IEEE Access
Multidisciplinary ⋮ Rapid Review ⋮ Open Access Journal

Received November 22, 2021, accepted December 5, 2021, date of publication December 13, 2021, date of current version December 24, 2021.

Digital Object Identifier 10.1109/ACCESS.2021.3135040

The Determination Method of Battlefield Monitoring Interval Period Based on the Complicatedness of Situation Changes

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This work was supported in part by the Youth Program of National Natural Science Foundation of China under Grant 71901217, and in part by the Military Scientific Research under Project 20191A020107.

ABSTRACT Commanders are aware of the battlefield situation (BS) by monitoring the battlefield periodically. When the monitoring interval period is too short, there will be a huge cognitive load, which seriously affects commanders' situation awareness (SA). When the monitoring interval period is too long, there will be omission of important information, which also affects commanders' SA. Therefore, it is necessary to set the reasonable interval period of monitoring battlefield. In this paper, BS signal is defined to represent BS changes, according to the characteristics of BS changes. Then Fourier transform (FT) is used to analyze frequency characteristics of BS signal in order to describe the complicatedness of BS changes. The discriminant of reasonable monitoring interval period (DRMIP) is derived, according to the commanders' requirements accuracy of BS. When the complicatedness of BS changes cannot be obtained previously, the highest frequency iteration algorithm (HFIA) is proposed to obtain the best monitoring interval period according to iterative BS signal. In the case of setting the threshold of difference, the validity of the proposed method was verified by simulation calculation method.

INDEX TERMS Battlefield situation (BS), Fourier transform (FT), monitoring interval period.

I. INTRODUCTION

Monitoring battlefield by systems is the basic means for commanders to be aware of battlefield situation (BS) [1], [2]. Generally, commanders use a variety of sensing devices to periodically monitor the battlefield [3]. But sensing devices are the scarce resource in the battlefield. Each sensor needs to monitor multiple targets, it can only be used in a multiplexed form and not exclusively by a single target. So it does not allow the commander to monitor the battlefield continuously, the commander can only monitor the battlefield intermittently. When the commanders monitor the battlefield too few times, the differences between adjacent monitoring scenes are great. There will be omission of situational information, if it is serious enough, which may cause the commanders' cognitive error [4], [5]. When the commanders monitor the battlefield too many times, the difference between adjacent monitoring scenes is small. The commanders will get too many meaningless information that will increase the cognitive load and cause a waste of sensing resources [6]. Therefore, there is a realistic military technical problem to determine the reasonable interval period of monitoring battlefield, according to the characteristics of BS changes.

At present, some methods for determining the monitoring period in specific tasks have been studied [7]–[15]. Lv [7] analyzed basic function and components of the Space Situational Picture (SSP), and established the basic process of constructing SSP. Zhang *et al.* [8] proposed an unbiased risk mining algorithm for real-time monitoring in order to improve the performance of real time monitoring. Fu [9] researched on the related monitoring algorithms of Airport traffic monitoring system. Tao *et al.* [10] proposed a model on measurement of situation change rate based on Shannon's information theory, and obtained the relationship between situation changes rate and accuracy of the forecast. Zheng *et al.* [11] designed a radar passive jamming situation

The associate editor coordinating the review of this manuscript and approving it for publication was Jesus Felez.

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detection scheme. Qian [12] designed a real-time battlefield situation monitoring system for the location information of battlefield equipment. Alevizakos *et al.* [13] used a multi-factor analysis method to determine the monitoring period, which improved validity of monitoring.

Previous studies have achieved some results in specific tasks, specific systems, and specific scenarios. However, more in-depth research is needed in the generality of the problem.

Therefore, this paper researches on the determination method of the monitoring interval period, according to the complicatedness of BS changes. The paper is organized as follows: firstly, BS changes are numerically described as a time-varying "**BS signal**," according to analysis the characteristics of BS. With the goal of commanders' awareness of BS, the relationship between the complicatedness of BS changes and the monitoring interval period is derived. When the complicatedness of BS changes cannot be obtained previously, the method for determining BS monitoring period is designed. Finally, a simulation case is used to verify the validity of the method.

II. MODEL OF DETERMINING MONITORING INTERVAL PERIOD BASED ON COMPLICATEDNESS OF BS CHANGES

Generally, the commanders can only monitor BS intermittently and periodically through sampling [16], [17]. In the process of monitoring, if the changes of BS are beyond the range that the commanders can predict, the commanders need to shorten the monitoring interval time to improve the understanding of BS. The monitoring interval period is related to the characteristics of BS changes. For example, although the aircraft fly fast, the position of the aircraft is still basically predictable when the aircraft is following along a fixed trajectory. At this time, the commanders can monitor the aircraft with a longer monitoring interval period. However, contrast with aircraft, the soldier's speed is slow, commanders still have to monitor the soldier for a shorter monitoring interval period when soldier's movement is irregular. In summary, when BS changes are regular, the commanders can predict BS changes with longer monitoring interval period. When BS changes are irregular, the commanders need to decrease the monitoring interval period. Therefore, the monitoring interval period needs to be determined according to the complicatedness of BS changes.

