Signal hunting algorithm with low energy consumption based on packet difference mechanism in sensor network

Zhao Jinhui[1], Zhuang Yi[1], Xu Yan[1]

1.College of Computer Science and Technology, Nanjing University of Aeronautics and Astronautics, Nanjing, 210016, China

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Abstract. To deal with the difficulties of getting network positioning signals existing in sensor network as well as the problem of the hunted signals being polluted by electromagnetic radiation, mechanism of hunting for sensor positioning signals based on correlator difference accumulative algorithm is proposed in this paper. First of all, proportionality coefficient between the extreme value and second-extreme value of the interfering energy of the signals is selected as the mediation threshold to calculate the optimum value of the mediation threshold to capture the signals. After that, differential mechanism is designed to evade efficiently frequency shift resulted from Doppler factors of positioning signals; moreover, based on the frequency of Doppler high frequency positioning signals and the probability under low signal to noise ratio environment, theoretical analysis is conducted on the algorithm put forward in this essay in anti-noise performance and early warning performance. The simulation results have shown that compared with the current relevant sensor signal capturing techniques and under the same data receiving strength, the hunting algorithm raised in this paper has much higher early warning performance and anti-noise performance.

Introduction

At present, Sensor positioning signal hunting is to capture the carrier wave launched by the navigational sensor and the phase codes parameters. Terminals are usually required to adopt various ways to capture signals. Sensor navigational and sensor service terminal often adopts parallel acquisition pattern, and then specific value of the phase carried by the carrier wave could be calculated through FFT changes, in which way the signals could be captured. Generally speaking, when the sensor positioning signal is rather weak, to obtain the optimum ratio of signal loss to profit, it is often required that the algorithm could eliminate fully the Doppler error resulted from high movement of the sensor. The sensor group consisted of navigational sensors is located at the core of sensor network and it is the cerebral center of the whole system. The positioning signals launched by various terminals through hunting navigational sensors keep fixing position lines on the spherical hyper plane. Once the positioning signal of certain terminal is captured, the position of the captured terminal could be fixed accurately through the signal. Since the intensity of the sensor positioning signal is rather low and the signal to noise ratio index is poor, it is always interfered by intense natural noises. So, to capture sensor signals at low signal to noise ratio is the key link of realizing complete navigation. Chatzigiannakis I introduced signal coherence accumulative means, which could reduce bit errors by lowering natural noise effect existed in sensor navigation data; however, due to insufficient consideration of Doppler effects brought by high movement of the sensors, the bit errors might keep increasing with the time passing. Tang Bin et al. had conducted differential treatment on the captured signals first, and then non-coherent treatment on orthogonal signal set, which could reduce efficiently the influences of natural noises on positioning signals. However, since decoding of orthogonal codes requires complex orthogonal calculation, when the intensity of nature noises increases sharply or when it is at strong electromagnetic interference, serious error effects are possibly to be caused. Li etc, et al accumulated relevant bit errors through delay effect and reduced efficiently correlated bit errors by adopting square-based threshold decision mechanism within the scope of Doppler time shifting; however, since the sensor signals are at high-frequency signal section, simple accumulation of coherent codes by delaying is easily to cause decreasing of capturing efficiency and when the frequency of searching positioning signal at the terminal is large, the terminal chip would be easy to be overloaded.

Sensor sensor positioning signal analysis and hunting analysis

Sampled sensor positioning signals could be divided into envelope, level sequence and frequency shift, which could be written in the following signal analytical form:

$$y_n = Ad(t_n)c[(1+\eta)(t_n-\tau)] \times \cos[2\pi(f_{IF}-f_D)t_n+\phi_0]+v_n \quad (1)$$

