Numerous researchers have used sensing nodes in the terrain to collect electromagnetic environment information and synthesize electromagnetic spectrum maps under time series by interpolation and other means, thus representing the EMES. The EMES data in this paper are synthesized based on electromagnetic spectrum maps, and the experimental data are generated through three software simulations, Wireless Insite, LocaSpace 4, and MATLAB 2018b. Firstly, we selected a local area of the Taklamakan Desert with longitude 87.7753298691E-87.8692208574E, latitude 40.2132687192N- 40.2849404708N and an area 64 km in LocaSpace 4, and evenly extract 6400 geographic elevations at intervals of 100 meters. The geographical data was introduced into Wireless Insite, with the constant dielectric set to 4, the conductivity set to 0.01, and no vegetation cover, while four communication radios with a transmitting power of 50dBW and a frequency of 15MHz were set up. The electric field strength values for the area were calculated by the simulation to form a map of the electromagnetic spectrum at a single moment in time.

The experiments were set up with two datasets, consisting of 1 training set and 3 test sets for different application scenarios. We show some of the data from the training and test sets shown in **Figure 2**, and the datasets were constructed along the following lines as illustrated in **Table 2 - Table 6**.

**Dataset 1:** The EMES dataset is generated according to the method of constructing electromagnetic spectrum map data for a single moment as described above. In practical application, due to the significant error in the method of constructing electromagnetic spectrum maps and the complexity of electromagnetic environment changes, we define that under the standard normal electromagnetic spectrum map, the electromagnetic spectrum map with the same number of radio radiation sources, the noise of -15dB or less, fluctuation of radiation source location within 200m, and fluctuation of radio transmitting power within 10% are all normal EMES data. Based on this principle, we simulated and generated 3000 frames of normal electromagnetic spectrum maps as the sample data of normal EMES, named training set 1, to build a model to learn the potential data distribution and characteristic parameters of normal EMES.

Dataset 1 contains three test data, named test set 1, test set 2, and test set 3. All three test sets have 500 frames of electromagnetic spectrum maps, using the movement and disappearance of electromagnetic radiation sources and changes in emitted power to simulate the tactical behavior of electromagnetic radiation sources on the battlefield, such as position changes and power adjustments. Test set 1 focus on the movement and disappearance of a single source, with the ratio of normal to abnormal close to 3:2; test set 2 focuses on the movement and disappearance of multiple sources, with the ratio of normal to abnormal close to 3.5:1.5; test set 3 focuses on the variation of the emitted power and quantity of sources, with the ratio of normal to abnormal close to 3:2. The above three test sets identify anomalous data as being outside the range defined by the normal EMES.

**Data set 2:** Unlike data set 1, this data is not a single determination of whether the electromagnetic spectrum map conforms to a fixed distribution but incorporates the temporal dimension into the data set, mainly used to identify contextual anomalies. The training data are spaced 1 minute per frame of electromagnetic spectrum map data. The dataset has 2880 frames of electromagnetic spectrum map data, i.e., the normal EMES of the region during 48 hours, named training set 2. Training set 2 conceptualizes the fixed time switching on and off of radiation sources in the region, the regular adjustment of emission power, and the inclusion of traditional resting time into the design scope during 48 hours. The data in **Table 6** represent the percentage change in the emitted power of the radiating source. Therefore, in dataset 2, we define test samples that do not conform to their variation patterns as anomalous EMES. Based on this definition, we try to train models that conform to the objective life pattern and can determine the contextual anomalies.

Dataset 2 includes three test sets: test set 4, test set 5, and test set 6. The anomaly of the test set 4 is based on the addition of total domain noise. Gaussian white noise with three grades of low, medium, and high interference intensity is added in three different periods to test the model's ability to judge the noise anomaly. Test set 5 simulates the regular energy adjustment of the fixed radiation source, and the radiation source location is kept unchanged; test set 6 simulates the regular disappearance of the fixed radiation source, and the radiation source location is kept unchanged. Test set 5 and 6 are used to test the model's ability to detect contextual anomalies.

