Preliminary study on the estimation of radioactive source position using plastic scintillating fiber and machine learning

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1. Introduction

Plastic Scintillating Fiber
as a radiation detecting sensor

Advantageous features

- High sensitivity
- Electromagnetic resistance
- Fast response
- Flexible

Disadvantageous features

- Hard to precisely measure the A.C.
  → Theoretical source position estimation method has limit

A.C. : Attenuation Coefficient

How to improve the accuracy of position estimation? → **Machine Learning data analysis**

Source of image : https://www.kuraray.com/products/psf

2. Materials and Experimental Setup

Plastic Scintillating Fiber
BCF-12

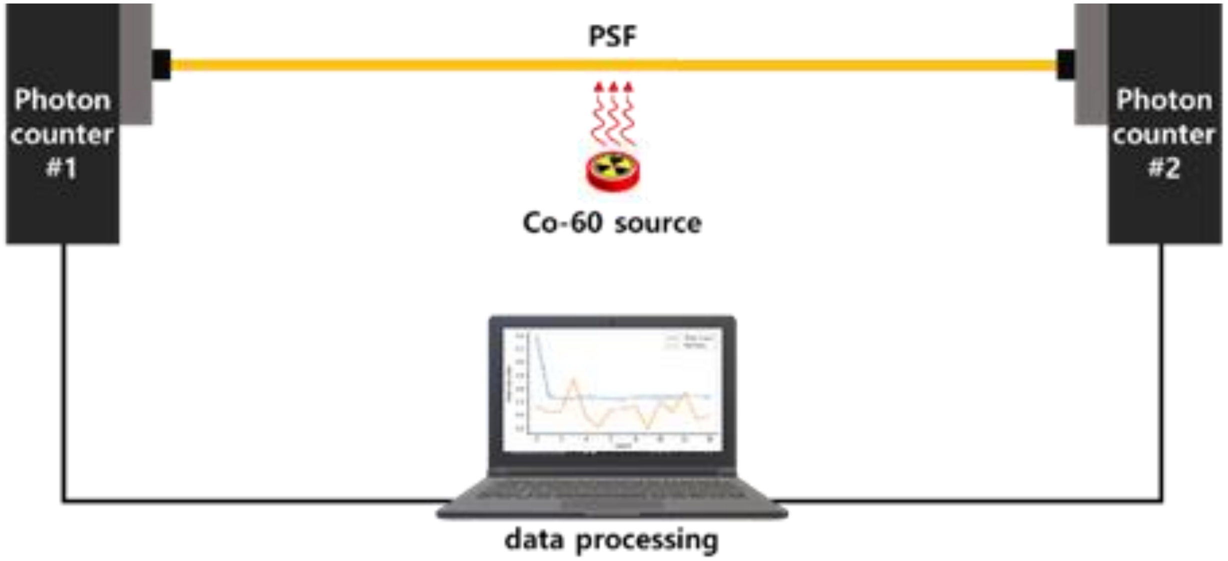
Specific properties	Value
Core material / diameter (mm)	Polystyrene / 3.0
Cladding material / thickness (μm)	PMMA / 90
Refractive index of core / cladding	1.6 / 1.49
Emission peak (nm)	435
Decay time (ns)	3.2

Photon Counter
H11890-210

Specific properties	Value
Photocathode area diameter (mm)	8
Detectable range (nm)	230 ~ 700
Detect wavelength peak (nm)	400