A. THE COMPLICATEDNESS OF BS CHANGES

Battlefield Situation (BS) is the current state and development trend of the elements that commanders are concerned about on the battlefield [18]. Battlefield elements include military deployment, weaponry deployment, battlefield environment, important targets and so on [19].

BS changes is affected by comprehensive multi-elements. How to consider multiple elements to monitoring BS changes is a problem.

Assuming that the battlefield changes are affected by two elements A and B. Element A changes very quickly. In order to meet the requirements of monitoring element A, it is necessary to monitor the battlefield once every minute. Element B changes slowly. In order to meet the requirements of monitoring element B, it is necessary to monitor the battlefield once every hour. Because every time the battlefield is monitored, the state of all elements in the battlefield can be observed at the same time. Therefore, we can use the period of monitoring element A to monitor the battlefield, which can meet the requirements of monitoring A and B at the same time.

Then we only need to use the monitoring interval period of the most complicated element to monitor battlefield.

In order to measure the complicatedness of BS changes, we define BS signal and its complicatedness.

Defination 1 (BS Signal): Suppose the status of BS at a moment can be represented as a status value, then a numerical curve over time $y(t)$ is called BS signal in order to describe BS changes. t is the time variable.

Note that the BS signal here is not a simple signal in the information domain, and it does not refer to a single signal detected by a sensor or monitoring device. BS signal is a compound signal which is processed and calculated by some quantitative methods from all battlefield situation. BS signal contains all the elements that can be monitored on the battlefield. The value of BS signal is to reflect the relative change of whole battlefield situation.

There are many ways to calculate the situation signal [20]–[22]. This paper will not discuss too much here.

BS signal is irregular and difficult to analyze in the time-domain. For this reason, this paper transforms BS signal into a frequency-domain signal. BS signal has the following characteristics: 1) $y(t)$ is continuous and finite; 2) t is in a finite interval. Then BS signal is absolutely integrable and satisfies the conditions of Fourier transform (FT) [23]. We can use FT to decompose BS signal into sinusoidal signals, which have certain amplitude, phase, and frequency. These sinusoidal signals have a high regularity [24]. So it is easier to analyze BS signal, to transforming BS signal from the time-domain into the frequency-domain. BS signal in the frequency-domain describes the complicatedness of different elements changes and is described as follows:

$$\mathrm{Y}(\mathrm{w}) = \int_{-\infty}^{+\infty} y(t) e^{-i\omega t} dt \tag{1}$$

Defination 2 (The Complicatedness of BS Changes): The highest frequency component w_{max} in Y (w) is defined as the complicatedness of BS changes.

Generally, when BS changes are complicated, the amplitude changes of BS signal $y(t)$ is more drastic per unit time and the more high-frequency components are contained in Y (w). When BS changes are simple, the amplitude changes of $y(t)$ are more gentle per unit time and the more low-frequency components are contained in Y (w). A specific frequency component w in Y (w) can be represented as the complicatedness of certain element changes in BS. The value of Y (w) can be represented as the influence of the certain element on the overall BS. Therefore, the highest frequency component w_{max} of BS signal can be defined as the complicatedness of the overall BS changes. In other words, the most complicated element influences the complicatedness of the overall BS changes. The granularity describing the BS depends on the highest frequency components w_{max}. The physical meaning is that the larger w_{max}, the more detailed information is contained in BS signal.

B. REASONABLE MONITORING INTERVAL PERIOD

The determination conditions of the reasonable monitoring interval period T include two parts: (1) Commanders can be aware of BS changes according to monitoring interval period T; (2) Save monitoring resources. In other words, the commanders need to be aware of BS as accurately as possible based on the longest monitoring interval period.

Commanders periodically monitor continuously changing BS. Generally, the shorter the monitoring interval period T, the more accurate the commanders can be aware of BS.

We suppose that BS signal y(t) is shown in Fig. 1.

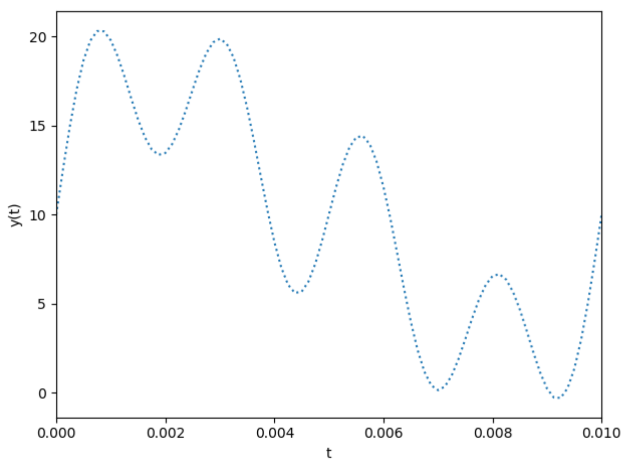

FIGURE 1. BS signal.

A monitoring is a "snapshot" of the BS changes at a certain moment, which is a sampling of BS signal $y(t)$. For example, the commanders can obtain the status value $y(t_0)$ according to monitoring BS at time t_0. A sampling of BS signal can be represented as unit impulse function signal $\delta(t - t_0)$ in mathematics. The unit impulse function signal characteristics are as follows:

(1) $\delta(t - t_0) = 1$, when $t = t_0$.
(2) $\delta(t - t_0) = 0$, when $t \neq t_0$.

