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Application of SPRT to Image Data Sequence for Remote Monitoring System

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Abstract: Recently, remote monitoring camera systems are widely used for security. In such systems, we need an important function that it automatically detects the some change of the scenes from monitoring cameras. Generally, in wireless remote monitoring camera systems, the scene images are transmitted as compressed data (e.g., JPEG file), because of the wireless channel capacity. This paper shows the automated detection of the change point for the time series data of compressed JPEG file quantity (Kbytes) from monitoring camera, applying sequential probabilistic ratio test (SPRT) and Chow Test that is well known as a standard method for structural change detection of time series data.

***Keywords*:** Remote monitoring camera system, sequential probability ratio test (SPRT), security

I. INTRODUCTION

Remote monitoring camera systems are widely used for security in recent society (Masuda et al [1]). Because information quantity of images from monitoring cameras is very massive, we need a function in such camera system that automatically detects the some change in the image sequence. Thus, it is better that the method adopted in the function can simply detect the change as promptly and correctly as possible, for quick security action.

Here, we note that, in general, wireless remote monitoring camera systems send the scene images as compressed data (e.g., JPEG file), because of limit of the wireless channel capacity. In addition, if some movement happens in the ordinal images, the quantity of the JPEG image file differs from those of ordinal images.

In this paper, we show a method for the automated change point detection in time series data of JPEG file quantity (Kbytes), using sequential probabilistic ratio test (SPRT) (Wald [2], Kawano et al [3]). Moreover, we show its effectiveness in comparison with Chow Test (Chow [4]) that is well known as a standard method for structural change detection of time series data.

II. CHANGE DETECTION USING SPRT

For the change detection problem, we propose an application of Sequential Probability Ratio Test (SPRT) that has been mainly used in the field of quality control.

1. SPRT

The SPRT is used for testing a null hypothesis H_0 (e.g. the quality is under pre-specified limit 1%) against hypothesis H_1 (e.g. the quality is over pre-specified limit 1%). In addition, it is defined as follows:.

At each stage of successive events $Z_1, Z_2, \cdots Z_i$ that are respectively corresponding to observed time series data, the probability ratio λ_i is computed.

$$\lambda_i = \frac{P(Z_1 \mid \mathbf{H}_1) \cdot P(Z_2 \mid \mathbf{H}_1) \cdots P(Z_i \mid \mathbf{H}_1)}{P(Z_1 \mid \mathbf{H}_0) \cdot P(Z_2 \mid \mathbf{H}_0) \cdots P(Z_i \mid \mathbf{H}_0)} \quad (1)$$

where $P(Z \mid H_0)$ denotes the distribution of Z when H_0 is true and $P(Z \mid H_1)$ denotes the distribution of Z when H_1 is true.

Two positive constants C_1 and C_2 ($C_1 < C_2$) are chosen. If $C_1 < \lambda_i < C_2$, the experiment is continued by taking an additional observation. If $C_2 < \lambda_i$, the process is terminated with the rejection of H_0 (acceptance of H_1). If $\lambda_i < C_1$, the process is terminated with the acceptance of H_0.

$$C_1 = \frac{\beta}{1-\alpha} \qquad C_2 = \frac{1-\beta}{\alpha} \quad (2)$$

where α means type I error (reject a true null hypothesis), and β means type II error (accept a null hypothesis as true one when it is actually false).

2. Procedure

The concrete procedure of structural change detection is as follows (see an example of time series data in Fig.1).

Step1: Make a prediction expression and set the tolerance band (***a***) (e.g. ***a***=**2**σ_S) that means permissible error margin between the predicted data and the observed one.

Step2 : Set up the null hypothesis H_0 and alternative hypothesis H_1.

H_0 : Change has not occurred yet.

H_1 : Change has occurred.

Set the values α, β and compute C_1 and C_2, according to Equation (2). Initialize i = 0, $\lambda_0 = 1$.

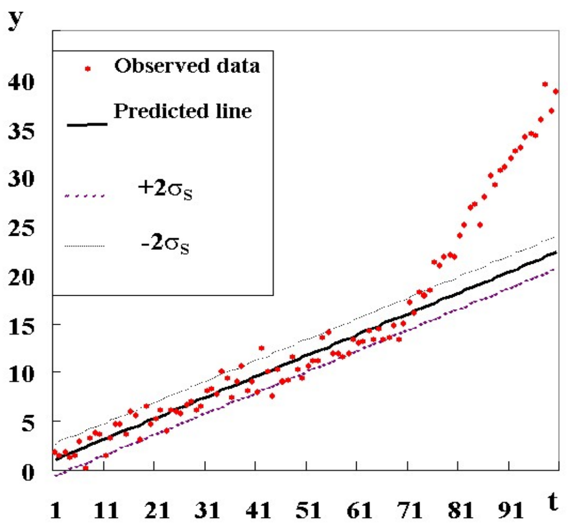

Fig.1. Example of time series data where the change point tc* =70.

