A methodology to predict the proton beam range from the scintillated light distribution using deep-learning

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Purpose:

This study aims to predict the proton beam range with the conversion of the scintillated light distribution into the proton depth-dose distribution. The feasibility of the methodology using Deep-Learning (DL) and Monte Carlo (MC) simulation was tested in this stage.

Materials and Methods:

The scintillated light and the proton dose distributions was generated from the plastic scintillator and water respectively using TOPAS MC simulation tool. In the MC environment, the scintillator phantom (physical density = 1.05 g/cm^3) and the water phantom were sized in 10x10x30 cm^3, and the proton beam with mono-energy was irradiated through the field size of 1x1 cm^2 on the scintillator surface of 10x10 cm^2. The proton beam energy is ranged from 100 MeV to 200 MeV with 0.5 MeV intervals for each simulation. The generated datasets from MC were separated with 201 training sets, 11 testing sets, and 21 validation sets for the DL. The U-net modelling as the convolution neural network was applied for the conversion of the two-dimensional (2D) scintillated light image into the 2D proton depth-dose image in the DL framework of Tensorflow with Keras. The predicted depth-dose distributions were compared with the simulated distributions as the ground truths, and the accuracies and the uncertainties for predicted Bragg peak positions were estimated by the likelihood fit.

Results:

The DL using U-net model produced properly the predicted depth-dose distribution from the scintillated light distribution. Although the similarity of proximal depth-dose profile and the sharpness of Bragg peak was not satisfied due to the statistical limitation when compared with simulated MC results, the stopped position of proton beam was clearly described with the beam range accuracy less than 2 mm.

Conclusions:

The DL methodology to analyze the scintillated light distribution for the proton beam range estimation is feasible in terms of the acceptable range accuracy. The fine-tuning of parameters and structure for DL model as well as the larger dataset would be need for the consistence with simulated results in future studies.

Keywords:

Deep-learning, Scintillation, Proton beam range, MC simulation