Navigation and location experiment and method analysis of multiple radiation sources detection

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Abstract. It is a completely new navigation and positioning method by using the particle ray emitted from known targets, which provides a new idea for the existing navigation and location. Therefore, a multi-source navigation and positioning method is proposed, and the principle of locating the detector by four radioactive sources of 22Na, 60Co, 137Cs and 252Cf is analyzed, and an analog positioning system consisting of a detector, an operational amplifier, a digitizer and a sampling server is set up. Based on the simulation positioning system, the positioning method is verified experimentally, and the whole positioning process using the positioning method is reported. The location of the detector coordinates is (152.5, 231.8, 182), which verifies the feasibility of the positioning method. The location result and the true coordinates of the detector (100, 200, 150) have error and the image is in the shadow. The factors that affect the positioning error are analyzed, which provides a new idea and method for the study of pulsar navigation and positioning.

1. Introduction
As we all know, there are a variety of positioning systems in the world, such as the GPS global navigation and positioning system, and the GPS navigation and positioning system, which play a vital role in their respective countries and even in the world. The Beidou navigation and positioning system, which is currently being built in our country, believes that the future will bring great development to the military and people's livelihood in our country, and bring great convenience to other countries in the world. However, the existing navigation and positioning systems have innate shortcomings, need to launch a large number of satellites and build ground stations as support, and can only provide ground and air targets positioning, if during the war, these navigation and positioning systems are facing the danger of being attacked, and so on. With the development of space technology, the future spacecraft in deep space can not make use of the existing technology to navigate and locate. Therefore, a location method of multi source navigation and positioning system is proposed, that is to detect the ray emitted by the known target, so as to realize the location of the detector, and put the detector in different carrier to realize the location of the carrier. The establishment of multi source navigation and positioning system can break through the limitation of navigation and positioning system only on the ground and air targets. It can not only realize the positioning of the carrier in the ground and air, but also realize the positioning of the carrier in the space, and provide its speed, position, attitude and other navigation information in
the operation, and can be used as well. [1] The backup and expansion of the existing navigation and positioning system has very broad application prospects.

Multi source navigation and positioning system can be applied in many ways. The use of pulsar for navigation and positioning is one of the most important applications. [2] Pulsar is a neutron star with high speed rotation, and has a stable radiation period. [3] Up to now, the number of pulsars found is about more than 2300, of which more than 150 X rays can be emitted. More than 140 gamma rays can be emitted. [4] The characteristics of X-ray and gamma ray can be transmitted by pulsars, and the multi source navigation and positioning system can be put into specific use. The multi source navigation and positioning method proposed in this paper is the exploration of the new navigation and positioning method, and also provides new ideas and methods for exploring the use of pulsars for navigation and positioning.

2. Positioning principle

Multi source navigation and positioning requires at least four known targets with radiant energy.[5] In the experiment, four radioactive sources of 22Na, 60Co, 137Cs and 252Cf were placed in different positions of the coordinate system to simulate the known targets, such as Figure 1, the circular point was the radioactive source, the scintillator detector was placed at the distance from its R distance, and the relative area of the radiation source was S. The scintillator detector is used to detect the energy of four radioactive sources placed in the coordinate system respectively. The position of scintillation detector in coordinates is unknown. In real environment, the detector is to be placed on the carrier, so in the simulation experiment, the distance between the calculated detector and the radioactive source is also the distance between the carrier and the known target position. In the experiment, the energy detected by the detector can calculate the distance between the detector and the different radiation sources. When the detector reaches the distance between the four different sources, the detector can be simulated.

