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Short Note

# Modifications to KB2D program in GSLIB to allow use of tabulated covariances calculated with fast Fourier transform method☆

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## 1. Introduction

### 1.1. KB2D routines

The KB2D routine in GSLIB (Deutsch and Journel, 1997) can be employed to generate a file with ordinary kriging estimates and kriging variances when the sampling domain is two-dimensional. The GSLIB version of the program uses as input, among other parameters, a file of sampled data and parameters for a semivariogram model. The objective of our research was to modify the program to allow the reading of covariance tables instead of the parameters for conventional semivariogram models.

### 1.2. FFT method to calculate covariance matrix

This approach, according to the formulation by Yao and Journel (1998), works as follows:

(1) Generate an experimental correlogram map on a regular grid. The grid typically has multiple nodes without estimates. The user has to specify the minimum number of data to be considered in the estimates at every node. In the implementation by Ma and Yao (in press), this task is performed by program CORRMAP.

(2) In the implementation by Ma and Yao (in press), program INTMAP fills in the blanks typically present in the grid generated in step 1 by using a smooth local interpolation.

(3) In the implementation by Ma and Yao (in press), program MULTSMTH corrects the smoothed grid to generate a third grid that is a tabulation of a positively semidefined correlogram. This condition is required to assure a unique solution for the kriging system of equations yielding a non-negative kriging variance.

(4) Convert the correlogram tabulation in step 3 to a covariance tabulation by multiplying the correlogram grid by the sampling variance.

## 2. Application to the HALIMBA data set

We employ variable V1 in the Halimba (see Appendix A) multivariate sampling to test the modified version of KB2D. We run both the classical kriging with a semivariogram model and the modified kriging program reading a covariance table.

Figs. 1–3 are maps of the different stages in the preparation of the tabulated positive semidefinite covariance.

Fig. 4 shows kriging results with the original kriging program (using the semivariogram model). The model used is: nugget effect = 1.25; spherical semivariogram; sill = 4.05; azimuth = 50°; maximum range = 125 m; minimum range = 108.75 m.

☆Code available from server at http://www.iamg.org/CGEditor/index.htm.

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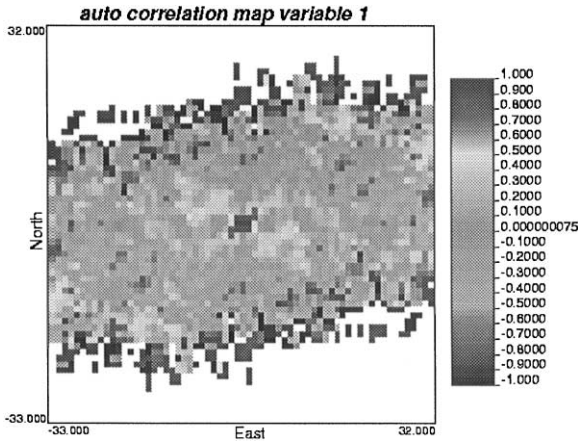


Fig. 1. Correlogram map for variable V1 made with CORRMAP program.

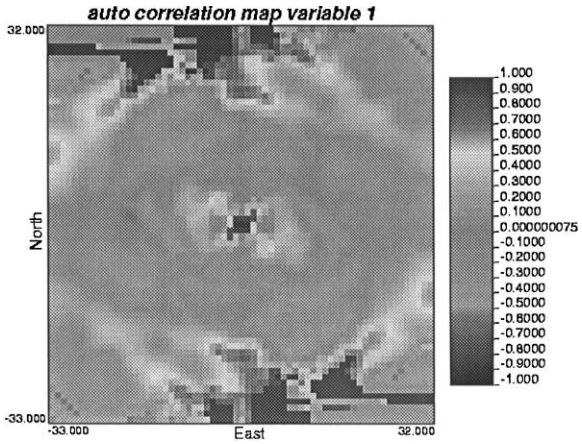


Fig. 2. Interpolated correlogram map for variable V1 built with INTMAP program.

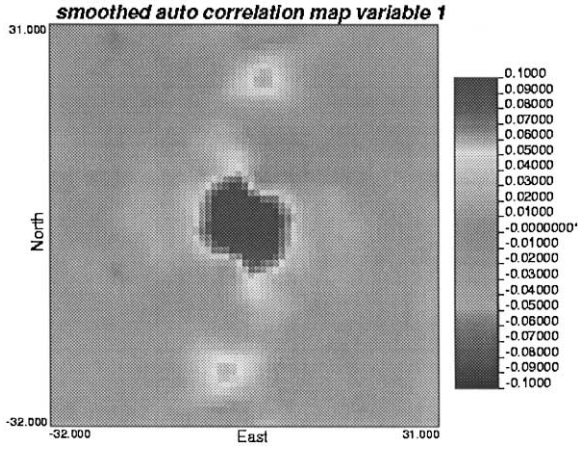


Fig. 3. Final correlogram map for variable V1 built with MULTSMTH program.

