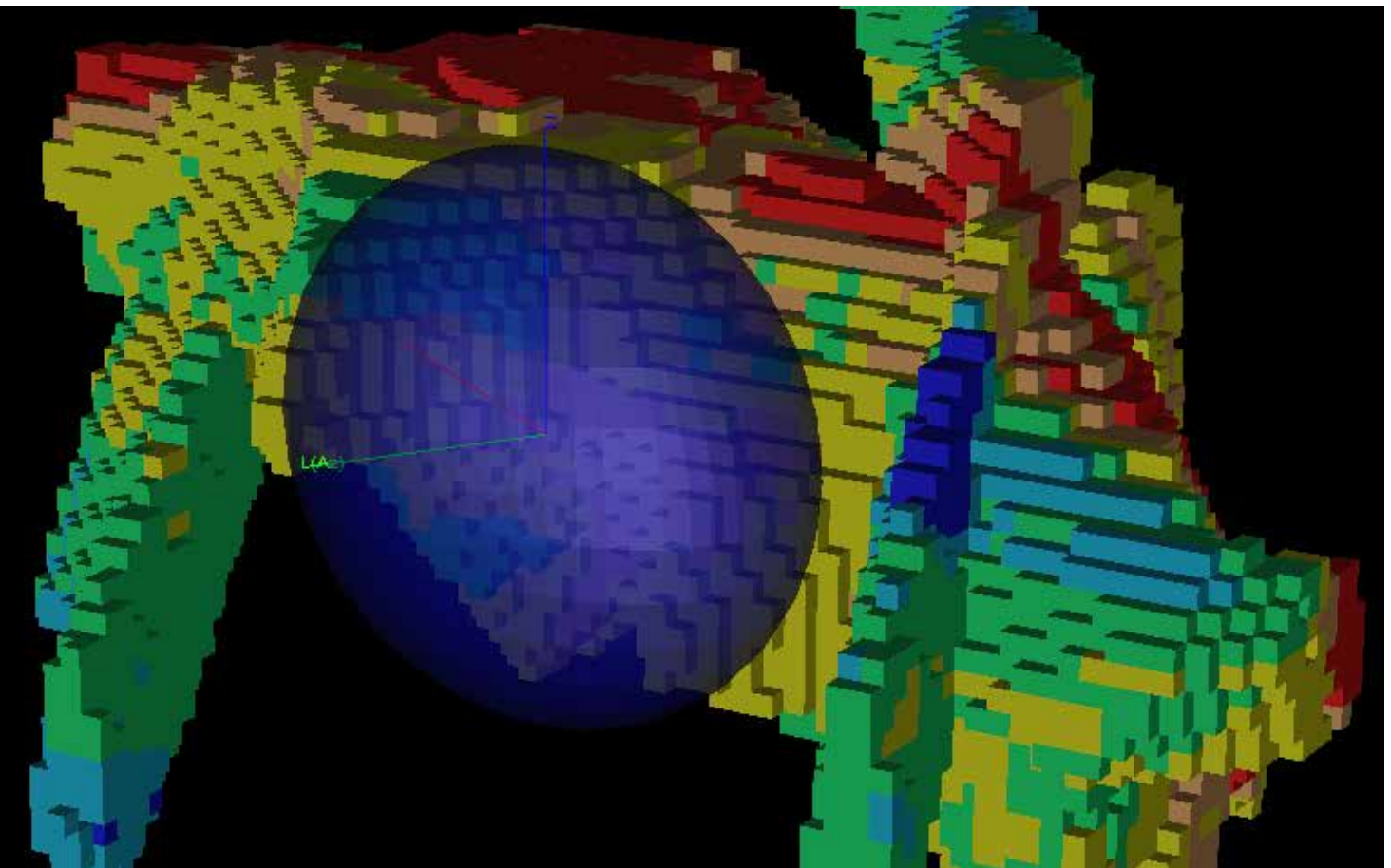


WHITE PAPER

HOW GEOVIA GEMS DEFINES BLOCK DISCRETIZATION AND BLOCK VARIANCE



EXECUTIVE SUMMARY

For confidence and clarity when discussing interpolation results from GEOVIA GEMS™, it is important to understand how GEMS undertakes block discretization and defines the term block variance. This paper explains the algorithms used in GEMS to complete block discretization, validating results generated from ordinary kriging interpolation using three products: GEMS, GEOVIA Surpac™ and GSLIB when varying the discretization factor. The term “block variance” as referenced in GEMS is defined and its use clarified in special-model kriging results produced by GEMS.