The periodic monitoring is to obtain the status of BS changes discretely according to the interval period T. The status value obtained at time t_0 can be described by mathematical functions $y(t_0) = y(t) \cdot \delta(t - t_0)$.

Defination 3 (Sampling Monitoring Signal (SMS)): Suppose that the commanders monitor BS at interval period T. The obtained discrete signal is defined as the sampling monitoring signal, which can be described as follows:

$$y_s(t) = y(t) \cdot \sum_{n=-\infty}^{+\infty} \delta(t - nT) \tag{2}$$

The sampling monitoring signal is shown in Fig. 2.

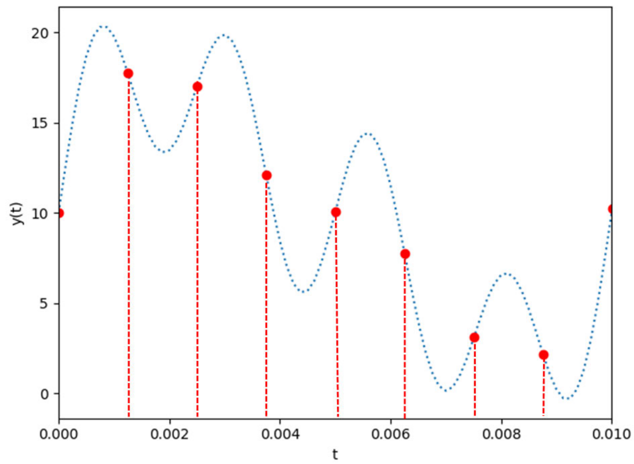

FIGURE 2. The sampling monitoring signal.

The "dashed curve" denotes BS signal and the "red dots" denote the sampling monitoring signal $y_s(t)$ in Fig.2.

The commander can infer status values that are not being monitored. It can be assumed that the change of status values between two adjacent monitoring is linear.

Defination 4 (Restored Signal): Connect the discrete points in $y_s(t)$ with a straight line to form a continuous broken signal. We define the continuous broken signal as restored signal, which is described as $y_c(t)$. $y_c(t)$ describes the commanders' awareness of BS changes.

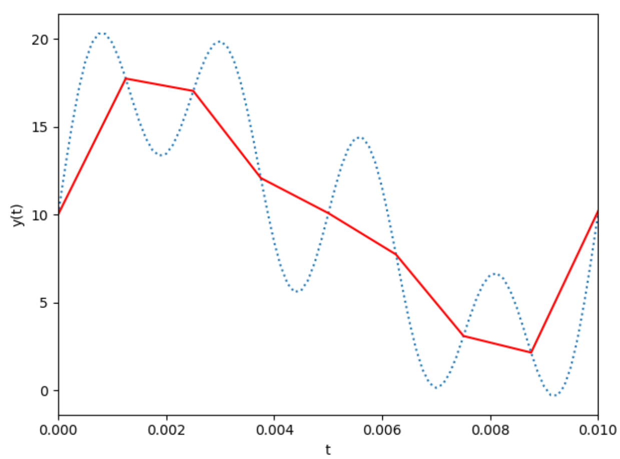

FIGURE 3. The restored signal.

$y_c(t)$ can roughly restore $y(t)$. Nevertheless, there is an error between the restored signal $y_c(t)$ and BS signal $y(t)$ shown in Fig.3. The error can be represented by the Difference degree D.

Defination 5 (Difference Degree D): In the time interval (t_0, t_1), the normalized difference between $y(t)$ and $y_c(t)$ can be describe as follows:

$$D = \int_{t_0}^{t_1} \frac{|y(t) - y_c(t)|}{|y(t)|(t_1 - t_0)} dt \tag{3}$$

When the Difference degree D is below an acceptable threshold, we set that the commanders have not lost important information of BS and can be aware of BS changes accurately by monitoring. When the Difference degree D exceeded an acceptable threshold, we set that the commanders lost important information of BS and could not correctly be aware of BS changes.

Therefore, the reasonable monitoring interval period T is the longest monitoring interval period when the Difference degree D is below a set threshold.

C. MATHEMATICAL DERIVATION OF MONITORING INTERVAL PERIOD THROUGH COMPLICATEDNESS OF BS CHANGES

In this section, we derivate the mathematical relationship between the complicatedness of BS changes w_{max} and the reasonable monitoring interval period T. Set $T = f(w_{max})$.

If the commanders are aware of BS changes accurately by monitoring, the first condition to be satisfied is that the $y_s(t)$ has the same complicatedness as the $y(t)$. In other words, $y_s(t)$ and $y(t)$ have the same characteristics in the frequency-domain.

Since $y_s(t)$ is a discrete point on the $y(t)$, $y_s(t)$ is also absolutely integrable and satisfies the conditions of FT. We can use FT to obtain the frequency characteristics of $y_s(t)$.