Fig 1. Radiant sources radiate energy in a spherical manner

The radiation source radiates energy around the sphere, as shown in Figure 1. If the detector detects that the number of particles in the unit time radiation of the first location is $T_0$, then the radiation source is the center of the ball and the distance R of the detector is a sphere, then the following formula is obtained.

$$ T_0 = T \cdot \frac{S}{4\pi R^2} \cdot \epsilon $$ (1)

$T$ is the number of particles emitted in unit time of the radiation source. The epsilon is the detector count correction factor, and the R is the distance between the radioactive source and the detector. $T_0$ is the number of particles detected by the unit time detector, and the S is the area of the detector. Obtain
In the same way, according to the number of radioactive particles in three other locations detected by the unit time scintillator detector, the distance between the radioactive sources and the detectors at different locations is $R_2$, $R_3$, $R_4$, such as Figure 2.

\[ R = \sqrt{\frac{T \varepsilon S}{4 \pi T_0}} \]  \hspace{1cm} (2)

In the coordinate system, $R_1$, $R_2$, $R_3$ and $R_4$ are calculated according to formula (2), and the following equations are listed:

\[
\begin{align*}
(x - x_1)^2 + (y - y_1)^2 + (z - z_1)^2 &= R_1^2 \\
(x - x_2)^2 + (y - y_2)^2 + (z - z_2)^2 &= R_2^2 \\
(x - x_3)^2 + (y - y_3)^2 + (z - z_3)^2 &= R_3^2 \\
(x - x_4)^2 + (y - y_4)^2 + (z - z_4)^2 &= R_4^2
\end{align*}
\]  \hspace{1cm} (3)

$(x_1, y_1, z_1)$ is the coordinates $O_1$ of the first location radiate source. $(x_2, y_2, z_2)$ is the coordinates $O_2$ of the second radioactive sources. $(x_3, y_3, z_3)$ is the coordinate $O_3$ of the radioactive sources of the third positions.

By solving the equation of three variables and two times, the coordinate position of the detector is obtained, and the coordinates of the detector in the coordinate system are obtained.

3. Simulation positioning system and experiment

The construction and experiment of the simulation positioning system is the key to the verification of the positioning method. Then, the composition, working principle and the specific experimental process of the simulation positioning system are introduced.
3.1. Composition of analog positioning system
The laboratory built a ground simulation system to simulate the location and analysis, and selected a source with a weaker immunity level to facilitate operation and management in the experiment. The ground simulation system consists of three parts: data acquisition, data transmission and sampling server. The core components of data transmission are scintillator detector, AD8014 operational amplifier and IT6333b power supply. The core components of data acquisition are 4 channels, 10 bits, and a digital spectrometer with a sampling rate of 1GSPS. The core of the sampling server is Root analysis software and Wavedump sampling software. [6] The 22Na, 60Co, 137Cs and 252Cf radioactive sources used in the experiment are 9×105Bq, 9×104Bq, 9.9×103Bq and 9.8×104Bq respectively. In the data transmission device, the scintillation detector converts the energy of the detected source to the analog electrical signal through the photoelectric conversion. It is transmitted to the data acquisition device after the operation amplifier is amplified and processed. The digital spectrometer transforms the analog signal into the digital signal and transmits it to the sampling server. The Wavedump sampling software can be obtained. Some sampling information, such as baseline location, sampling rate, sampling waveform, etc. are obtained, and the collected data are stored, and the data collected by the Root analysis software are analyzed and processed. Through the analysis and processing of the collected data, we can get the number of particles per unit time emitted by scintillation detector.

3.2. Ground positioning experiment
In the laboratory, the three axis Cartesian coordinate system is set up at a certain point. The radioactive sources are placed in different positions for testing. The locations of 22Na, 60Co, 137Cs and 252Cf radiation sources in the coordinate system are O1(240,275,258), O2 (70,445,110), O3 (265, 45, 55), O4 (35,162,305). The ground Analog positioning connection diagram, such as Figure 3, builds the hardware equipment of the ground simulation and positioning system, and connects the three parts of the data acquisition, data transmission and sampling server through a fiber, cable and other connection lines, such as Figure 4, of which the scintillation detector coordinates are (100,200,150).
the trigger rate. For 3.0MB/s, the effect of testing time factor on positioning error is reduced to a minimum, and the uniform setup time is 5000S.

![Real time test waveform](image)

**Fig 5.** Real time test waveform

After the 22Na radioactive source of the first coordinate location is tested, the other three coordinates of the radioactive source are tested separately. The collected data is stored in the sampling server for later analysis and processing.

4. Calculation of location results and analysis of positioning error

The data collection is finished, the positioning experiment is over. By analyzing the number of events detected by the detector, the positioning method is used in this paper, and the cause of the error caused by the location results is analyzed.

