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Population Distributions by Different Depth Levels of HEPRI

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1. Introduction

Level 3 Probabilistic Safety Assessment (PSA) predicts various consequences such as population dose, early fatality, and latent cancer fatality with the dispersion of radioactive materials, several exposure pathways, and an emergency response model. To date, some research institutes have developed the best-estimate consequence models [1,2]. We believed that a precise calculation of population distribution is also important to construct the best-estimate model. In this regard, we developed the Hanyang Emergency Pre-Risk Information (HEPRI) program [3], which calculates population distributions with a 'divide and conquer algorithm.' Moreover, the HEPRI program can calculate the population distribution automatically with the number of calculations, called 'depth value.' The population distribution becomes more precise with the higher depth value. This study focuses on population distributions by different depth values.

2. HEPRI Program

The population calculation by the HEPRI program is based on the 'divide and conquer algorithm.' This section covers the meaning of the 'divide and conquer algorithm' and how to calculate a population distribution with the algorithm.

2.1 Divide and Conquer Algorithm

The 'divide and conquer algorithm' recursively breaks down a problem into two or more sub-problems of the same or related type until these become simple enough to be solved directly, which can be expressed by Fig. 1.

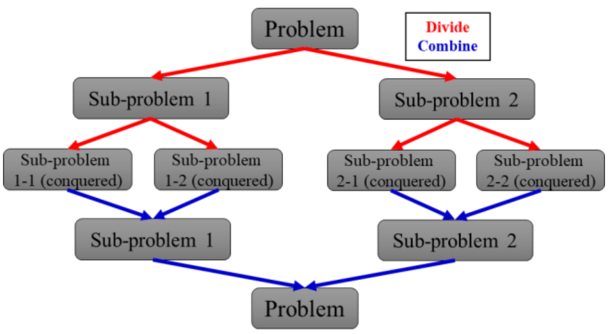
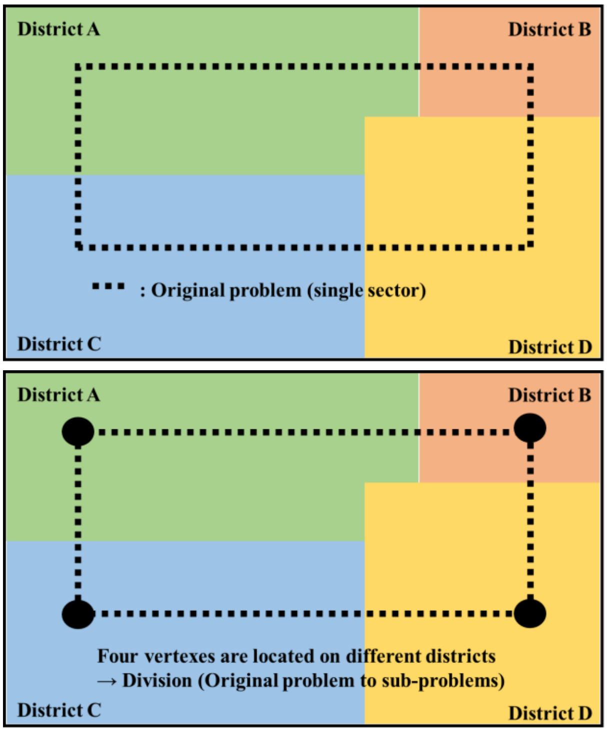


Fig. 1. Simplified flowchart of 'divide and conquer algorithm.'

The algorithm in Fig. 1 can be efficiently used for solving many problems such as sorting, multiplying large numbers, finding the closest pair of points, and syntactic analysis [4]. The first step is to divide the problem if the problem is divisible. The second step is to solve each sub-problem, called 'conquer step,' and divide insolvable sub-problems until it is solvable. The final step is to combine many sub-problems' solutions and solve the original problem.

2.2 Calculation Process

The original problem in the HEPRI program is to calculate a population distribution and land fractions for each sector. To solve the original problem, a recursive function is used. The recursive function in the HEPRI is to distinguish whether four vertexes of a rectangle are included inside the single administrative district or not. If four vertexes of a rectangle are not included inside the single administrative district, the rectangle is divided into four sub-rectangles. Such division process repeatedly proceeds until the single administrative district contains four vertexes of the sub-rectangle. The finite number of repetitions is called depth level (maximum level is ten), which a user determines. Finally, the calculation process can be expressed in Fig. 2.



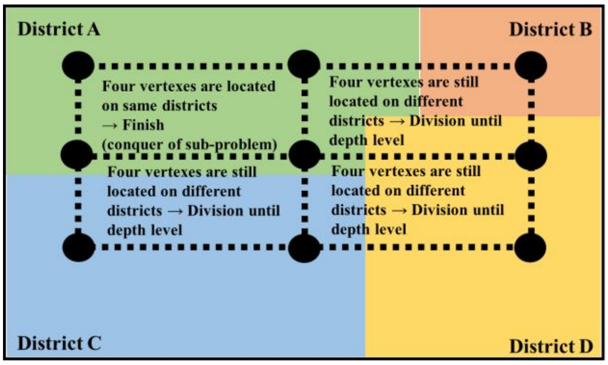


Fig. 2. Example of calculating population with 'divide and conquer algorithm.'