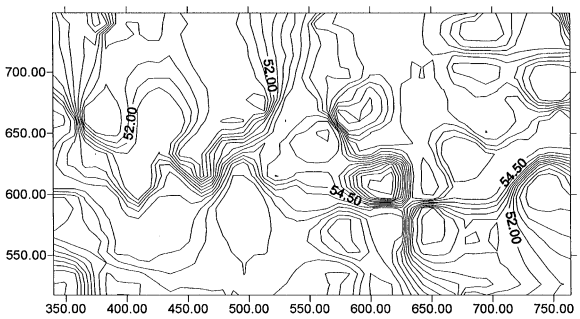


Fig. 4. Kriging result on variable V1 with existing program (using semivariogram model).

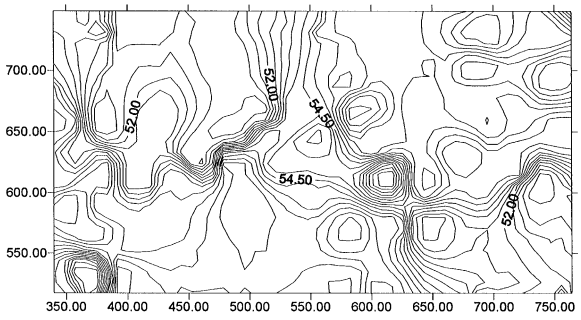


Fig. 5. Kriging result on variable V1 using covariances calculated with FFT method.

Fig. 5 shows kriging results with correlograms built with FFT method.

## 3. Conclusions

This paper provides all necessary modifications to GSLIB program KB2D to run ordinary kriging in two dimensions using a tabulation of a covariance function calculated with fast Fourier method (FFT). The proposed modifications for the KB2D routines in GSLIB produce results equivalent to those obtained with an analytical semivariogram model. Real data have been used to illustrate the preparation of the covariance table and to compare results obtained with the new and the existing version of KB2D.

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Table 1
Halimba2.dat data set

| *Y* (m) | *X* (m) | V1 (%) | *Y* (m) | *X* (m) | V1 (%) | *Y* (m) | *X* (m) | V1 (%) |
|---|---|---|---|---|---|---|---|---|
| 564.5 | 690.4 | 52.5 | 566.6 | 582.1 | 57.5 | 671.7 | 642.1 | 55.8 |
| 666.6 | 541.1 | 54.4 | 643 | 511.1 | 54.8 | 571.4 | 612.6 | 56.1 |
| 676.2 | 683.6 | 56 | 569.5 | 367.3 | 56.7 | 606.6 | 739.3 | 49.9 |
| 713.5 | 477.8 | 50.7 | 648.1 | 485 | 50.1 | 613.8 | 612.9 | 50.4 |
| 730.1 | 742.2 | 55.7 | 629.8 | 486.9 | 56.4 | 520.4 | 343.9 | 53 |
| 719.3 | 607.9 | 56.3 | 590 | 495 | 56.9 | 649.2 | 755.6 | 54.8 |
| 764.9 | 674.9 | 55.7 | 600.9 | 551.2 | 55.3 | 528.2 | 396.2 | 57 |
| 659.2 | 425.1 | 52.9 | 646.1 | 554.6 | 53 | 611.4 | 643 | 56 |
| 617.2 | 340.3 | 55.2 | 640.7 | 605.6 | 56.2 | 657.2 | 379.9 | 50.8 |
| 664.3 | 482.3 | 50.9 | 703.3 | 647.1 | 56 | 628.7 | 527.4 | 53.6 |
| 668.1 | 588.8 | 58 | 703.5 | 687.1 | 57.2 | 627.4 | 675.6 | 54.1 |
| 729.9 | 691.1 | 54.3 | 695.1 | 748.2 | 58.2 | 614.6 | 408.2 | 52.7 |
| 619.8 | 556.9 | 53.7 | 613.8 | 376.7 | 56.2 | 589.7 | 381.6 | 55.2 |
| 583.8 | 432.2 | 55.3 | 653.9 | 342.2 | 56 | 659.9 | 698.9 | 56.5 |
| 674.7 | 682.6 | 56.3 | 664.9 | 500.9 | 50.4 | 630.9 | 458.9 | 50.7 |
| 517.7 | 605.8 | 57 | 610.7 | 689.8 | 54.7 | 665.1 | 715.2 | 55.8 |
| 633.4 | 362.7 | 53.9 | 531.2 | 366.1 | 50.3 | 626.4 | 715.9 | 54.6 |
| 559 | 404.5 | 55.4 | 585 | 354.7 | 57.1 | 571.7 | 648.9 | 51.5 |
| 531.2 | 366.1 | 50.3 | 691.7 | 575.4 | 55.5 | 524.6 | 574.6 | 55.5 |
| 754.3 | 778 | 52.3 | 607.9 | 439.8 | 54.8 | | | |

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## Appendix A

The Halimba multivariate sampling to test the modified version of KB2D is given in Table 1.

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Yao, T., Journel, A.G., 1998. Automatic modeling of (cross) covariance tables using fast Fourier transform. Mathematical Geology 30 (6), 589–615.