Basic study for application of inverse radiation problem to airborne radiation measurement

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Since accident of the Fukushima Daiichi Nuclear Power Station (FDNPS), some unmanned vehicle was applied for radiation measurement around the FDNPS. Japan Atomic Energy Agency (JAEA) is developing a radiation measurement method using a small multi-rotor helicopter (micro UAV) for measurement of radiation in the environment. The micro UAV is expected to be useful due to measuring the radiation distribution at small areas (such as personal residence area) easily. In the conventional method, there are some premises to convert from count rate to dose rate at 1 m above the ground (agl.). 1) The dose rate at 1 m agl. is constant, 2) topography is a plane (plane source model) and 3) relationship of altitude and count rate are exponential correlation. Therefore, it is difficult that dose rate by airborne radiation measurement is precisely measured at the mountains and uneven place of dose rate by the conventional method. In addition, the influence of the radiation from a structure and tree on the ground is not ignored at the low altitude less than 50 m that micro UAV can fly stably. In this study, the successive approximation method which is used in the medical radiation such as Positron Emission Tomography (PET) is attempted to apply to environmental radiation measurement.
Our micro UAV was based on the commercial drone system produced by 3D Robotix Co., Ltd. (Calofornia, USA). The radiation detector was selected the GAGG scintillation detector (2cm ×2cm ×2cm) which is manufactured by Furukawa Co., Ltd. (Tokyo, Japan). The gamma-ray spectrum data was collected every three seconds with the position data by Groval Positioning System (GPS). A DSM (Digital surface model) data was acquired from photographs by the microUAV. For comparison, a radiation distribution on the ground was obtained using a survey meter with GPS (NESI Co., Ltd. Ibaraki, Japan).
The algorithm of the successive approximation method was assumed the measured value at the detector is expressed as the sum of the product of attenuation coefficient and ground point. The measured value(Yi) at the detector(i) is expressed by equation [1].
$Yi = \Sigma[j=1 \rightarrow B] \ \lambda j \ Cij$ [1]
where B is number of ground calculation point, Cij is attenuation coefficient and λj is calculation value at ground point(j) respectively. The attenuation coefficient (Cij) applied the air attenuation coefficient and the angle correction factor of the detector. Distance and angle attenuation coefficient were used of total energy photons count to the distance of Cs-137(662keV) point source was calculated by montecalro simulation (PHITS: Particle and Heavy Ion Transport code System by JAEA).
The airborne monitoring by micro UAV conducted in two areas (approximately 1 km^2) at Fukushima prefecture. A flat area and a forest area were selected. The count rate data is obtained by flying 10m or 50m agl. and 10m line spacing. These data was applied by the algorithm of the successive approximation method. These results was compared by conversion results of conventional method at same place. NMSE (Normalised Mean Square Error) which is compared with the airborne data and the ground data was defined for evaluation of accuracy of the algorithm of the successive approximation method.
In flat area, NMSE of the conventional method is 0.105 and NMSE of the successive approximation method is 0.034. Successive approximation method was close to the ground value compared with the conventional method. On the other hands, NMSE of the conventional method is 0.302 and NMSE of the successive approximation method is 0.214 in the forest area. The difference of attenuation factor by radiation energy and radiation attenuation of tree is not taken into account in the current algorithm. This method can expected detailed map by doing optimizing the algorithm and accumulate measurement

results in many areas.

Keywords: Drone, micro UAV, Remote radiation measurement, Terrain correction, Successive approximation method, Fukushima Daiichi Nuclear Power Plant Accident