In equation (2), $\sum_{n=-\infty}^{+\infty} \delta(t - nT)$ is a periodic function, which can be expanded into the form of Fourier series. Then

$$\begin{aligned} y_s(t) &= y(t) \cdot \sum_{n=-\infty}^{+\infty} \delta(t - nT) \\ &= y(t) \cdot \sum_{k=-\infty}^{+\infty} a_k e^{-i\omega_s t} \end{aligned} \tag{4}$$

where ω_s is monitoring frequency. The relationship between ω_s and the monitoring interval period T is:

$$\omega_s = \frac{2\pi}{T} \tag{5}$$

According to Fourier series formula,

$$a_k = \frac{1}{T} \int_{-\frac{T}{2}}^{\frac{T}{2}} \sum_{-\infty}^{+\infty} \delta(t - nT) e^{-i\omega t} dt = \frac{1}{T} \tag{6}$$

The equation (2) can be written as:

$$y_s(t) = y(t) \cdot \frac{1}{T} \sum_{k=-\infty}^{+\infty} e^{-i\omega_s t} \tag{7}$$

The frequency characteristics of BS signal after FT are expressed as equation (1).

Suppose that the highest frequency component in Y(w) is w_{max}. The frequency characteristics of $\frac{1}{T} \sum_{k=-\infty}^{+\infty} e^{-i\omega_s t}$ is $\frac{2\pi}{T} \sum_{k=-\infty}^{+\infty} \delta(w - kw_s)$. Since the multiplicative relationship in the time-domain of the function is equivalent to the convolution relationship in the frequency-domain, the frequency characteristics of the sampling monitoring signal $y_s(t)$ are described as:

$$\begin{aligned} Y_s(w) &= \frac{1}{2\pi} Y(w) * \left[\frac{2\pi}{T} \sum_{k=-\infty}^{+\infty} \delta(w - kw_s) \right] \\ &= \frac{1}{T} \sum_{k=-\infty}^{+\infty} Y(iw - ikw_s) \end{aligned} \tag{8}$$

In equation (8), $Y_s(w)$ is the periodic extension function of Y(w). Each extension component has the same shape as Y(w). The extension interval period in frequency-domain is w_s, and the $Y_s(w)$ amplitude is $\frac{1}{T}$ times the Y(w) amplitude.

Since all of the status value of BS signal are real numbers. Y(w) is conjugate symmetric function, then the bandwidth of Y(w) is $2w_{max}$.

When the extension components of $Y_s(w)$ do not overlap, the characteristics of $Y_s(w)$ are similar to the Y(w). Then the commanders can obtain the complicatedness of BS changes according to sampling monitoring signal. Thus, the condition of the monitoring frequency must satisfy $w_s > 2w_{max}$. And the reasonable monitoring interval period is $T = \frac{2\pi}{\omega_s}$.

Based on the similar characteristics of $Y_s(w)$ and Y(w), we need to ensure the accuracy of the restored signal in the time-domain according to the Difference degree D. Take Fig. 1 as an example, we use contrasting cases to research the more reasonable monitoring interval period T.

Set that when Difference degree $D < 0.1$, the commanders can be aware of the BS changes accurately in time-domain. The characteristics of Y(w) are shown in Fig. 4.

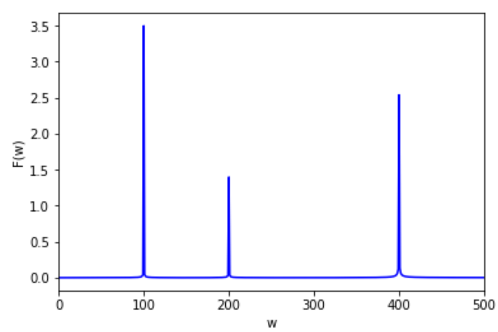

FIGURE 4. Characteristics of Y(w).

The decomposed frequency components contain 100, 200, and 400 in Fig. 4. Then $w_{max} = 400$. Since the reasonable monitoring interval period T is related to the highest frequency component of BS signal w_{max}, We set the monitoring frequency to $w_{max}, 2w_{max}, 3w_{max}, 4w_{max}$. The different results are shown in Fig. 5.

In (a), (c), (e), (g) and (i) of Fig.5, the blue dashed curves represent BS signal $y(t)$ and the red curves represent the restored signal at different monitoring frequencies. The frequency characteristics of $y(t)$ are shown in (b). The frequency characteristics of restored signals at different monitoring frequencies are shown in (d), (f), (h) and (j).

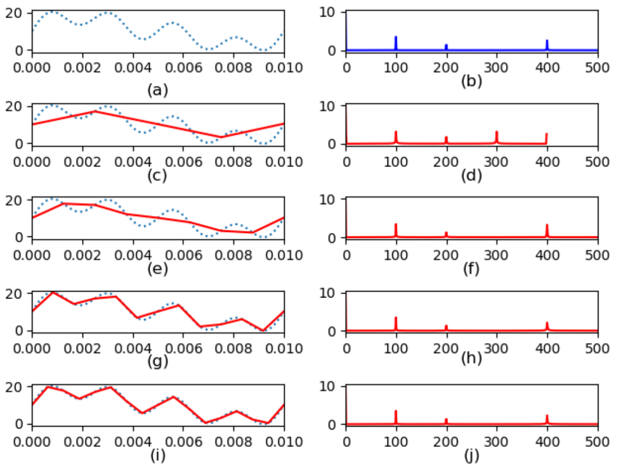

FIGURE 5. The restored results in different monitoring frequency.