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| (a) Training Set 1, t=3 | (b) Test Set 1, t=142 | (c) Test Set 2, t=490 | (d) Test Set 3, t=140 |
| (e) Training Set 2, t=1190 | (f) Test Set 4, t=280 | (g) Test Set 5, t=500 | (h) Test Set 6, t=220 |

**Figure 2. Partial data plots of the training set and test set**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Table 2. Train Set 2   |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | | Source number | 0000-0500 | 0500-0600 | 0600-1400 | 1400-1800 | 1800-2000 | 2000-2400 | | 1 | —— | 0--10% | 10%--200% | 200%--10% | 10%--0 | —— | | 2 | —— | —— | 0%--50% | 50%--20% | 20%--0 | —— | | 3 | —— | —— | 0%--10% | 10%--20% | 20%--10% | 10%--0% | | 4 | —— | —— | —— | —— | 0%--200% | 200%--0% | |  | 1-300 | 301-360 | 361-840 | 841-1080 | 1081-1200 | 1201-1440 |   Table 3. Test Set 4、5、6   |  |  |  |  | | --- | --- | --- | --- | | Source number | 1100-1400 | 1400-1800 | 1800-2000 | | 1 | 128.75%--200% | 200%--10% | 10%--0 | | 2 | 31.25%--50% | 50%--20% | 20%--0 | | 3 | 6.25%--10% | 10%--20% | 20%--10% | | 4 | —— | —— | 0%--200% | |  | 1-180 | 181-420 | 421-540 | | Test Set 4 | At 50-100, #1 suffers interference in units of 0.0015.  At 240-300, #2 suffers interference in units of 0.003.  At 480-520, #4 suffers from interference in units of 0.004. | | | | Test Set 5 | At 1-420, the energy of radiation source #1 is expanded by 0.5 times at 10-minute intervals.  At 420-540, the energy of radiation source #4 is expanded by 6 times at 10-minute intervals | | | | Test Set 6 | The source of radiation #4 disappears once every 10 minutes. | | | |

Table 4. Test Set 1

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| Timing (frames) | Type | Status |
| 1—50 | Normality | Stationary |
| 51—80 | Anomaly | Radiation source # 1 moving due east, 100 m/frame. |
| 81—120 | Anomaly | Stationary |
| 121—150 | Anomaly | Radiation source # 1 moving due west, 100 m/frame. |
| 151—300 | Normality | Stationary |
| 301—320 | Anomaly | Radiation source # 1 moving due south, 200 m/frame. |
| 321—360 | Anomaly | Radiation source # 1 moving due north, 100 m/frame. |
| 361—400 | Anomaly | Disappearance of radiation source # 1 |
| 401—500 | Normality | Radiation source # 1 appears, stationary |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Table 5. Test Set 3   |  |  |  | | --- | --- | --- | | Timing (frames) | Type | Status | | 1—50 | Normality | Stationary | | 51—80 | Normality | Stationary | | 81—120 | Anomaly | Stationary | | 121—150 | Anomaly | Radiation source # 1 moving due west, 100 m/frame.  Radiation source # 2 moving due north, 100 m/frame.  Radiation source # 3 moving due south, 100 m/frame.  Radiation source # 4 moving northeast, 100√2 m/frame. | | 151—400 | Normality | Stationary | | 401—420 | Anomaly | Radiation source # 2 and # 4 moving to the southwest, 200√2 m/frame. | | 421—480 | Anomaly | Radiation source #1 disappears.  Radiation source #4 disappears. | | 481—500 | Normality | Radiation source # 1 appears. | | Table 6. Test Set 3   |  |  |  | | --- | --- | --- | | Timing (frames) | Type | Status | | 1—50 | Normality | Stationary | | 51—80 | Anomaly | The energy of radiation source # 4 is reduced by 80% | | 81—120 | Anomaly | Radiation source #2 disappears.  Radiation source #4 disappears. | | 121—150 | Anomaly | New radiation source # 5 in the southwest corner. | | 151—400 | Normality | Radiation source #5 disappears and all the rest appear. | | 401—420 | Anomaly | New radiation source # 6 in the southeast corner | | 421—480 | Anomaly | Presence of radiation source # 5, sudden increase of energy by 50%.  The presence of a normal source of radiation # 6 with a 50% increase in energy.  The rest of the sources show a 50% decrease in energy. | | 481—500 | Anomaly | Radiation source #5 disappears.  Radiation source #6 disappears.  Recovery of radiation source # 3. | |