A Multi-sensor Fusion System for Embedded Devices Considering by Sensor Reliability

Jiale Qiao, Jindong Zhang, Yuze Wang, Chenhui Yu, Sai Gao

Jilin University, Changchun 130012, China

Keywords: Multi-sensor, embedded device, simulation results show that algorithm

Abstract: This paper presents a multi-sensor information fusion system based on SVM (Support Vector Machine) and D-S evidence theory, and applies it to embedded devices. Each time the data collected by multi-sensor is received, the data will be brought into the decision tree of the binary classification SVM and the decision vector will be output. The decision result of the system considers that the reliability of different sensors is different, so the probability redistribution of decision vectors is carried out by using the reliability. Finally, D-S evidence theory is used to fuse each decision vectors after probability redistribution. The simulation results show that the algorithm takes into account the different reliability of the sensor and is simple in calculation and short in processing time. It is suitable for embedded devices with low computing speed.

1. Introduction

At present, multi-sensor information fusion technology has been applied in many fields, and has become a hot emerging science and technology. Military applications in military defense and marine defense systems, etc. While it has been applied in many fields, such as intelligent industrial control, micro-surgery, unmanned driving and so on in recent years. [1-3] Usually, in a complex multi-sensor recognition system, Because of the difference of the type, precision and position of each sensor, the reliability of the sensor in the decision-making system is also different. STANAG2511 has been related to the definition of reliability and credibility. According to the standard of STANGA2511, it is necessary to consider the reliability of different sensors as the basis for decision-making.

Many studies have proposed relevant algorithms to quantify the reliability and participate in decision-making. Based on this, this paper proposes a multi-sensor information fusion algorithm for embedded devices with less computation. The initial decision is made by SVM, and the decision vectors output by SVM are redistributed according to the reliability of the sensor itself. Finally, the classical D-S formula is used for information fusion [4]. Experiments show that the algorithm is simple in calculation and short in processing time, and is suitable for embedded devices.

2. Algorithm Description

Using this algorithm, the data collected by multi-sensor can be processed in real time, and a small amount of time is spent on information fusion. Firstly, the data collected by sensors are input into the SVM for classification (if the focal elements in the recognition framework are larger than 2, then the binary classification SVM tree is used to get the decision vector). Because the reliability of each sensor is different, the probability correction of the sensor's decision vector is carried out by using the reliability of the sensor, and the redistribution vector is obtained. Finally, the D-S fusion rule is used to fuse the redistribution vectors of each sensor, and the final result is obtained. If all the original data are directly put into SVM for calculation, not only does it not take into account the different reliability of different sensors, but also increases the amount of calculation. The flow chart of the algorithm is shown in Figure 1.

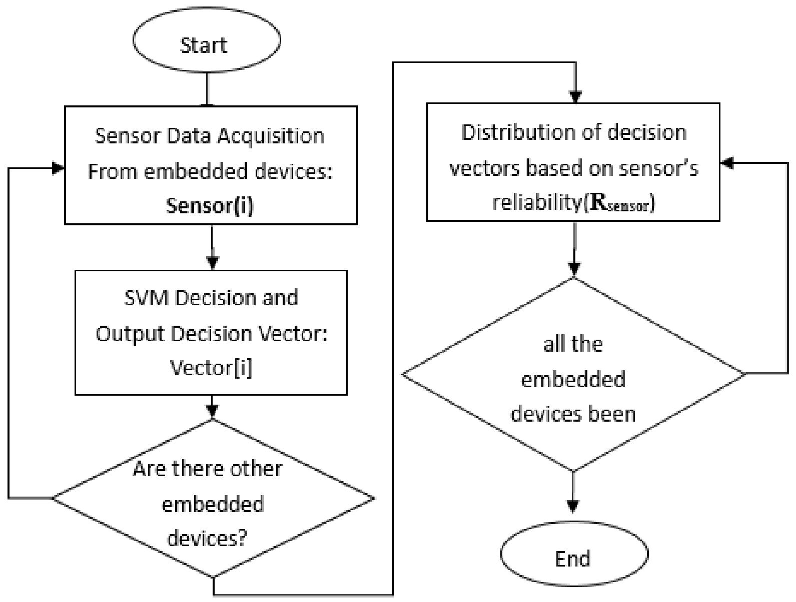

Figure 1. The flow chat

3. Main Modules Design

When sensor collects the data, it should input the data into SVM for decision-making. If the number of focal elements in the recognition framework is more than 2, multiple binary SVMs are used for decision-making, and finally a decision vector is output. It is easy to know the characteristics of SVM, and the decision vector consists of one and several zeros. The specific process is shown in Figure 2, where the initial decision vector is composed of 0 or 1 of the four circular outputs. The number of SVM classifiers depends on the number of focal elements. The process of SVM classification is equivalent to each sensor voting for its own supporting focal elements.