As the (c), (e), (g), (i) shows, the restored signal in the time-domain is getting more similar to BS signal with the increase of the monitoring frequency. In (e), (f), when monitoring frequency is $2w_{max}$, the restored signal has the same characteristics as the BS signal in the frequency-domain, which also verifies conclusion of "$w_s > 2w_{max}$." However, the calculated Difference degree D is 0.213, which exceeds the set threshold and does not meet the similarity requirements in time-domain. In (g), (h), When monitoring frequency is $3w_{max}$, the restored signal has the same characteristics as the BS signal in frequency-domain. The calculated Difference degree D is 0.093, which is lower than the set threshold and meet the similarity requirements in time-domain. In (i), (j), When monitoring frequency is $4w_{max}$, the restored signal still meets the requirements in time-domain and in frequency-domain.

As a result, commanders can be aware of the complicatedness of BS changes accurately when $T = \frac{2\pi}{2w_{max}}$. In terms of Difference degree D of restored signal in the time domain, we shorten the monitoring interval period to determine a more reasonable monitoring interval period according to the set threshold. The more reasonable monitoring interval period can be described as:

$$T = \frac{2\pi}{h \cdot w_{max}} \quad (h > 2) \tag{9}$$

where the value of h is related to the set threshold, and the characteristics of BS signal. Equation (9) is called discriminant of reasonable monitoring interval period(DRMIP).

III. FURTHER RESEARCH OF THE MODEL

Although the reasonable monitoring interval period can be determined based on the complicatedness of BS changes, it cannot be obtained previously the complicatedness of the whole BS changes in actual battlefield [25], [26]. How to determine the reasonable monitoring interval period without the whole BS changes? In this section, we predict and adjust the monitoring interval period of the whole BS according to the partial BS signal.

In general, the complicatedness of BS changes will change over time. For example, if the target on the battlefield was in the preparation stage, the battlefield environment is relatively simple and BS signal changes are relatively flat. If the target on the battlefield was in a highly confrontational stage, the battlefield environment become complicated and BS signal changes are relatively drastic. The frequency components of the BS signal are different at different stages. Thus the monitoring interval period based on inappropriate part is not applicable to the whole BS.

Therefore, this paper constructs the highest frequency iterative algorithm (HFIA) in order to predict the complicatedness w_{max} of the whole BS changes.

Assumption: The battle can be roughly divided into several combat, and each combat occurs successively. The fiercest levels of fighting in different combat are roughly the same. In other words, the whole BS signal can be divided into several parts, and each part of BS signal contains w_{max} of the whole BS changes. So it is logical to find w_{max} according to partial BS signal. However, such partial interval cannot be found directly at the signal level, HFIA is needed to solve it.

The specific algorithm is as follows:

Step 1: Suppose that the battle begins at time t_0. Determine the appropriate time increment $\Delta\tau$, parameter M. Let the variable $m = 0$ and $n = 1$;

Step 2: Calculate the highest frequency component w_n of BS signal in time interval $(t_0, t_0 + n\Delta\tau)$.

Step 3: when $w_n < w_{n+1}$, let $n = n + 1$, initialize the variable m and return to the step2.
when $w_n \geq w_{n+1}$, let $m = m+1$. If $m \leq M$, let $n = n+1$ and return to the step2. If $m > M$, let $w_{max} = w_n$ and algorithm ends.

According to the previous derivation results, when the whole battlefield situation cannot be obtained previously, the reasonable monitoring interval period can be expressed as:

$$T = \frac{2\pi}{h \cdot w_{max}} = \frac{2\pi}{h \cdot w_n} \tag{10}$$

The HFIA flow is shown in Fig. 6.

In HFIA, the setting of parameter M is related to the accuracy of calculated w_{max}. When M is bigger, the accuracy of calculated w_{max} is higher but the calculation become more complex.

HFIA can determine partial BS signal that contained the higher frequency component. Then it can estimate w_{max}. Without the whole BS signal, the reasonable monitoring interval period can be calculated based on the partial BS signal.

IV. CASE STUDY

In order to verify the validity of proposed method, we take a case, calculate the reasonable monitoring interval period and analysis the results.