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INTRODUCTION

Having confidence in the results produced by a block model interpolation during resource estimation is essential when relying and taking advantage of software applications, such as GEMS, to complete calculations. This paper aims to clarify the terms “block discretization” and “block variance”, and the context in which each is applied inside the software package. These terms are widely used and encountered by the geological and geostatistical community and understanding how they are applied in GEMS will lead to successful and confident use in the software and its capabilities. An outline of each term, its use in a practical context, and worked examples when compared with the Surpac and GSLIB software packages, is included.

BLOCK DISCRETIZATION

When setting up an interpolation profile for interpolating values into a block model in GEMS, users are asked to enter values for the x, y, and z dimension that GEMS will use to discretize the blocks; that is, the subdividing of the blocks that are being interpolated.

For this analysis, ordinary kriging (OK) interpolation was completed on a set of 3103 gold assay values using GEMS, Surpac and GSLIB with identical estimation parameters. The kriged gold, block variance and kriging variance values are reported using a 3 x 3 x 3 and 4 x 4 x 4 block discretization in the x, y, and z dimensions. A comparative analysis of these results is provided using the following interpolation parameters:

- Minimum number of samples used to estimate a block value = 3
- Maximum number of samples used to estimate a block value = 15
- Isotropic search radius = 100 m
- Variogram nugget value = 0.20
- Variogram sill value = 1.00
- Variogram range value = 100
- Block size for interpolation = 10 x 10 x 10

The following results were generated by GSLIB, Surpac and GEMS for Au OK (Ordinary kriged gold values), BV (Block Variance), and KV (Kriging Variance) in three spatially independent blocks within the interpolated block model using a 3 x 3 x 3 block discretization:

Block 1 ($X_{\text{centroid}} = 7385$, $Y_{\text{centroid}} = 1725$, $Z_{\text{centroid}} = 135$)

PARAMETER	GSLIB		SURPAC		GEMS	
	Value	Value	Vs. GSLIB	Value	Vs. GSLIB	
Au OK	1.707	1.707	0.000	1.706	-0.001	
BV ¹	0.725	0.725	0.000	0.721	-0.004	
KV	0.287	0.287	0.000	0.284	-0.003	

Block 2 ($X_{\text{centroid}} = 7365$, $Y_{\text{centroid}} = 1685$, $Z_{\text{centroid}} = 105$)

PARAMETER	GSLIB		SURPAC		GEMS	
	Value	Value	Vs. GSLIB	Value	Vs. GSLIB	
Au OK	4.213	4.213	0.000	4.218	0.005	
BV ¹	0.725	0.725	0.000	0.721	-0.004	
KV	0.187	0.187	0.000	0.185	-0.002	

¹ Block Variance in GEMS is calculated using the formula: Adjusted Sill value of the variogram (1.00 in this example) – Block Variance (or WBV). Where, WBV is the within the block variance as calculated by the GEMS Block Variance parameter. This is discussed further under the Block Variance section of this article.

Block 3 ($X_{\text{centroid}} = 7245$, $Y_{\text{centroid}} = 1515$, $Z_{\text{centroid}} = 25$)

PARAMETER	GSLIB		SURPAC		GEMS	
	Value	Value	Vs. GSLIB	Value	Vs. GSLIB	
Au OK	1.799	1.799	0.000	1.795	-0.004	
BV ¹	0.725	0.725	0.000	0.721	-0.004	
KV	0.092	0.092	0.000	0.090	-0.002	

From these results, it is clear that Surpac and GSLIB produce the same results when undertaking ordinary kriging with a block discretization of 3 x 3 x 3. However, there is a minor disparity between the GEMS results and those of the two other software packages.

This disparity can be explained based on the level of discretization used. Discretization is used to approximate a volume integral over the block volume for the block being estimated. In the GEMS kriging program, a Gaussian Quadrature formula is implemented for the discretization levels 1, 2, 3, 5, 6, 10, and 20. For level 4, a simple weighting of equal weights over equal intervals was implemented in GEMS due to the disparity in results compared to other software packages. It is, therefore, proposed that when comparing ordinary kriging results from GEMS with other software packages for validation, that a level 4 discretization (or 4 x 4 x 4 in the x, y, and z dimensions) should be used.

