Development of the radiation mapping algorithm considering altitude information

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1. Introduction

In the event of a release of radioactive materials from domestic or neighboring nuclear facilities, a timely response is crucial. Particularly when the exact release amounts and behaviors are uncertain due to incidents in neighboring countries, responses based on real-time monitoring data become essential. This necessitates strategies that can immediately detect and respond to subtle changes in routine environmental radiation dose rate monitoring systems [1].

In the Republic of Korea, environmental radiation dose rate measurements are primarily conducted using monitoring systems installed at a height of 1 m above the ground. These systems are installed nationwide as part of the national radiological emergency preparedness system, with data being collected and managed in real time. However, only information measured at a single altitude is currently collected and managed, which fails to account for variations in dose rates according to altitude [2].

Meteorologically, wind direction and speed vary significantly with altitude. When radioactive materials are released into the atmosphere, radioactive plumes may move at altitudes different from ground level due to wind and weather conditions. Therefore, situations may arise in which radioactive materials reach the location of a monitoring system but go undetected due to altitude differences. To minimize such scenarios, it is necessary to collect and manage radiation data not only at the surface but also at various altitudes [3].

One method for measuring data at different altitudes is the use of drones. Drones can periodically measure designated altitudes above radiation monitoring systems to collect data. The collected data can then be managed statistically to promptly detect and respond to anomalies when subtle changes occur under routine conditions.

As part of this research, we developed an algorithm to efficiently manage and visualize environmental radiation dose rate data measured at various altitudes. Through the developed algorithm, altitude-specific environmental radiation dose rate data can be visualized on maps, allowing information to be presented intuitively and promptly. This will help decision-makers accurately assess the spread of radiation in the event of an accident and carry out swift and appropriate protective measures.

2. Methods and Results

In this study, we developed an algorithm to visualize the terrain boundaries of the entire Republic of Korea in three dimensions and to generate altitude-specific maps (at 1 m, 25 m, and 50 m) for the spatial representation of environmental radiation dose rate data. For this purpose, administrative boundary data were extracted from shapefiles (SHP files) provided by the National Base Map, using provincial-level boundary information as a reference. The measurement locations were based on the sites of environmental radiation monitoring stations installed throughout the country and their corresponding altitudes.

2.1 Data generation and processing

For visualization purposes, virtual data were generated based on the locations of 244 environmental radiation monitoring stations across the country. The data were saved in CSV format and included latitude, longitude, altitude, and radiation dose rate values. Measurements were simulated at three altitudes—1 m, 25 m, and 50 m—at each monitoring location. The dataset was then restructured into a data frame to enable effective analysis of radiation dose rate variations by altitude. Fig. 1 shows the example of the dataset.

Latitude	Longitude	Altitude1	Measurement1	Altitude2	Measurement2	Altitude3	Measurement3
37.7657331772579	128.870217435979	1	0.992	25	0.843	50	0.694
		1	1.069	25	1.016	50	0.962
37.5072403426251	129.124162633769	1	0.91	25	0.774	50	0.637
37.149743896852	129.205226483683	1	1.193	25	1.133	50	1.074
37.1683274481181	129.289411674662	1	1.057	25	0.898	50	0.740
37.1836364781033	129.130036262412	1	1.099	25	0.989	50	0.879
37.23256955	129.343560883905	1	1.031	25	0.979	50	0.928
37.2741221179591	129.179272800937	1	1.141	25	1.084	50	1.027
37.1008342180227	129.17976429131	1	1.064	25	0.904	50	0.745
38.2077027216981	128.591938961081	1	0.914	25	0.823	50	0.731
		1	1.141	25	1.027	50	0.913
38.0804288472864	128.617003337601	1	1.171	25	1.054	50	0.937
37.1741355927808	128.459183771518	1	0.969	25	0.872	50	0.775
37.3373730365471	127.947063001282	1	0.99	25	0.941	50	0.891
		1	0.95	25	0.903	50	0.855
37.3809306680873	128.661997296481	1	1.189	25	1.070	50	0.951
38.147954164816	127.304747537921	1	1.107	25	0.941	50	0.775
37.8679956160244	127.74837984446	1	1.008	25	0.857	50	0.706
37.1706095861213	128.988998929306	1	1.082	25	0.920	50	0.757
37.6731559703419	128.706304295244	1	1.002	25	0.952	50	0.902
37.683782946675	127.880269766999	1	1.028	25	0.925	50	0.822
		1	0.916	25	0.870	50	0.824
37.4920675417656	127.985151422152	1	1.183	25	1.006	50	0.828
37.8460399600504	127.500769805641	1	1.049	25	0.892	50	0.734
37.6601481347218	126.833016757437	1	1.002	25	0.952	50	0.902
37.4396371822962	127.002295004039	1	1.178	25	1.001	50	0.825
37.4530781311129	126.855937737127	1	1.111	25	1.055	50	1.000
37.4292876633623	127.255069212664	1	1.116	25	1.004	50	0.893
37.5943497638182	127.129640137928	1	1.097	25	0.932	50	0.768
37.6295710577508	126.711963585911	1	1.035	25	0.880	50	0.725
37.636616841679	127.217995427756	1	1.116	25	1.060	50	1.004
37.5035709606885	126.765349745352	1	1.056	25	1.003	50	0.950
37.4201775351126	127.126279964189	1	1.054	25	0.896	50	0.738
37.2576341602533	126.971898464354	1	1.173	25	1.114	50	1.056
37.3362257674903	126.714648122541	1	0.96	25	0.864	50	0.768
37.2807841469771	126.843698582297	1	1.05	25	0.893	50	0.735
37.0083078624137	127.279209977315	1	1.128	25	1.072	50	1.015
37.3942980869639	126.956858356687	1	0.987	25	0.938	50	0.888