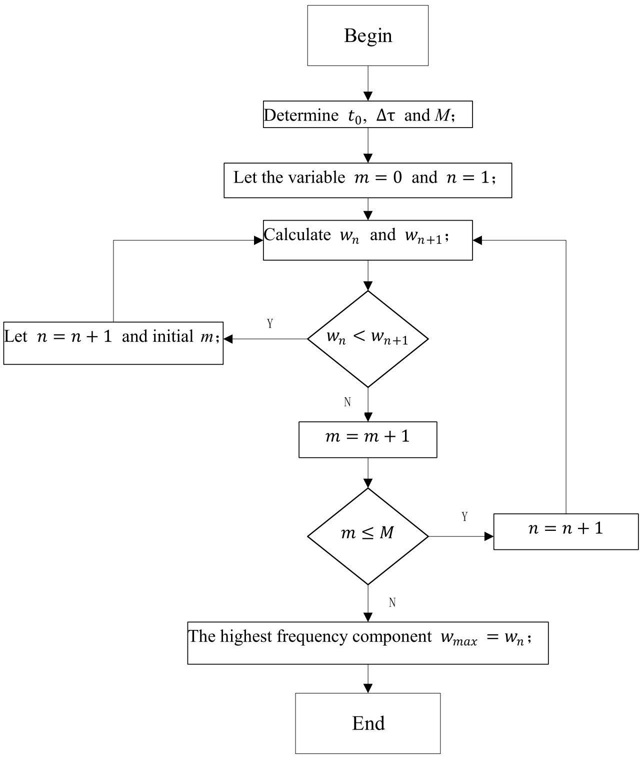

FIGURE 6. **The flow of HFIA.**

A. CASE DATE SETTINGS

A BS signal is obtained after quantitative processing of the situation changes in a certain battle, as shown in Fig. 7.

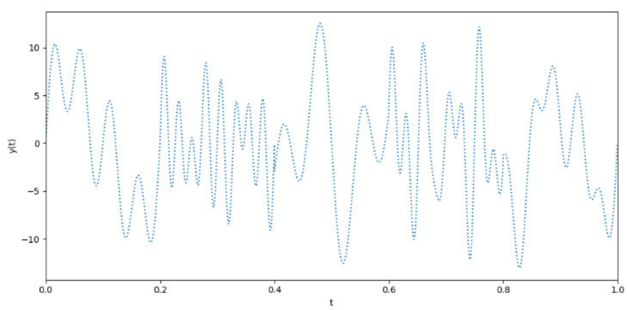

FIGURE 7. **Simulate battlefield situation signals.**

According to threshold and signal characteristic, set the acceptable threshold to 0.06, the reasonable monitoring interval period $T = \frac{2\pi}{3 \cdot w_{max}}$. In the HFIA, the appropriate parameters are set to: $t_0 = 0$, $\Delta\tau = 0.1$ and M = 2.

Suppose that the BS signal throughout whole monitoring period cannot be obtained previously. It is necessary to tentatively set the future monitoring interval period according to the initial BS signal.

B. THE REASONABLE MONITORING INTERVAL PERIOD CALCULATION

Without using HFIA, the time interval of the initial BS signal can be roughly estimated from experience. We get the BS signal in the time interval (0, 0.2), which is shown in Fig. 8.

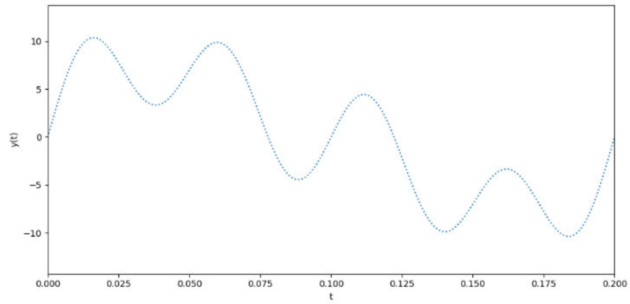

FIGURE 8. **BS signal in the time interval (0, 0.2).**

In the time interval (0, 0.2), the frequency characteristics of BS signal are shown in Fig.9.

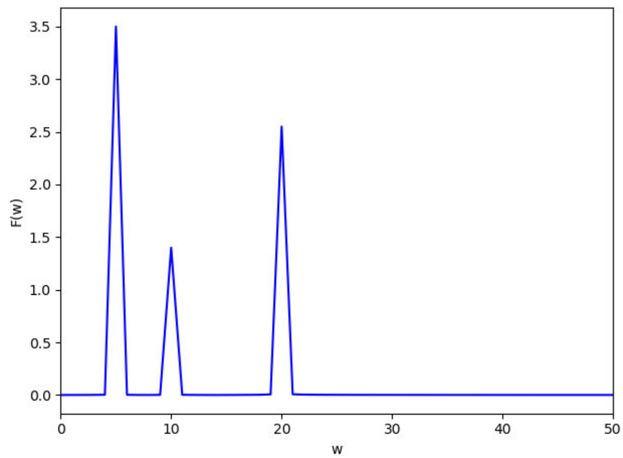

FIGURE 9. **The frequency characteristics of BS signal in the time interval (0, 0.2).**

In fig.9, the highest frequency component is 20. Then the monitoring interval period in the time interval (0, 0.2) is described as:

$$T = \frac{2\pi}{3 * 20} = \frac{\pi}{30} \tag{11}$$

The restored signal is shown in Fig.10 when the monitoring interval period is $\frac{\pi}{30}$.