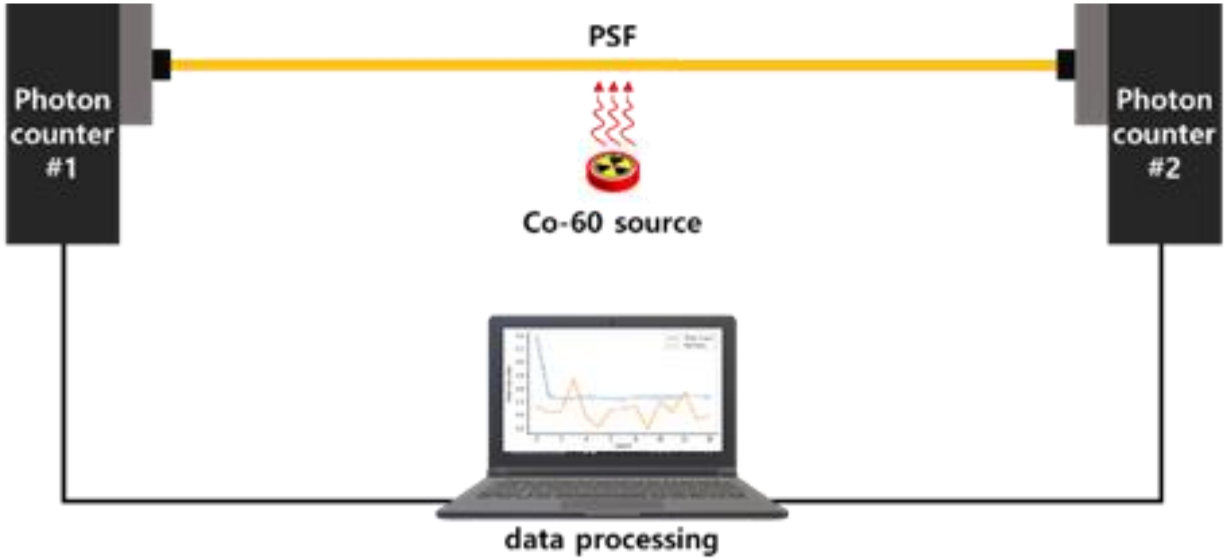
2. Materials and Experimental Setup

❖ 1-Dimensional radioactive source position estimating system



- Single strand of 1 m length BCF-12 is used.
- Two photon counters are connected at both ends of BCF-12.
- 49 μCi Co-60 source is used.
- Training data are obtained from 10 to 90 cm along the BCF-12 by 5 cm interval.
- Test data are obtained not only at the same position for training data, but at the three random positions.
  - Random position estimation results confirm that the machine learning model is usable at any located sources.

❖ 1-Dimensional radioactive source position estimating system



- Training data : 20,000 data at each measuring position
- Test data : 5,000 data at each measuring position

- Theoretical equation to estimate the position of the source
  - $x = \frac{L}{2} + \frac{1}{2\mu} \ln \frac{I_2}{I_1}$ (*x*: estimated position of source, *L*: length of fiber, *I*: counted number of photons

Machine Learning model

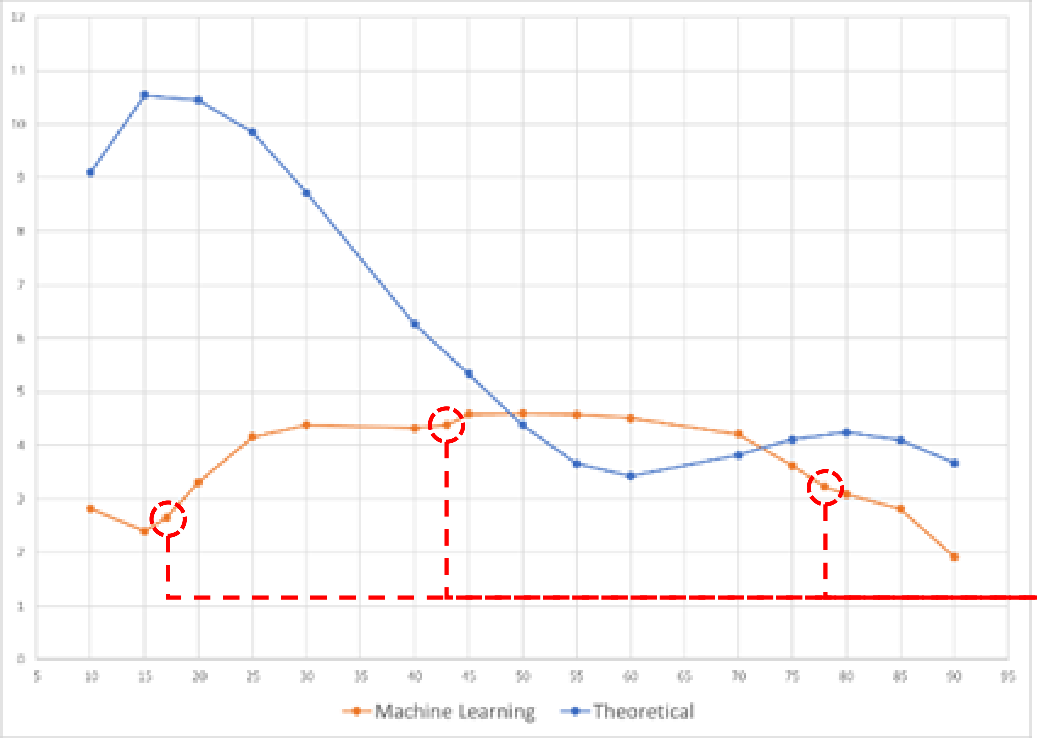
Specific properties	Value
Activation function	ReLU
Optimizer	Adam
Number of hidden layers	2
Number of nodes at each hidden layer	32

- If there is no reduction of validation loss while 10 times of epochs are over, modeling stopped.
- 10% of training data are separated to be used as validation dataset.

- Comparison between the mean absolute errors of machine learning test results and theoretical estimation

MAE : Mean Absolute Error

Graphical comparison



Overall MAE comparison

	Theoretical	ML
MAE (cm)	6.11	3.66

Random position estimation results

4. Conclusions

- The 1-dimensional radioactive source position estimating system is developed.
- Machine learning model is constructed to enhance the accuracy in the source position estimation.
- About 40.1% of improvement ratio is shown compared to the theoretical estimation.
- Further studies will be carried on the optimization of machine learning model.

Thank You