4.1. Derivation and calculation of the positioning results

Through the analysis and processing of the data collected by the test, after the calibration, the 22Na, 60Co, 137Cs and 252Cf energy spectra are drawn, such as Figure 6, Figure 7, figure 8, and Figure 9. At the same time, the number of radioactive source particles detected by four different coordinate position detectors are 2366989, 293361, 722646, 107700 respectively. The scintillator detector used in the experiment is the output of double end signal. When analysis and processing, the event is less than 15ns as true event [7], and the number of true events is 2319649, 281627, 708193, 105546 respectively. After counting the total number of events detected and the number of true events after screening, the counting correction factor is calculated. The formula is as follows:

$$\varepsilon = \frac{\text{True number}}{\text{Total number of events}}$$

(4)
By formula (4), the correction factor of scintillation detector for different coordinates of radioactive sources is calculated as 0.98, 0.96, 0.98 and 0.98 respectively. In the absence of radioactive sources, 5000S was detected and 4440 particles were detected. After removing the background noise, the number of radioactive sources arriving at four different coordinate locations is 2315209, 277187, 703753 and 101106 respectively. According to the test time, the number of radioactive sources detected in different locations per unit time is 463, 55, 140 and 20 respectively. The specific data are shown in Table 1.

**Table 1.** The number of events detected by the detector to four sources of radiation

| Radioactive Source | Total number of events detected | The number of true events after screening | Number of events detected without a radioactive source | The number of events per second detected by unit time |
|--------------------|---------------------------------|-----------------------------------------|--------------------------------------------------------|-----------------------------------------------------|
| $^{22}$Na          | 2366989                         | 2319649                                 | 4400                                                   | 463                                                  |
| $^{60}$Co          | 293361                          | 281627                                  |                                                        | 55                                                   |
| $^{137}$Cs         | 722646                          | 708193                                  |                                                        | 140                                                  |
| $^{252}$Cf         | 107700                          | 105546                                  |                                                        | 20                                                   |

The size of the scintillator detector used in the experiment is: 6mm (H) x 6mm (W) x 130mm (L). When testing, the scintillator detector and the radioactive source are not placed on the same plane, so the area of the radiation source of the radiation source is determined as the largest area of the scintillation.
detector: 780 mm². According to the calculated data, the distance R1, R2, R3 and R4 between O1, O2, O3, O4 radiation source and detector O5 are calculated by formula (2), and 344 mm, 312 mm, 66 mm, and R4 respectively. The obtained data is replaced by the equation group (3), and the coordinates of the detector O5 are calculated by using the least square method and three yuan two times overdetermined equations. The coordinates of the detector are located, and the specific data, such as Table 2, are realized. There is a deviation between the positioning result and the real coordinates of the detector (100, 200, 150), but the feasibility of the positioning method is verified, and the positioning accuracy should be further improved.

Table 2. Coordinates of four radioactive sources and the coordinates of the calculated detector

| Radioactive Source | Radioactive source coordinates /mm | The distance between a detector and a radioactive source /mm | Location of detector coordinates /mm |
|--------------------|----------------------------------|----------------------------------------------------------|-------------------------------------|
| ²²Na               | O₁ (240,275,258)                 | 344                                                      | O₅ (152.5,231.8,182)               |
| ⁶⁰Co               | O₂ (70,445,110)                  | 312                                                      |                                     |
| ¹³⁷Cs              | O₃ (265,45,55)                   | 66                                                       |                                     |
| ²⁵²Cf              | O₄ (35,162,305)                  | 546                                                      |                                     |

5. Conclusion
The multi source navigation positioning method is put forward, the ground simulation positioning system is built, and the ground simulation positioning experiment is carried out. By analyzing and calculating the collected data, the coordinate position of the detector is located, the location of the detector is realized, the feasibility of the method is verified, and the real guidance for the future is realized. Navigation positioning has made a reserve of theory and method. The next step will mainly improve the positioning accuracy of the method, including improving the making method of scintillation detector, improving the signal to noise ratio of data acquisition, optimizing the algorithm of data analysis and so on, and laying the foundation for real investment.

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