2.3 Calculation Results

In this study, we calculated the population of four representative sites in Korea (Kori, Wolsong, Hanul, and Hanbit) by the HEPRI program. The population distributions are based on sixteen angular divisions, one-kilometer intervals, and an outer boundary of thirty kilometers. Besides, the district's level is '-eup, -myeon, or –dong.' The minimum depth level was fixed at two, and the maximum was changed from two to ten (base case's min. and max. are two). In addition, the computer specifications are Intel i7-7700K (CPU) and 16GB(RAM).

Average change rates of population distribution compared to the previous case with computing time are presented in Tables I, II, III, and IV. For example, the average change rate of 2.15 percent in Table I means that the population of case 3 is changed by 2.15 percent from case 2.

Table I: Average change rate of population for Kori 2 by different depth levels

Case	Depth level		Average change rate (%)	Computing time (hh:mm:ss)
	Min.	Max.		
1 (Base)	2	2	N/A	00:02:21
2	2	3	3.62	00:02:31
3	2	4	2.15	00:03:41
4	2	5	0.43	00:06:38
5	2	6	0.19	00:14:14
6	2	7	0.07	00:30:01
7	2	8	0.02	01:01:37
8	2	9	0.01	01:55:50
9	2	10	0.00	03:52:16

Table II: Average change rate of population for Wolsong 1 by different depth levels

Case	Depth level		Average change rate (%)	Computing time (hh:mm:ss)
	Min.	Max.		
1 (Base)	2	2	N/A	00:02:39
2	2	3	4.77	00:02:43
3	2	4	1.76	00:03:30
4	2	5	0.71	00:05:39
5	2	6	0.29	00:09:57
6	2	7	0.09	00:21:08
7	2	8	0.03	00:37:16
8	2	9	0.01	01:14:59
9	2	10	0.00	02:38:02

Table III: Average change rate of population for Hanul 1 by different depth levels

Case	Depth level		Average change rate (%)	Computing time (hh:mm:ss)
	Min.	Max.		
1 (Base)	2	2	N/A	00:03:01
2	2	3	1.98	00:03:00
3	2	4	0.72	00:03:26
4	2	5	0.25	00:04:43
5	2	6	0.12	00:07:20
6	2	7	0.03	00:12:41
7	2	8	0.01	00:27:38
8	2	9	0.00	00:51:13
9	2	10	0.00	01:46:16

Table IV: Average change rate of population for Hanbit 1 by different depth levels

Case	Depth level		Average change rate (%)	Computing time (hh:mm:ss)
	Min.	Max.		
1 (Base)	2	2	N/A	00:03:07
2	2	3	2.97	00:03:09
3	2	4	1.08	00:04:06
4	2	5	0.29	00:06:02
5	2	6	0.14	00:10:05
6	2	7	0.04	00:24:45
7	2	8	0.02	00:54:33
8	2	9	0.01	01:19:19
9	2	10	0.00	02:35:28

The above results reveal no significant difference in the population, but the calculation time significantly increases under depth levels of eight or nine. In addition, the calculation time increases by many administrative districts in the boundary. Hence, selecting a depth level depends on a user, and we believe that the above results can help select a suitable depth level.

Finally, the calculated populations (case 9) for specific boundaries (2, 5, 16, 26, and 30 km), as shown in Fig. 3, are presented in Table V.

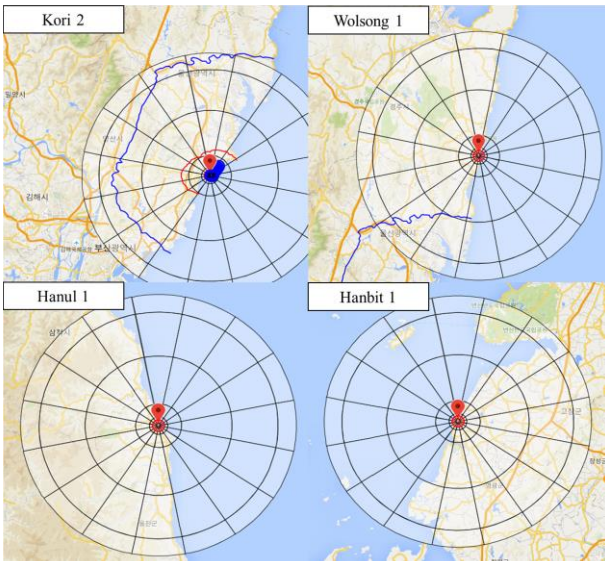


Fig. 3. Polar coordinate of four sites (2, 5, 16, 26, and 30 km from the innermost ring)

Table V: Population by distances with maximum depth level of ten (K2: Kori 2, W1: Wolsong 1, U1: Hanul 1, and Y1: Hanbit 1)

Pop.	Distance from the NPP (km)				
	2	5	16	26	30
K2	863	7,296	285,714	2,344,286	3,492,871
W1	451	2,705	120,728	971,556	1,242,956
U1	366	6,661	31,348	42,443	52,712
Y1	1,607	6,442	41,912	95,174	126,586

3. Conclusions

One of the important factors for constructing a best-estimate consequence model is population distribution. For this reason, we developed the HEPRI program, calculating population distributions by 'divide and conquer algorithm.' This study focused on the average change rate of the population by different depth levels. As a result, there was no significant difference in the population at a higher depth level than eight, but computing time highly increased. Consequently, we conclude that the above results can help potential HEPRI users to select a suitable depth level. As future work, we will compare our results with other results calculated by different computer codes.

Acknowledgment

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