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Selection of Spatial Interpolation Method for Deriving Dose Maps in Worker Dose Assessment

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1. Introduction

Nuclear power plant workers are exposed to radiation in various work situations, and dose assessment should precede worker dose control and radiation dose optimization. However, in some work situations, such as emergency situations, there may be a lack of information for dose assessment, and it may be time and economic limitations to obtain all the necessary information for dose assessment. In this case, dose maps based on spatial interpolation can be utilized to estimate worker radiation dose.

Spatial interpolation is a methodology that estimates the unknown value of an arbitrary point by interpolating data from multiple sample points. Various methodologies can be utilized for spatial interpolation depending on the characteristics of sample, and it is necessary to select the most appropriate methodology before deriving a dose map based on spatial interpolation.

In this study, we selected the most appropriate spatial interpolation method for deriving dose maps in worker dose assessment. For this purpose, we investigated the following spatial interpolation methods: Inverse Distance Weighting (IDW), K-Nearest Neighbor (K-NN), Radial Basis Function (RBF), and Kriging. Then, dose maps were derived for hypothetical exposure situations based on each methodology and the results were compared.

2. Investigation of Spatial Interpolation Methods

2.1. IDW interpolation method

The IDW method performs interpolation by assuming that the similarity between arbitrary points is inversely proportional to their distance. When utilizing the IDW method, weights are calculated for each distance based on the distance between the target calculation point and the sample point, and value of the target point is assigned by performing a weighted average. It is fast and easy to calculate, but it has the limitation of being relatively inaccurate.

2.2. K-NN interpolation method

K-NN method performs interpolation by utilizing K sample points nearest to the target point. The K-NN method first identifies the K samples that are nearest to the target point and performs a weighted average based on the distance from each sample point. It has the advantage of being less affected by noise in the sample data, but the interpolation result may be over- or under-fitted depending on the value of K specified by the user.

2.3. RBF interpolation method

The RBF method uses a radial basis function to calculate weights based on distance. When utilizing the RBF method, one of the sample points is targeted as the target point before spatial interpolation, and the distance and weight to the other sample points are calculated to derive the weight by distance. Then, the interpolation function is derived by fitting the weights by distance according to the form of the basis function. The RBF method is easy to process unevenly distributed data, but interpolation results may vary depending on the basis function form and related factors.

2.4. Kriging interpolation method

The Kriging method performs interpolation by estimating the form and parameters of a model related to the predicted value. When using the Kriging method, weights by distance are evaluated through sample points, and weights by distance are derived by fitting the values according to the model. We do not consider sample point values above the correlation distance, as we expect that the greater the distance between the target point and the sample point, the less the values are related. The interpolation result of Kriging method is relatively accurate, but it has the limitation of complex calculation and long time.

Table I: Investigation result of spatial interpolation methods

Methods	Advantages	Weakness
IDW	Quick and easy to claculate	Relatively inaccurate
K-NN	Less affected by noise	Selection of k value is required
RBF	Easy to process unevenly distributed data	Selection of basis function is required
Kriging	Relatively high accuracy	Selection of model is required

3. Preliminary dose map derivation

Based on the methods previously investigated, a dose map for a hypothetical exposure situation was derived. The dose maps were derived for a hypothetical workspace with two lead box each containing 1,000 MBq of Cs-137 and 500 MBq of Co-60 point sources. It was assumed that spatial dose rate measurements were performed on 20 random points in the space. The measurement data was replaced by the results of the Microshield computer code.

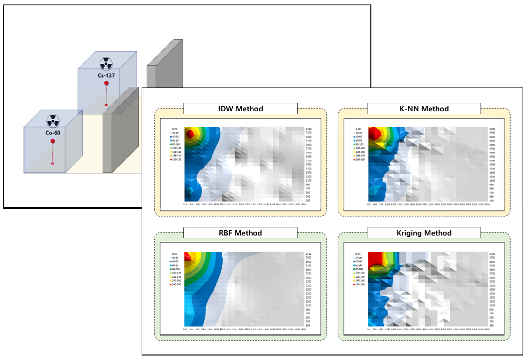

Figure 1: Assumed exposure situation and result of preliminary dose map derivation

The error was analyzed by comparing the results of the spatial interpolation methods with the results of the Microshield computer code, and the same input data was used when deriving dose map through each method. To compare the error over the entire space, the error of the entire space was summed up using the least-squares method. For K-NN method, RBF method, and Kriging method, it is necessary to select factors, models, etc. within the methodology. For the comparison of each method, we selected the factor with the minimum error rate compared to the Microshield computer code results. In the case of K-NN method, the error rate was 5.82% when the K value was 3, 4. For the RBF method, the error rate was 30.64% when using the Multiquadric function as the basis function, and the error rate was 3.99% when using the Gauss model for the Kriging method.

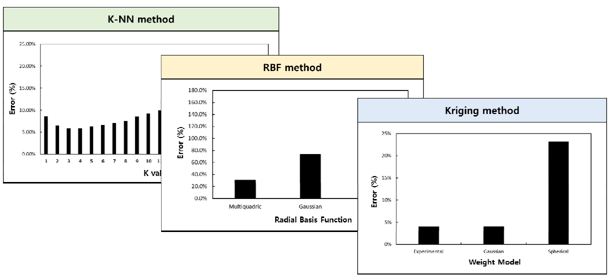

Figure 2: Analysis of dose map derivation result to select factors with minimum error per methodology

To select the most appropriate spatial interpolation method, the results of each derived dose map were compared. The comparison of Microshield computer code showed that the Kriging method and K-NN method had lower errors than the IDW method and RBF method. This is because it is less affected by variations in the sample model by multiple sources, such as specifying the nearest K points or considering only points within the correlation distance.

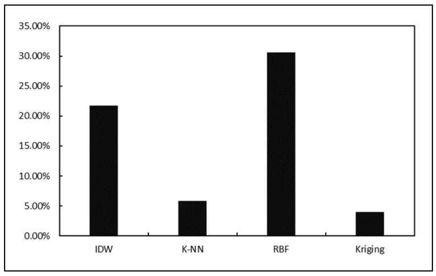

Figure 3: Error analysis result of dose map derivation by spatial interpolation methods

4. Conclusions

In this study, the most appropriate spatial interpolation method was selected before deriving a spatial interpolation-based dose map for worker dose assessment. For this purpose, IDW, K-NN, RBF, and Kriging method were investigated as typical spatial interpolation methods. Then, dose maps were derived under the assumption of a hypothetical exposure situation. The results of each method were compared with the results of the Microshield computer code, and the errors were analyzed. The results showed that the K-NN and Kriging methods had lower errors compared to the other methods. The results of this study can be utilized as a basis for spatial interpolation-based dose maps for worker dose assessment in the future.

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REFERENCES

[1] Cafer Mert Yesilkanat et al., Dose rate estimates and spatial interpolation maps of outdoor gamma dose rate with geostatistical methods; A case study from Artvin, Turkey, 2015.
[2] Peter J. Diggle and Paulo J. Ribeiro Jr., Model-based Geostatistics, 2006.
[3] Hong-lae Cho and Jong-chul Jeong, Mapping of Environmental Data Using Spatial Interpolation Methods, 2007.