Remark: The statement of the null hypothesis H_0, "Change has not occurred yet.", means in statistical sense. It means that the generation probability for the data to go out from the tolerance band is less than (or equal to) θ_0 (for instance, 1%). Similarly, the statement of the alternative hypothesis H_1, "Change has occurred." means that the generation probability for the data to go out from the tolerance band is greater than (or equal to) θ_1 (for instance, 99%). Additionally, we suppose that θ_1 is considerably greater than θ_0.

Step3: Incrementing i (i = i+1), observe the following data y_i. Evaluate the error $|\varepsilon_i|$ between the data y_i and the predicted value from the aforementioned prediction expression.

Step4: Judge as to whether the data y_i goes in the tolerance band or not, i.e., the ε_i is less than (or equal to) the permissible error margin or not. If it is Yes, then set $\lambda_i = 1$ and return to Step3. Otherwise, advance to Step5.

Step5: Calculate the probability ratio λ_i, using the following Equation (3) that is equivalent to Equation (1)

$$\lambda_i = \lambda_{i-1} \frac{P(\varepsilon_i \mid \mathbf{H}_1)}{P(\varepsilon_i \mid \mathbf{H}_0)} \quad (3)$$

where, if the data y_i goes in the tolerance band, $P(\varepsilon_i|H_0) = \theta_0$ and $P(\varepsilon_i|H_1) = \theta_1$, otherwise, $P(\varepsilon_i|H_0) = (1-\theta_0)$ and $P(\varepsilon_i|H_1) = (1-\theta_1)$.

Step6: Execution of testing.

(i) If the ratio λ_i is greater than C_2 (= $(1-\beta)/\alpha$), dismiss the null hypothesis H_0, and adopt the alternative hypothesis H_1, and then End.

(ii) Otherwise, if the ratio λ_i is less than C_1 (= $\beta/(1-\alpha)$), adopt the null hypothesis H_0, and dismiss the alternative hypothesis H_1, and then set $\lambda_i = 1$ and return to Step3.

(iii) Otherwise (in the case where $C_1 \le \lambda_i \le C_2$), advance to Step7.

Step7: Observe the following data y_i incrementing i. Evaluate the error $|\varepsilon_i|$ and judge whether the data y_i goes in the tolerance band, or not. Then, return to Step5 (calculation of the ratio λ_i).

III. APPLICATION TO IMAGE SEQUENCE

As a simple automated change detection method of the scenes from a monitoring camera, we apply the SPRT method to the time series data of compressed JPEG file quantity (Kbyte).

Fig.2 and Fig.3 show two sets of images when a person has moved at low speed and high speed, respectively, in front of a bookshelf. Fig.4 and Fig.5 show two graphs on time series data of JPEG file volumes, corresponding to Fig.2 and Fig.3, respectively.

We assume that change point is the time point when the some change happens, that is, when some person appears in the image data. The SPRT can detect the change point quickly from the sequence of image data. We show experimental results of change detection using two tests (SPRT and Chow Test) and discuss those effectiveness.

