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A data fusion method for distributed sensor networks

Field of the invention

[0001] The present invention relates to a method for improving the system performance in distributed sensor networks, and more particularly, related to a distributed system which is composed of several local sensors and a fusion center.

Background

[0002] The deployment of multiple sensors for signal detection in an intelligent transportation application may substantially enhance system survivability. Due to the lack of the communication capacities available in early distributed systems, decisions were made in the local sensors and only the binary results were sent to the fusion center. This is also called the decentralized detection. Each local sensor transmits its binary decision to the fusion center where the global decision is obtained based on k-out-of-n fusion rule. However, the optimal fusion rule requires the prior knowledge of the probability of false alarm (PFA) and the probability of detection (Pd) at each local sensor, which is not always available in practice. To remove this restriction, a blind adaptive decision fusion was developed. It uses the estimated local PFA and Pd instead of true values. When the environment is stationary, the adaptive fusion can obtain performance similar to that of the optimal fusion.

[0003] If the channel capacities between local sensors and the fusion center are large enough to allow local sensors to transmit nonbinary decisions or local statistics to the fusion center, better performance may be achieved. In such a system, the observations available at each local sensor are quantized to produce a multiple digit decision which is sent to the fusion center. The Sum rule performs as well as the optimum rule when SNRs happened to be identical in local sensors, and only has a tolerable loss when local SNRs differ significantly. However, when the SINRs of local sensors are different, the performance degradation of Sum rule will occur.

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Summary of the invention

[0004] A data fusion method for distributed sensor network is disclosed, in order to improve performance when the SNRs of local sensors are different.

[0005] This system involves multiple distributed sensors spatially and observing the same range cell. All local sensors are linked to a central processor which fuses data received from all sensors. The observations at the local sensors are assumed to be conditionally independent.

[0006] The steps of the invention are as follows:

A. Local sensors receive and store N pulse data.

B. Local sensors calculated local R statistics based on the stored data.

C. Local sensors transmit local R statistics to the fusion center.

D. Fusion center calculated global R statistics based on local R statistics from local sensors

E. Fusion center make detection decision based on global R statistics

[0007] In step A, suppose x_{in} is the data for ith sensor and nth pulse.

[0008] In step B, the R statistics for ith sensor, r_i, is calculated by:

$$r_i = \frac{1}{\sigma_i^2} \sum_{n=1}^{N} (x_{in} x_{in}^*)$$

Where N is the pulse number and σ_i^2 is the noise power.

[0009] In step D, the weighted R statistics is calculated by weighting local R statistics by itself, which is as follows:

$$R = \sum_{i=1}^{L} r_i^2$$

Where L is the sensor number.

[0010] In step E, the fusion center compares global R statistics with a threshold. If R is larger

than the threshold, a target is detected.

Brief description of the drawings

[0011] Fig.1 is a schematic diagram of the distributed detection system in Parallel.

[0012] Fig.2 is a schematic diagram of the data fusion method process

[0013] Fig.3 is a schematic diagram of the performance of 10 pulses accumulation

[0014] Fig.4 is a schematic diagram of the performance of 50 pulses accumulation

Detailed description of the invention

[0015] This invention is further exemplified with the use of the figures and the embodiments.

[0016] A typical parallel network is shown in Fig.**1**. This system involves L sensors distributed spatially and observing the same range cell. $LP_1 \ldots LP_N$ which are denoted as **120** are local sensors. All sensors are linked to a central processor **110** which fuses data received from all sensors. The observations at the local sensors are assumed to be conditionally independent and the observation of the ith local sensors is denoted by x_i (i=1,..., L). Suppose x_{in} is the data for ith sensor and nth pulse. Thus the joint probability density function (PDF) of x_1, x_2, ..., x_L is in the following form.

$$f(x_1, x_2, \ldots, x_L) = \prod_{i=1}^{L} f(x_i)$$

[0017] Each local sensor forms the local result u_i basing on its own observation x_i and transmits u_i to the fusion center. Then, the fusion center combines all u_i, which can be binary decisions, local statistics or all raw observations data, to yield the global decision u_0.

[0018] The target echo is embedded in a white complex Gaussian noise whose power is

unknown. Then the detection problem in the *i*th sensor is:

$$\begin{cases} x_i = n_i & H_0 \\ x_i = s_i + n_i & H_1 \end{cases}$$

Where n_i, s_i is the noise and target signal at the *i*th local sensor respectively.

[0019] According to the above assumptions, the conditional PDF of the single observation x_i at the *i*th local sensor is

$$\begin{cases} f(x_i \mid H_0) = \dfrac{1}{2\pi\sigma_i^2}\exp(-\dfrac{x_i x_i^*}{2\sigma_i^2}) \\ f(x_i \mid H_1) = \dfrac{1}{2\pi\sigma_i^2(1+\lambda_i)}\exp(-\dfrac{x_i x_i^*}{2\sigma_i^2(1+\lambda_i)}) \end{cases} \quad i = 1, 2, ..., L$$

where σ_i^2 and λ_i represent the noise power and SNR at the *i*th local sensor, respectively.