A stands for the sampled electrical level of the sensor signal positioning at the moment. Among which, y_n refers to the sensor positioning signal obtained at the moment t_n, $d(t)$ is the random code and there are two telegraph texts $+1$ and -1 in terms of probability; f_D is the frequency shift resulted from high relative velocity between the sensor and the ground; ϕ_0 is the phase distribution of sensor positioning signal at certain specific moment. In case the atmosphere does not affected by solar storm or are affected less, f_D and η satisfy the following relational expression: $f_D = \eta 1575.42\times10^6$; v_n refers to a steady, random Gaussian process signal, whose standard deviation is σ_v. $c(t)$ is the noise signal, which resulted mainly from electromagnetic pollution; η is the noise correction factor of $c(t)$ in signal Doppler frequency shift effect. When the obtained sensor positioning signal is strong, $\eta->0$, and vice verse, therefore, the influencing factor of η shall not be ignored. f_{IF} is the frequency of the demodulation signal obtained after demodulation;

Since y_n could be written in superposed form of disassembled copses component i_n and orthogonal component q_n, i.e.:

$$y_n = i_n + q_n \quad (2)$$

The analytical expression of i_n and q_n is as the follows:

$$i_n = c[(1+\eta')(t_n - \tau')]\cos[2\pi(f_{IF} - f_D')t_n] \qquad (3)$$

$$q_n = -c[(1+\eta')(t_n - \tau')]\sin[2\pi(f_{IF} - f_D')t_n] \qquad (4)$$

It is obvious that i_n and q_n satisfies $i_n \times q_n = 0$, among which η', τ', f_D' are respectively the maximum likelihood estimation of η, τ, f_D and meet the following relational expression: $f_D' = \eta' 1575.42\times 10^6$.

The received sensor positioning signal is a sum of sequences, i.e. i_n and q_n are respectively the child element of concurrent component sequences I and orthogonal component sequence Q, it is obvious that the analytical expression of I and Q could be expressed in the following form:

$$I = \sum_{i=1}^{N} y_n i_n \qquad (5)$$

$$Q = \sum_{i=1}^{N} y_n q_n \qquad (6)$$

Among which, N is the total dimension of the sampling period sequences, i.e. the limits in expression (5) and (6) are the sampling period. Substitute expressions (5) and (6) in (1), it could be obtained that:

$$Y = \sum_{n=1}^{N} y_n c[(1+\eta')(t_n - \tau')] \times \exp\{-j[2\pi(f_{IF} - f_D')t_n] + \phi_0\} \qquad (7)$$

Among which, η', τ', f_D' are same as expressions (3) and（4）, j is the complex number unit, exp is natural logarithm and ϕ_0 is the phase distribution of Sensor positioning signal at certain specific moment.

In the process of deploying sensor network, it is necessary to conduct low-pass filtering on sensor positioning signals, for modulation treatment is not conducted when sensor positioning signals are launched and the signal power is focused mainly at the low-pass section. Low-pass filtering could filter natural background noises. Defeind (7) is the analytical expression of sensor positioning signals captured at certain moment; however, it is just a mathematical expression. The analytical expression of sensor positioning signal after low-pass filtering could be expressed in the following form:

$$y_n = 0.5Ad(t_n)R_c(\Delta\tau)\sin c[(\Delta f_D)T_c] \times \exp\{-j[2\pi(\Delta f_D)T_c] + \phi_0\} + g_n \qquad (8)$$

Among which, $R_c(\Delta\tau)$ is the autocorrelation function of Doppler frequency shift, $\sin c$ is Singh function; T_c refers to low-pass filtering time; g_n is the natural noise function within T_c (mainly stationary random process).

Simulation and analysis

The algorithm proposed by NS2 simulation platform is simulated and the signal generation way is generated according to expression (1). The simulation parameters are as shown in Table 1:

Table 1 Simulation Parameters Table

Parameters	Values
Signal cycle duration (T_s)	600 ms
Frequency of sensor positioning signal (f)	1.575 MHZ
Mean value of background noise (m)	0
Background noise variance (σ^2)	1
Initial noise phase	π/2
Received SNR (dB)	-22dB
Input signal strength of the receiver	Random
Signal integration time	200ms, 400ms, 600ms
Times of signal capturing	2000
Signal deviation frequency	200HZ, 400HZ, 600HZ