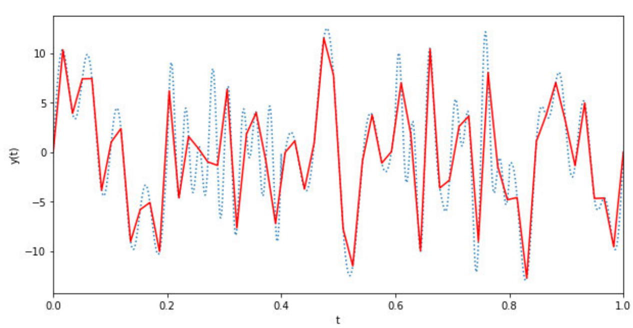

FIGURE 10. **Restored signal with the monitoring interval period $\frac{\pi}{30}$.**

In Fig.10, the blue dashed curves represent BS signal $y(t)$ and the red curves represent the restored signal $y_c(t)$. In time interval (0.2, 0.4) and (0.6, 0.8), The difference between $y(t)$ and $y_c(t)$ is large. The calculated Difference degree D is 0.153, which exceeds the threshold 0.06. Therefore, the time interval (0, 0.2) determined by experience cannot calculate the reasonable monitoring interval period.

Since the complicatedness of the BS changes has changed at different time intervals in Fig. 7. We need to adjust the proper highest frequency component according to the HFIA.

In time interval (0, 0.1), the frequency characteristics of BS signal and the highest frequency component $w_1 = 20$ are shown in Fig. 9.

In time interval (0, 0.2), the frequency characteristics of BS signal and the highest frequency component $w_2 = 20$ are still shown in Fig. 9.

In time interval (0, 0.3), the frequency characteristics of BS signal and the highest frequency component $w_3 = 40$ are shown in Fig. 11. Since $w_3 \neq w_2$, initialize the variable m.

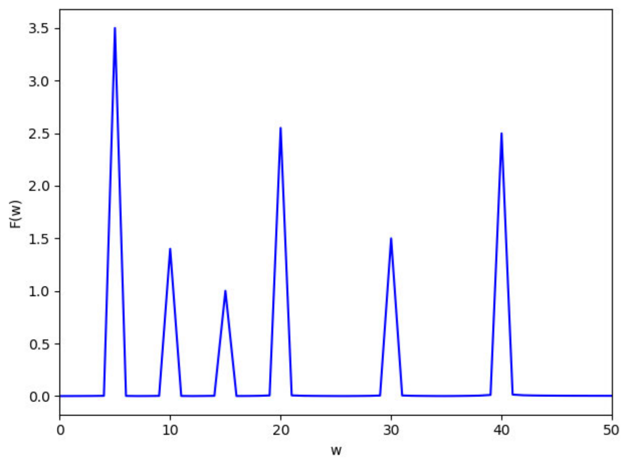

FIGURE 11. The frequency characteristics of BS signal in time interval (0, 0.3).

In time interval (0, 0.4), the frequency characteristics of BS signal and the highest frequency component $\mathrm{w}_2 = 20\mathrm{w}_4 = 40$ are still shown in Fig. 11. Since $\mathrm{m} = 1 < \mathrm{M}$, the algorithm continues.

In time interval (0, 0.5), the frequency characteristics of BS signal are shown in Fig. 12. The highest frequency component is still unchanged. $\mathrm{m} = 2 = \mathrm{M}$, the algorithm ends.

BS signal in the time interval (0, 0.4) contains the highest frequency component of the whole BS signal. The highest frequency component is 40. Then the reasonable monitoring interval period is described as:

$$T = \frac{2\pi}{3 * 40} = \frac{\pi}{60} \tag{12}$$

When the monitoring interval period is $\frac{\pi}{60}$, the restored signal is shown in Fig.13.

The calculated Difference degree D is 0.053, which lower than the set threshold 0.06. Therefore, commanders can be aware of the whole BS changes accurately with monitoring interval period $\frac{\pi}{60}$.

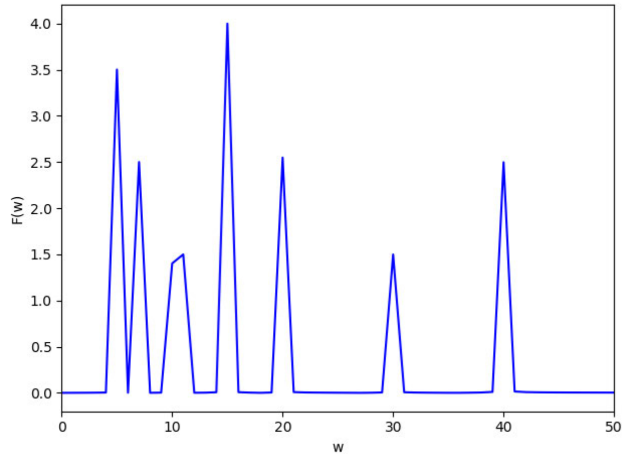

FIGURE 12. The frequency characteristics of BS signal in time interval (0, 0.5).

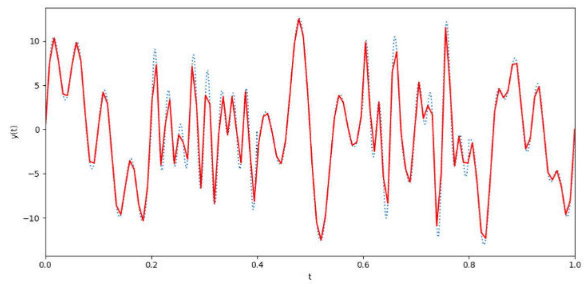

FIGURE 13. Restored signal with the monitoring interval period $\frac{\pi}{60}$.