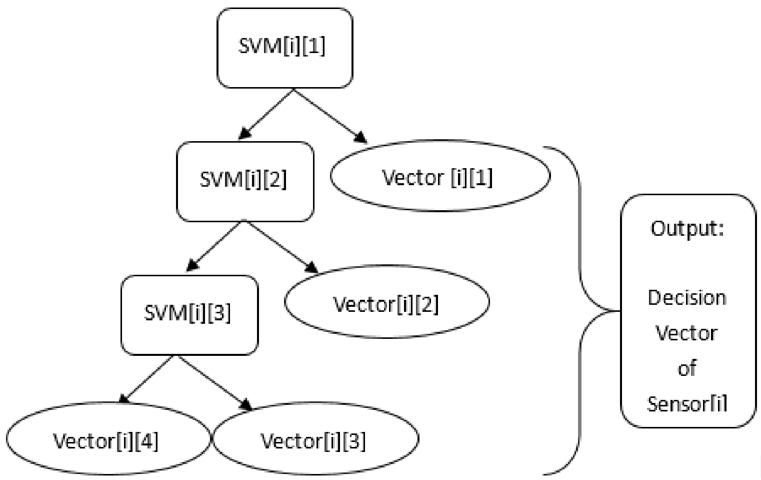

Figure 2. Multi-Classification SVM Decision Tree

However, it is obvious that the results of fusion decision using D-S evidence theory in the face of such output would seriously violate normal human cognition (that is, Zadeh's paradox). The reliability of the sensor itself should also be considered because of the influence of the variety, accuracy, observation position, environment and other factors of the sensor. Many studies have quantified the reliability. We use the size of sensor reliability to redistribute the decision vectors from SVM. The purpose is to fully consider the possibility of failure and to spread the risk of failure to other focal elements. Let $\alpha^T = (0,...,0,1,0,...,0)$ is the Decision Vector of SVM's Output, and the distribution formula adopted $\beta^T = (\frac{1-R_{sensor}}{N},...,\frac{1-R_{sensor}}{N}, R_{sensor}, \frac{1-R_{sensor}}{N},...,\frac{1-R_{sensor}}{N})$ .Whereas Rsensor represents the reliability of the sensor, N represents the number of focal elements. The decision vector after reallocation takes into account the risk of sensor failure, and assigns more weight to the support focal elements of the sensor with high reliability. Finally, classical D-S evidence theory is used to fuse and get the results. The algorithm is simple, easy to calculate on embedded devices, and has better real-time performance. The code of the algorithm is as follows:

```
IF Sensors have collected data THEN
FOR (i=first sensor data;i<last sensor data ;step+1)
Vector [i] ← SVM(data[i])//Data output decision vector via SVM
FOR (j=first value;i<last value of the vector ;step+1)
IF Vector[i] [j] =1 THEN Vector[i] [j] ← p[i]//P represents the reliability of the sensor.
END IF.
IF Vector[i] [j] =0 THEN Vector[i] [j] ← (1-p[i])//M represents the number of focal elements
END IF. END FOR
Result ← DS (Vector [1], Vector [2], Vector [3] .... Vector[M])//Using D-S Fusion Formula
END IF.
```

4. Result and Analysis

The laptop running the algorithm is configured as follow: CPU-Intel(R) Core(TM) i5-5200U CPU @ 2.20GHz, graphics card-AMD Radeon R7 M270, memory-6GB, hard disk-1TB. This experiment takes two sensors with different reliability as an example, and uses computer simulation. Using [1,1] and [3,3] as the centers of the positive and negative classes respectively, the positive and negative class data are generated by adding 0-mean Gaussian noise. The simulation results of positive and negative data distribution of Sensor1 and Sensor2 are shown in Figure 3 and Figure 4 respectively.