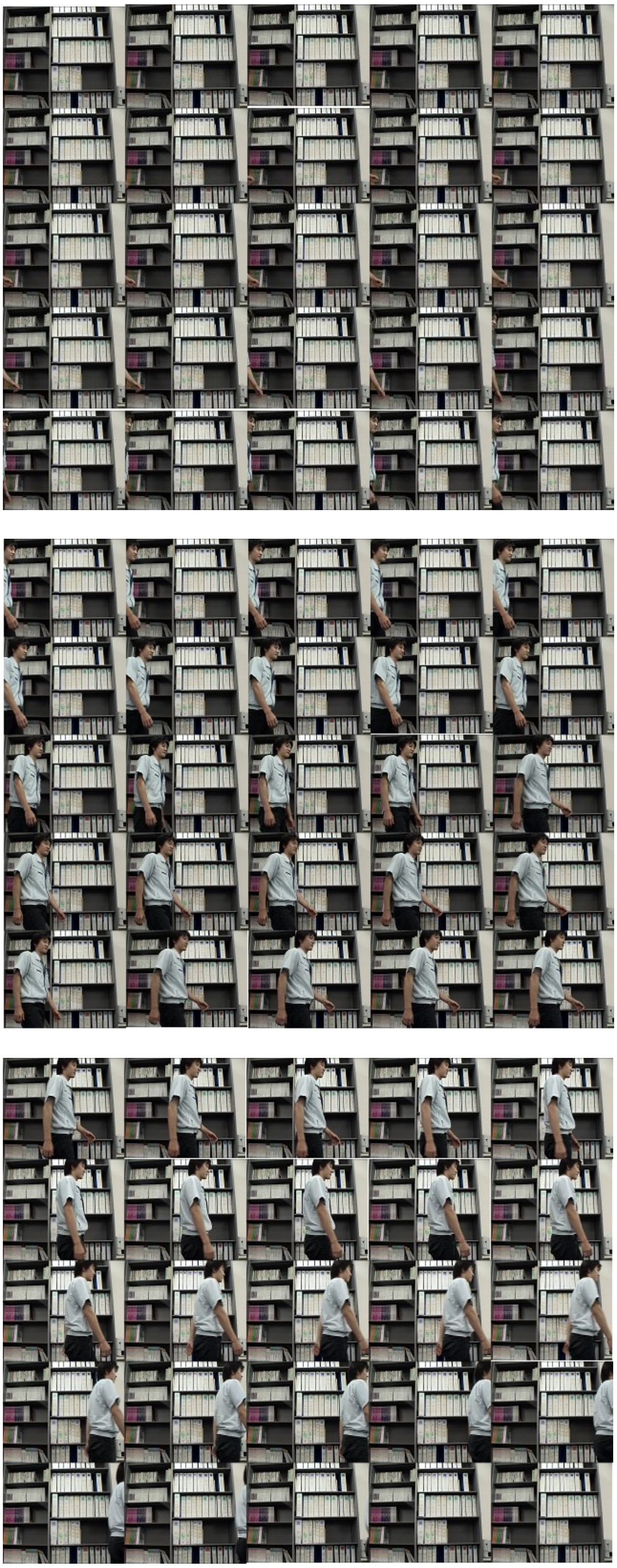

Fig.2. Example of images where someone passes by at low speed (Time is counted from upper left to lower right.)

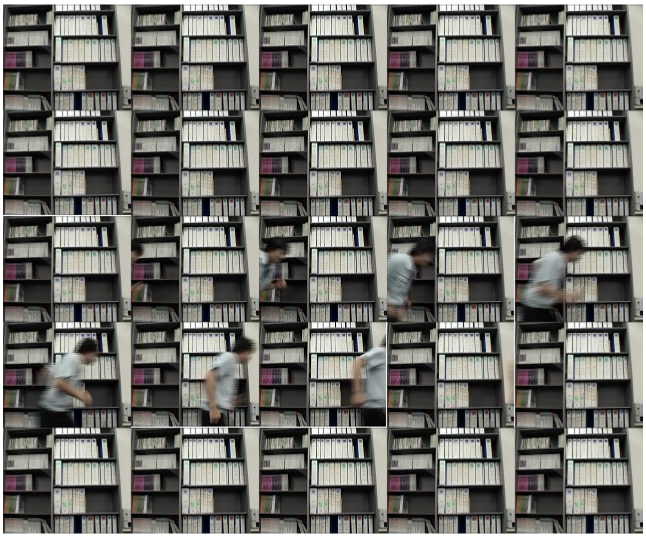

Fig.3. Example of images where someone passes at high speed. (Time is counted from upper left to lower right.)

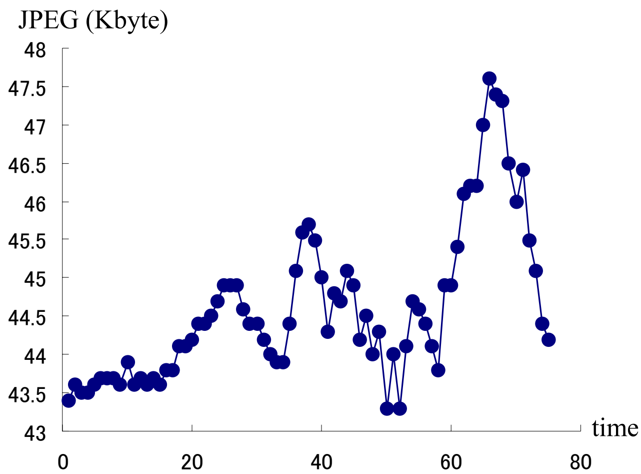

Fig.4. Total time series of image data, i.e., sequence of JPEG file volumes in Fig.2.

The results of change detection by the two Tests (SPRT and Chow Test) are shown in the graphs in Fig.6 and Fig.7, respectively, where the SPRT detects change points in the case of condition 1(θ_0=0.9, θ_1=0.1), and condition 2 (θ_0=0.87, θ_1=0.13), and condition 3(θ_0=0.8, θ_1=0.2).) The number of samples in the stage of learning and analysis, where samples are used for concretely deciding prediction model (regression line), is seven in both cases of low speed and high-speed passing-by movement and in both tests.