C. ANALYSIS OF CALCULATION RESULT

Analyzing the frequency characteristics of BS signal, the complicatedness of BS changes w_{max} at different time is shown in Fig.14.

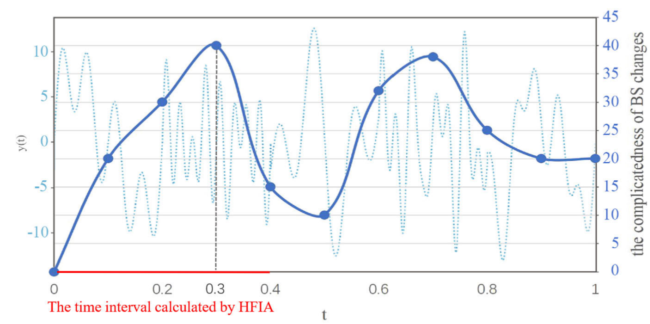

FIGURE 14. The complicatedness of BS changes at different moments.

In Fig.14, The complicatedness reaches the maximum at time 0.3, it is within the time interval (0, 0.4) calculated by the HFIA. That means the reasonable monitoring interval period can be calculated in the time interval (0, 0.4). The

HFIA works. If the monitoring interval period continues to be shortened to $\frac{\pi}{80}$, the restored signal is shown in Fig. 15.

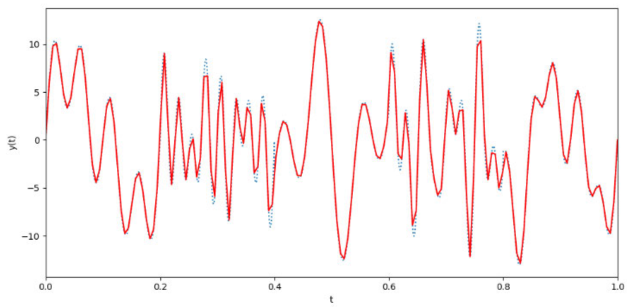

FIGURE 15. Restored signal with the monitoring interval period $\frac{\pi}{80}$.

The calculated difference degree D is 0.031, which lower than the set threshold 0.06.

Furthermore, we compare difference degree D in different monitoring interval periods, the result is shown in Figure.16.

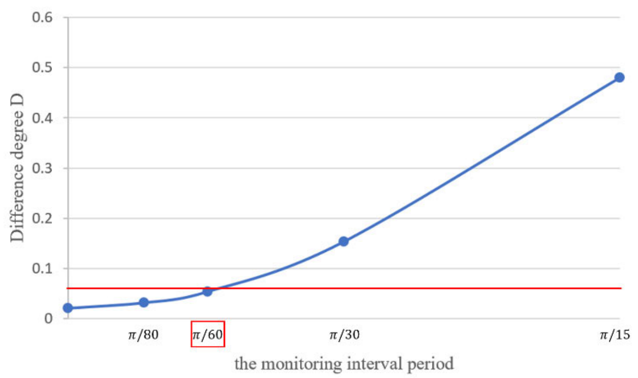

FIGURE 16. Difference degree D with different monitoring interval period.

In Fig.16, The shorter the monitoring interval period, the smaller the difference degree D. But their relationship is not linear relationship. when the threshold condition is met, the lower monitoring interval period will not produce obvious decline of difference degree D. In other words, it will not produce more valid information for commanders and cause a waste of monitoring resources. Therefore, the reasonable monitoring interval period in the case is $\pi/60$, which is just below the threshold.

In a word, when the whole BS changes cannot be obtained previously, it is not reasonable to determine the monitoring interval period based on the initial time interval of BS signal. The more reasonable monitoring interval period needs to be adjusted based on the HFIA. The validity of the method is verified through the calculation results in the case.

V. CONCLUSION

In this paper, the method based on the complicatedness of BS changes is proposed to determine the monitoring interval period of BS. According to research, the results are as follows:

1) The complicatedness of BS changes w_{max} affects the monitoring interval period T. When the whole BS changes is obtained, the restored signal has the same complicatedness as BS signal with the monitoring interval period $\frac{2\pi}{2w_{max}}$. Concerning the awareness accuracy of commanders in the time-domain, the monitoring interval period needs to be adjusted to $\frac{2\pi}{h \cdot w_{max}}(h > 2)$ according to the Difference degree D.

2) When the whole BS changes cannot be obtained previously, we can use HFIA to calculate the highest frequency component according to the initial BS changes. Then adjust the reasonable monitoring interval period of the whole BS changes according to the highest frequency component.

Nonetheless, since this paper summarizes some hypotheses, the method of application is limited by some conditions. For example, when the fierce levels of fighting in different stages are different, there will be a certain difference in the highest frequency component calculated by HFIA. Then the reasonability of the monitoring interval period will decrease. More work is needed to extend the application fields of the method.

ACKNOWLEDGMENT

(Teng-jiao Mao and Dongge Zhang contribute equally to this work.)

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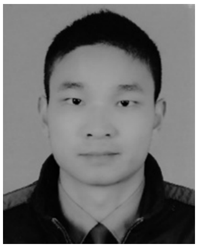

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