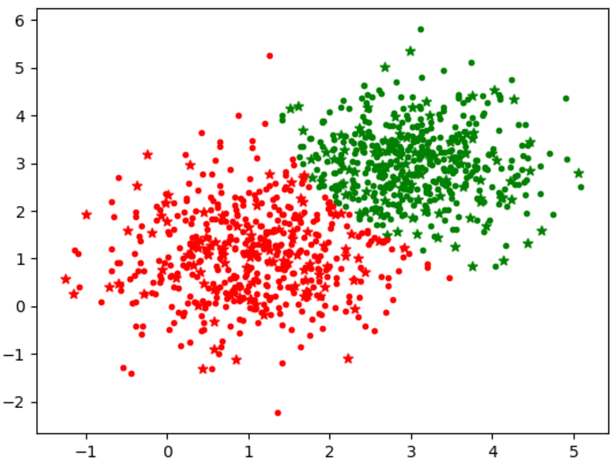

Figure 3. Simulation Diagram of sensor1

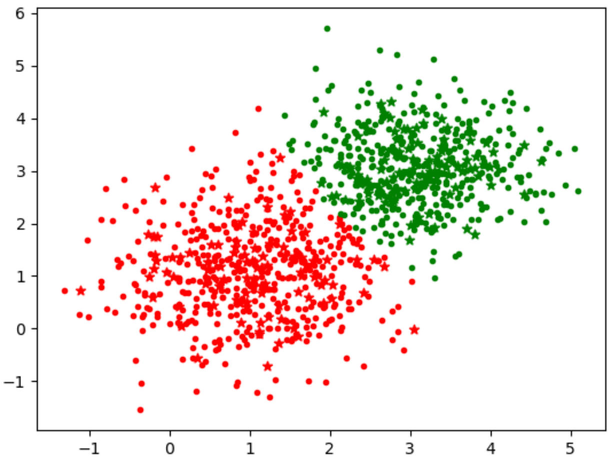

Figure 4. Simulation Diagram of sensor2

Figure 5 shows the change curve of the fusion result of the sample data when the sensor reliability changes. It can be seen that for a single sensor, the higher the reliability, the greater the weight of the impact on the final fusion results. Figure 6 shows the time consumed by multiple system processing. It can be seen that due to the small amount of calculation, the time consumed by the system is basically stable and the time consumed is relatively short.

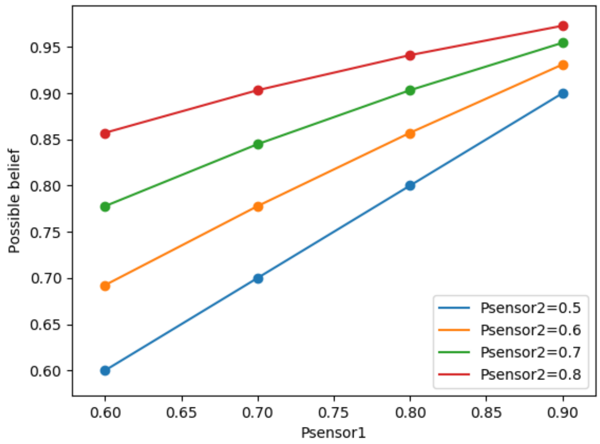

Figure 5. The Curve of P and Possible belief

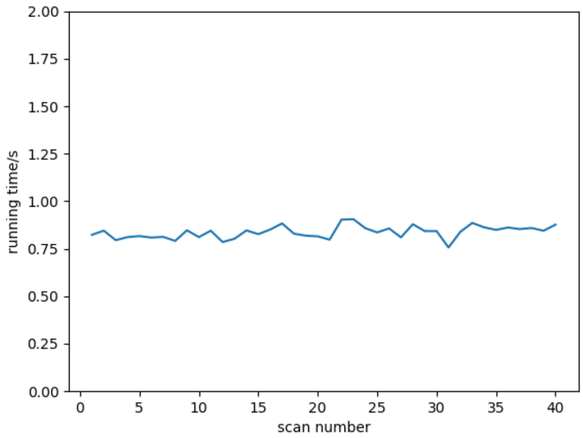

Figure 6. System Running Time

5. Conclusion

In this paper, a multi-sensor information fusion system based on D-S theory and SVM is proposed. It takes full account of the reliability of the sensor itself. Each sensor makes initial decision using binary SVM decision tree, and then fuses all sensor information using D-S theory after reliability correlation calculation. The algorithm has the advantages of simple calculation, fast running speed and good real-time performance in practical application.

Acknowledgements

This work was supported by the National Key Research and Development Program of China (2017YFB0102500), Natural Science Foundation of Jilin province (20170101133JC), the Korea Foundation for Advanced Studies' International Scholar Exchange Fellowship for the academic year of 2017-2018, and Jilin University (5157050847,2018B2018, 2017XYB252).

References

[1] Jiang Wen, A correlation coefficient for belief functions, International Journal of Approximate Reasoning, DEC 2018, Volume: 103, Pages: 94-106.

[2] Wu Jun, Su Yongheng, Cheng Yiweil, Multi-sensor information fusion for remaining useful life prediction of machining tools by adaptive network based fuzzy inference system, Applied Soft Computing, JUL 2018, Volume: 68, Pages: 13-23.

[3] Li Jie, Yang Xuezhou, Zhou Liang, Multi-Sensor Target Recognition Based-on Multi-Period Improved DS Evidence Fusion Method, Journal of Nanoelectronics and Optoelectronics, MAY 2018, Volume: 3, Pages: 758-767.

[4] Yang Dan, Ji Hongbing, Gao Yongchan, A robust D-S fusion algorithm for multi-target multi-sensor with higher reliability, Information Fusion, MAY 2019, Volume: 47, Pages: 32-44.

[5] An Jiyao, Hu Meng, Fu li, A Novel Fuzzy Approach for Combining Uncertain Conflict Evidences in the Dempster-Shafer Theory, IEEE Access, 2019, Volume: 7, Pages: 7481-7501.