From the results in both cases of low speed and high-speed passing-by movement, we find that the SPRT can detect the change quickly and correctly after the change happens. Moreover, the SPRT method is simple and takes very low computational cost (i.e., necessary time and memory storage for computation). On the contrary, the Chow Test tends to make a mistake in the early stage after the change happens, and to takes long time for correct change detection. In addition, the computational cost is considerably high. Then, we consider that the performance of SPRT is very effective in comparison with Chow Test, even if the time series data of sequence of JPEG file volumes is fluctuated by lighting and so on.

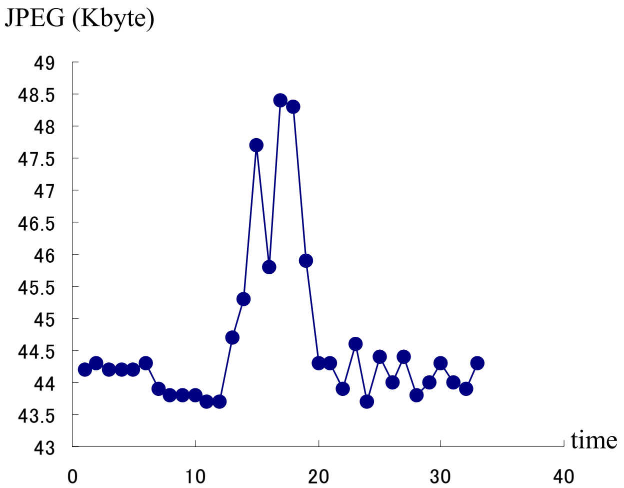

Fig.5. Total time series of image data, i.e., sequence of JPEG file volumes in Fig.3.

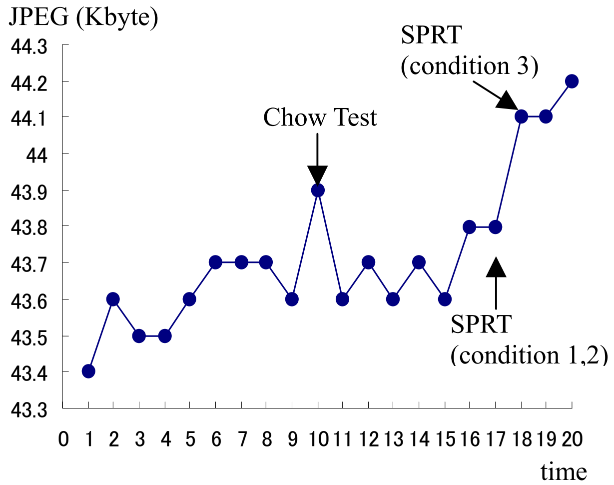

Fig.6. Change point detection (low speed passing-by movement in Fig.2) using SPRT and Chow Test. (condition 1 means (θ_0=0.9,θ_1=0.1), condition 2 is (θ_0=0.87,θ_1=0.13), and condition 3 is (θ_0=0.8,θ_1=0.2).)

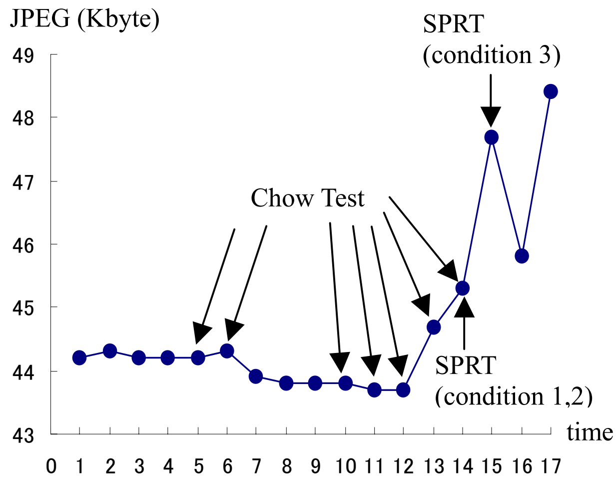

Fig.7. Change point detection (high speed passing-by movement in Fig.3) using SPRT and Chow Test. (condition 1 means (θ_0=0.9,θ_1=0.1), condition 2 is (θ_0=0.87,θ_1=0.13), and condition 3 is (θ_0=0.8,θ_1=0.2).)

IV. CONCLUSION

For security, remote monitoring camera systems are widely used. Because of channel capacity limitedness and of burdensome work for watching, it is desirable to reduce the number of transmission images. For this purpose, we have proposed a sequential probability ratio test (SPRT) for change detection of sequence of JPEG file volumes. Also, we have shown its effectiveness in comparison with Chow Test, based on experimental results.

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