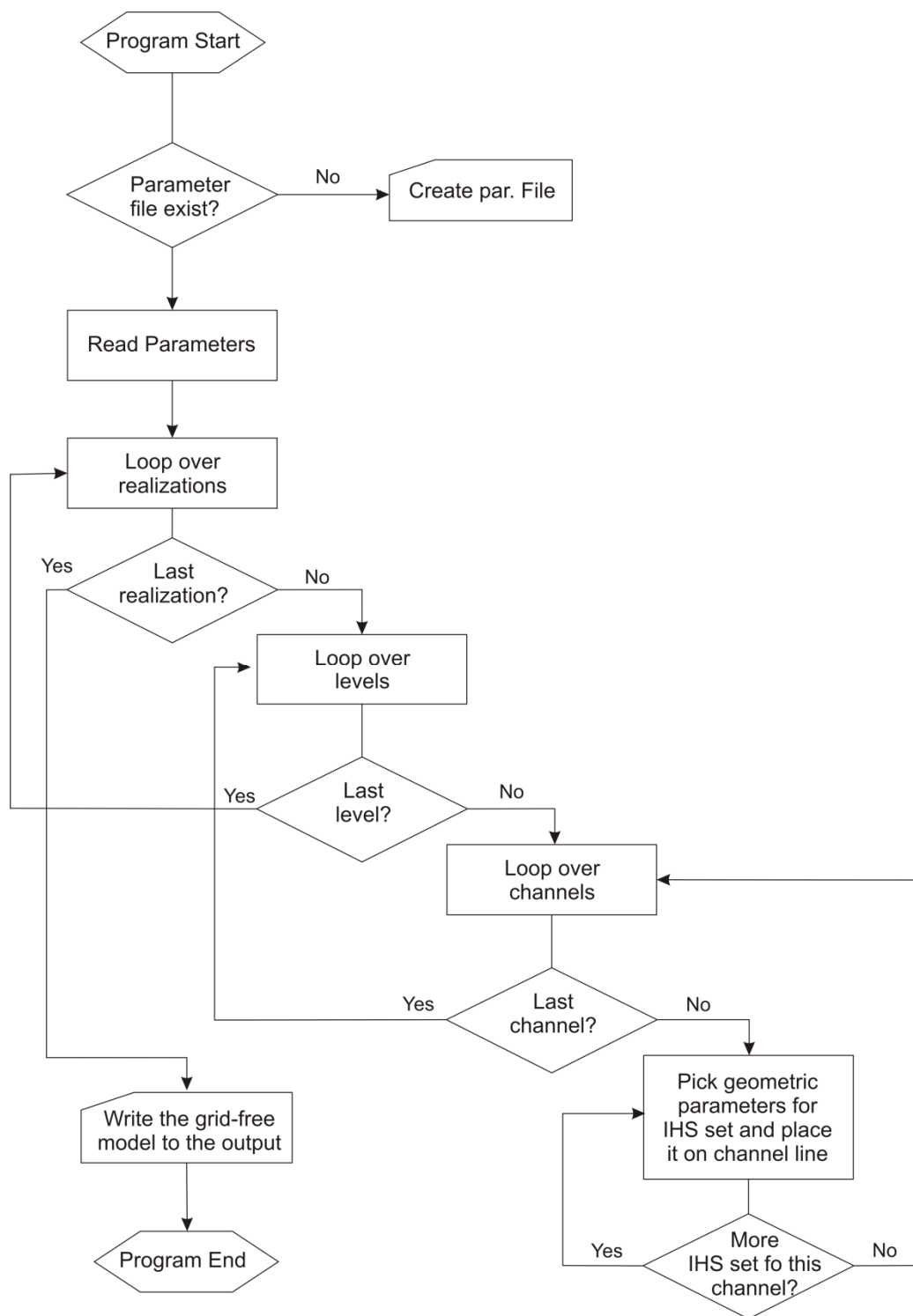
Yes

No

Figure 2: Workflow of the `IHSSIM` program for grid-free IHS facies modeling.

```
Grid Free IHS Facies Model  Generated with IHSSIM version 1.0
0.0          5000.0
0.0          5000.0
0.0            50.0
1
REALIZATION        1      2      5
IHS_SET            1
{
IHS_BODY      3007.9  762.1 2617.4  936.0 2104.4  715.8 2362.7  221.0 2743.5  120.1 2798.6     468.6
BOX           1963.3 3056.1    3.0 1053.0    4.9   20.0
ANCHOR        2875.7  441.1   20.0    4.9
PROFILE          0.0    0.0
CHANNEL        126.7    0.4
TOP_SHALE        1.3
BRECCIA          1.7
DRAPE         2926.4  652.8 2793.1  470.6 2781.8  380.7 2795.8  469.6    2.9   12.6
DRAPE         2896.9  616.2 2790.6  471.4 2771.8  336.1 2793.0  470.6    2.6   10.7
DRAPE         2945.2  727.7 2765.6  480.4 2730.7  242.0 2768.1  479.4    2.7    9.9
}
IHS_SET            2
{
IHS_BODY      3056.1  879.3 3149.7  632.2 3687.7  694.1 3715.0 1234.9 3298.0 1466.9 3228.1    1125.2
BOX           3007.9 3937.9  405.8 1584.0    4.9   20.0
ANCHOR        3177.0 1173.1   20.0    4.9
PROFILE          0.0    0.0
CHANNEL        126.7    0.4
TOP_SHALE        1.8
BRECCIA          1.6
DRAPE         3224.0 1106.4 3235.1 1118.6 3258.8 1243.5 3233.6 1120.0    2.1    8.7
DRAPE         3108.7  932.8 3238.9 1115.0 3284.2 1346.2 3237.2 1116.6    2.3    3.9
DRAPE         3232.0 1091.8 3246.3 1108.1 3278.6 1276.2 3244.6 1109.7    2.4    4.6
DRAPE         3200.9 1043.0 3247.9 1106.6 3301.5 1377.4 3246.4 1108.0    2.0    6.6
DRAPE         3123.2  888.6 3266.5 1089.2 3301.4 1270.3 3264.7 1090.8    2.4   10.9
}
```