[0020] The method process is shown in Fig.**2**. In step **210**, Local sensors receive and store N pulse data.

[0021] In step **220**, local sensor calculated local R statistics r_i based on received data:

$$r_i = \frac{1}{\sigma_i^2}\sum_{n=1}^{N}(x_{in}x_{in}^*)$$

[0022] In step **230**, local sensors send r_i to the fusion center.

[0023] In step **240**, the global R statistic is calculated by the fusion center, which is called Wsum(weighted sum) method:

$$R = \sum_{i=1}^{L} r_i^2$$

Where L is the number of local sensors.

[0024] the Wsum fusion rule, which weights these local R statistics differently, is to solve the problem that detection performance drops. This extension is important especially in case of

multiple pulses for the increased difference between local SNRs. This new rule does not sum up the R statistic directly but weights them by themselves.

$$R_{Wsum} = \sum_{i=1}^{L} r_i^2 \underset{H_0}{\overset{H_1}{>}} T$$

where T is the threshold decided by the desired P_{FA} of the system.

[0025] The Wsum rule changes the linear fusion of R statistics to the quadratic fusion, which enlarges the gap of local R statistics, thus making the bigger R statistics acquire more importance. With the reasonable assumption that local sensors with higher SNR will send bigger R statistics, we could expect Wsum rule outperform the Sum fusion when local SNRs are quite different. Besides, the Wsum rule doesn't need the local SNRs either, so it is also a nonparametric fusion rule and can be used conveniently.

[0026] In step **250**, the fusion center compares the R with a threshold. The threshold is decided by the desired P_{FA} of the system. If R is larger than the threshold, a target is detected. Because the Wsum rule is quartic power of observation and the SNR is the ratio of quadratic power of target signal to noise power. We define the total SNR of the Wsum rule as follows:

$$SNR_{Wsum} = \frac{\sqrt{E(r_{\text{Wsum}} \mid H_1)}}{\sqrt{E(r_{\text{Wsum}} \mid H_0)}} - 1 = \sqrt{\frac{1}{L}\sum_{i=1}^{L}(1+\lambda_i)^2} - 1 > \frac{1}{L}\sum_{i=1}^{L}\lambda_i$$

[0027] The Wsum rule can provide higher total average SNR than that given by the sum fusion rule.

[0028] Now we consider a parallel networks involving 3 local sensors. Other conditions are the same as before. The pulse number in **Error! Reference source not found.** and Fig.**4** are 10 and 50 respectively. **Error! Reference source not found.** shows the performance of the two rules with λ_1=2db and λ_2=λ_3. The improvement of the Wsum fusion rule over the Sum fusion rule is prominent for λ_2 and λ_3 both being low. In Fig.4, the similar results to the case of two sensors with 50 pulses are depicted.

[0029] From the above simulation results, it can be seen that when there's significant difference among local SNRs, the Sum rule degrades a lot. The Wsum method weights the R statistics with itself, so it emphasizes the use of the data with higher SNRs and mitigates the negative influence of local statistics with lower SNRs.

[0030] What is stated above is just an example of the embodiments of this invention, and is not meant to be restricting on the scope of the present invention. Any equivalent modification or adjustment of the scope of the invention falls within the scope of the present invention.

Claim

1. A data fusion method for distributed sensor networks, comprising:

Receiving and storing N pulse data by local sensors;

Calculating R statistics based on the stored data by local sensors;

Transmitting R statistics to the fusion center by local sensors;

Calculating weighted R statistics based on local R statistics from local sensors;

Making detection decision based on weighted R statistics.

2. The method of claim 1, wherein distributed sensor networks includes several local sensors and one fusion center which makes global decision based on the input of local sensors.

3. The method of claim 1, wherein local sensor calculates R statistics based on the stored data by local sensors according to the following formula:

$$r_i = \frac{1}{\sigma_i^2} \sum_{n=1}^{N} (x_{in} x_{in}^*)$$

x_{in} is the data for ith sensor and nth pulse, N_i is the pulse number and u_i is the noise power, R_i is the R statistics of ith sensor. σ_i^2 is the noise power of the ith sensor.

4. The method of claim 1, wherein the weighted R statistics is calculated by weighting local R according to the following formula:

$$R = \sum_{i=1}^{L} r_i^2$$

Where L is the sensor number.

5. The method of claim 1, wherein Fusion center making detection decision comprises:

Comparing global R statistics with a threshold.

If R is larger than the threshold, a target is detected.