To verify the efficiency of these algorithms, the times of signal capturing are all set as 2,000 times. Simulation is then conducted according to the parameters shown in Table 1 and the proportion between the early warning probability and mediation threshold thus obtained see Table 2. First, according to different signal accumulating time (200ms, 400ms, 600ms), AGDAM（Average Grouped Difference Accumulation Mechanism）, NGDAM（Not Grouped Differential Accumulation Mechanism）and GDAM（Grouped & Indifference Accumulation Mechanism） are put forward. This is because that the dimension of the mediation threshold is related closely with the signal intensity, i.e. the stronger the signal is, the higher the mediation threshold is and therefore, the larger the probability of early warning appears. Meanwhile, with the increase of signal accumulating time, the early warning probability would decrease. From Figure 1, it could be seen that the mediation threshold and early warning probability of AGDAM has obvious reverse variation relations: with the increase of the mediation threshold, the early warning probability decreases sharply. This is because grouping mechanism is adopted in this essay. With the increase of signal accumulating time, the larger the probability of occurring the most powerful signal and therefore, the mediation threshold would increase accordingly. Thus, early warning probability would be lowered greatly.

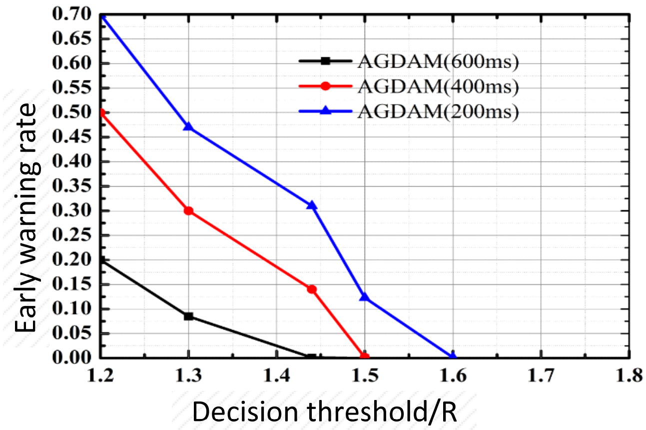

Figure 1 Test results of early warning rate under different mediation thresholds calculated with the algorithm raised in this essay

It could be seen from Figure 2 that with the change of signal accumulating time, there are obvious differences between the AGDAM, NGDAM and GDAM algorithms: within the same signal accumulative time, performance of AGDAM algorithm is much better than the latter two. This is because that the introduction of grouping and differential mechanism could reduce efficiently the accumulated noise effects within the same signal accumulating time and therefore the probability of occurring early warning would decrease. Besides, with the increase the signal accumulating time, the convergence rate of the AGDAM algorithm is obviously better than the latter two.

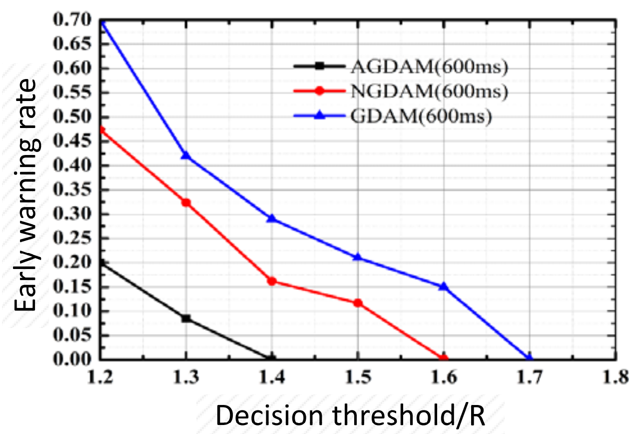

Figure 2 Test results of early warning rate under different mediation thresholds calculated with three algorithms

Conclusion

Taking proportionality coefficient between the extreme value and second-extreme value of the interfering energy of the signals as the mediation threshold, the optimum value of the mediation threshold to capture the signals is calculated. Then, specific mathematical version of Sensor navigational positioning signal is considered and differential mechanism is brought in to increase signal mediation threshold and early warning threshold index, and threshold operation is dealt with aim at the actual conditions of high Doppler frequency shift and poor SNR index. The simulation results have shown that the mechanism raised in this essay has improved much in early warning threshold index and mediation threshold, which is of practical significance in guiding the construction of sensor navigation network.

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