The following results were generated by Surpac and GEMS for the Au OK (Ordinary kriged gold value), BV (Block Variance), and KV (Kriging Variance) for the same spatially independent blocks within the interpolated block model using a 4 x 4 x 4 block discretization:

Block 1 ($X_{\text{centroid}} = 7385$, $Y_{\text{centroid}} = 1725$, $Z_{\text{centroid}} = 135$)

PARAMETER	SURPAC		GEMS	
	Value		Value	Vs. Surpac
Au OK	1.707		1.707	0.000
BV ¹	0.723		0.723	0.000
KV	0.285		0.285	0.000

Block 2 ($X_{\text{centroid}} = 7365$, $Y_{\text{centroid}} = 1685$, $Z_{\text{centroid}} = 105$)

PARAMETER	SURPAC		GEMS	
	Value		Value	Vs. Surpac
Au OK	4.216		4.216	0.000
BV ¹	0.723		0.723	0.000
KV	0.186		0.186	0.000

Block 3 ($X_{\text{centroid}} = 7245$, $Y_{\text{centroid}} = 1515$, $Z_{\text{centroid}} = 25$)

PARAMETER	SURPAC		GEMS	
	Value		Value	Vs. Surpac
Au OK	1.798		1.798	0.000
BV ¹	0.723		0.723	0.000
KV	0.091		0.091	0.000

BLOCK VARIANCE

When creating an interpolation profile in GEMS, users are prompted to select one of three options for Block Variance, namely Variance by Level, Constant, or Variance by Block. The Block Variance option allows users to define whether the block size (or height) is the same, or if it varies.

The option allows GEMS to vary the block variance if the block size changes because block models can be defined with variable heights. The default "Variance by Level" calculates the block variance once per level.

Note that the block variance is just one of the variables used when weighting the result, and if all the blocks are of the same size then it will be "Constant", as it is not associated with grade values. If the "Constant" option is chosen, the user must enter a common block height and block variance will be calculated once per rock type.

If the block model is defined as a Seam Model (quite rare), the block variance must be calculated on a block-by-block basis ("Variance by Block") as each block can have differing block heights (the X,Y grid will remain the same in all cases).

The instance of block variance used in GEMS refers to the "Within Block Variance" or WBV; that is, the theoretical variance of the samples within the block calculated from the variogram. This differs from the term "Between Block Variance" or BBV which is the variance of the true block grades. This variance depends only on the block size/shape and the variogram.

To calculate the Between Block Variance (BBV) when using the Block Variance calculated in GEMS, users must complete the following calculation from the interpolation results:

$$\text{BBV} = \text{Adjusted Sill Value of the Variogram} - \text{Block Variance (or WBV)}$$

If Block Variance is saved through the Special-model kriging results option (the WBV value will be saved), and if the user chooses to save the Kriging Variance through the Special-model kriging results option, WBV will also be used in the calculation. Kriging Variance is calculated from the variogram and kriging weights assigned during Kriging estimation. It provides a relative measure of accuracy of the locally kriged blocks with respect to data coverage. The following equation is used in GEMS to calculate the kriging variance:

Where,

$$\sigma_{k,v}^2 = 2 \sum_{i=1}^N \lambda_i \bar{\gamma}(V, i) - \sum_{i=1}^N \sum_{j=1}^N \lambda_i \lambda_j \gamma_{ij} - \bar{\gamma}(V, V)$$

- $\bar{\gamma}(V, i)$, is the average variogram value between block "V" and location "i"
- γ_{ij} , is the variogram value between location "i" and "j"
- $\bar{\gamma}(V, V)$ is the average variogram value within block "V", and
- $[\lambda_i, "i"=1 \text{ to } "N]$, are the N estimation weights

If the user chooses to save the Slope of Regression through the Special-model kriging results option, GEMS uses Between Block Variance. Calculating the Slope of Regression or Conditional Bias Slope summarizes the degree of over smoothing of extreme grade values. It is calculated in GEMS using the following equation:

$$\frac{(\text{Between Block Variance} - \text{Kriging Variance} + \text{Abs (Lagrange multiplier)})}{(\text{Between Block Variance} - \text{Kriging Variance} + 2 * \text{Abs (Lagrange multiplier)})}$$

CONCLUSION

Understanding the way GEMS defines and calculates interpolation and associated parameters can provide users with confidence in the values being created and aid in equipping users in validating results. This paper provides transparency on how GEMS undertakes block discretization for interpolation and defines how the Block Variance, Kriging Variance and Slope of Regression are calculated.

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