Fig. 1. Example of the dataset.

2.2 Algorithm development

The primary Python libraries used in the algorithm include Geopandas, Matplotlib, and NumPy. Geopandas was used to load the SHP files and perform coordinate system transformations (EPSG:4326). Matplotlib was employed to visualize the administrative boundaries in 3D and to display map layers at different altitudes. NumPy was used to perform fundamental operations for data processing. The detailed procedures of the algorithm are shown in fig. 2.

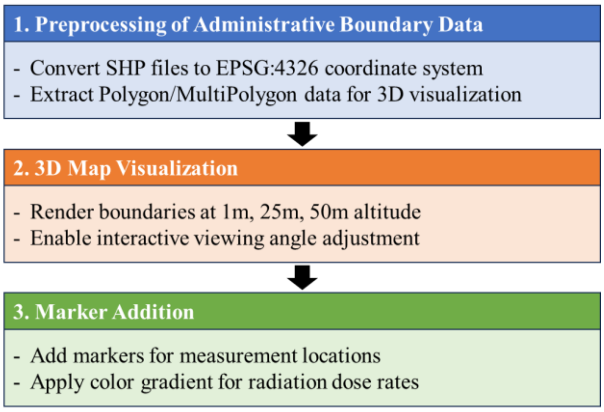

Fig. 2. Algorithm process for 3D radiation dose rates visualization.

2.3 3D visualization results

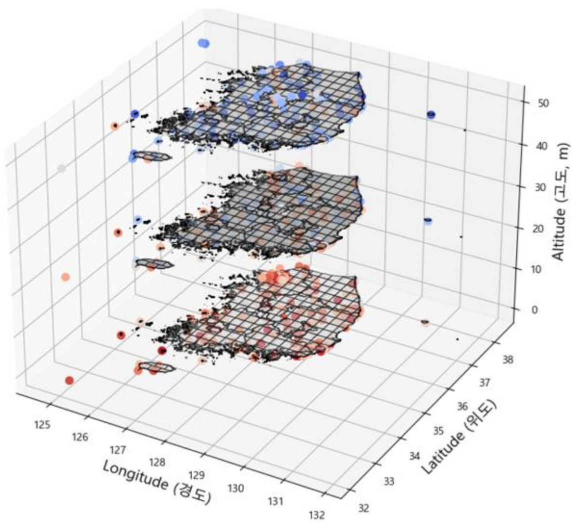

Fig. 3. 3D visualization result.

Figure 3 shows 3D visualization result by using the developed algorithm. Altitude-specific (1 m, 25 m, and 50 m) environmental radiation dose rate data from 244 monitoring stations across the Republic of Korea were visualized on a three-dimensional map. The results of the visualization are as follows:

First, the 3D map visualized administrative boundaries as separate layers corresponding to each altitude level, enabling users to intuitively observe the spatial distribution of radiation dose rates at specific altitudes. This clearly demonstrated that radiation dose rates can vary by altitude even at the same geographic location.

Second, radiation dose rate data at different altitudes were represented using markers, with a color gradient applied such that marker color intensity increased with higher radiation levels. This approach enabled a rapid and intuitive understanding of the vertical dispersion patterns and concentration changes of radioactive materials.

Third, the developed visualization system allows users to freely adjust the perspective and zoom level of the 3D map, facilitating multi-angle analysis of spatial characteristics and altitude-dependent radiation variations.

3. Conclusions

In this study, we developed an algorithm to manage and visualize radiation dose rate data at various altitudes, aiming to overcome the limitations of conventional environmental radiation monitoring systems. By utilizing altitude-based measurement methods with drones, it became possible to rapidly detect the three-dimensional dispersion patterns of radioactive materials. The developed algorithm is expected to support prompt and accurate responses in the event of a radiological incident. In the future, field data collection using drones will be conducted to validate the accuracy and reliability of the algorithm.

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