Figure 3: Example of `IHSSIM` output file.

```
                       Parameters for IHSRAST
                       ********************
Line    START OF PARAMETERS:
1       estuarine.dbs        -file for Geo-object database
2       ihssim.gfm           -file for grid-free model
3       ihssim.out           -file for output gridded model/cross section
4       500 5.0  10.0        -nx,xmn,xsiz
5       500 5.0  10.0        -ny,ymn,ysiz
6       500 0.05  0.1        -nz,zmn,zsiz
7       0 1 2 3 4            -facies code for CSS,SH,PBS,BR, and CHF
8       1                    -realization number
9       2                    -rasterization option: (1=model, cross-section:2=xy,3=xz,4=yz)
10      250 5 5 1            - slice number and discretization in x,y,and z if rasterization option > 1
```

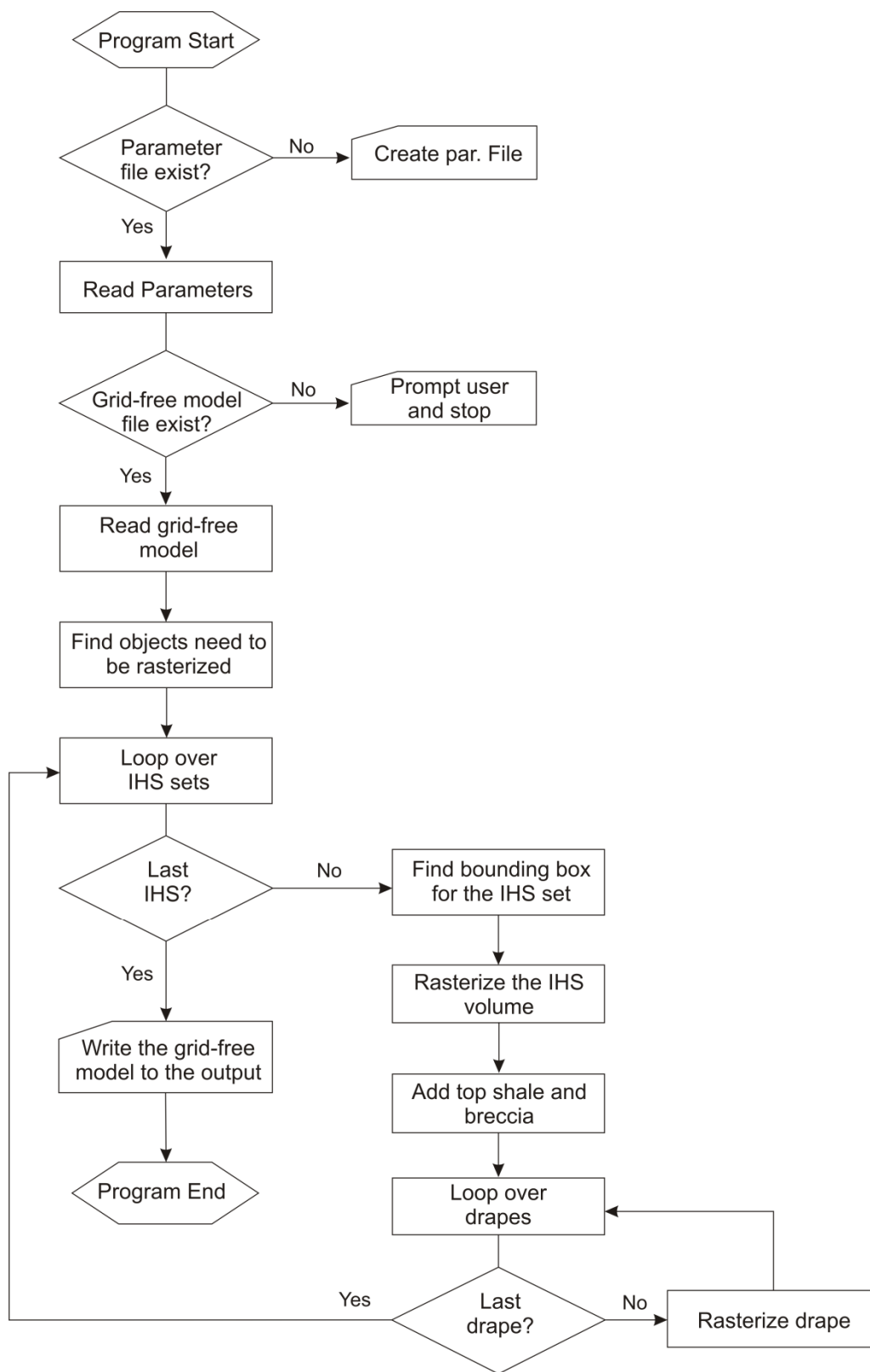**Figure 4:** Parameter file for the `IHSRAST`.

Figure 5: Workflow of the IHSRAST program for rasterization of grid-free IHS facies models.