Detection of Suspicious Activity and Estimate of Risk from Human Behavior shot by Surveillance Camera

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Abstract—In these days, surveillance camera system prevails as a security system at high speed because this system can monitor from remote places using Web camera attached to video monitor by network. Additionally, digital equipments such as Web camera, and hard disk drive are mass-produced, and are sold at low price. And, performance gain of these digital equipments improves at a rapid rate. Current surveillance camera system shows dynamic images from some oversight areas shot by multiple Web cameras at the same time. Then, this system makes observer's mind and body tired because he/she has to watch enormous number of dynamic images been constantly updated. Moreover, this system has a serious problem, which is an observer slips over predictor of crime. This study extracts Motion Region from moving person, and measures Motion Quantity for measuring his/her active state. And, this proposal method finds the detecting point of suspicious activity, and estimates the degree of risk of the suspicious activity.

Keywords-Motion region; human behavior; suspicious activity; degree of risk; surveillance camera;

I. INTRODUCTION

Surveillance camera system increases rapidly in various places in daily life such as school, hospital, station, and shopping mall, because this system can record aspect and action of suspicious person in image data. And, these surveillance camera systems work crime prevention, and collect information and evidence about criminality with effect. General surveillance camera systems consist of Web camera placed oversight area, and video monitor and hard disk drive are in monitoring room. And, these digital equipments are attached to the network with each other so that an observer can watch the oversight area from monitoring room using remote control. However, surveillance camera system has a matter of importance, which is an observer has to watch a lot of dynamic image shot by multiple Web cameras, due to rapid diffusion of Web cameras. In addition, Web camera is able to shoot in a long time because hard disk drive is possible to save large volumes of dynamic image data. But, this improvement of hard disk drive brings a matter, which is an observer spends much time and energy trying to detect image data implicated in a crime from large amount of dynamic image data. This study approaches a detection method of suspicious activity from the watched person's behavior in dynamic image in real time, and measures the degree of risk using detecting branch position between suspicious and unsuspicious activity.

The surveillance camera system for overlooking person's behavior focuses attention on total or part of human body, and tracks the motion of one, as [1]-[4]. For this reason, subject detection using Particle Filter is better known as [2]. [5]-[10] extract characteristic color or shape of photographic subject, and track it. And, [11] tracks multiple subjects. Motion recognition makes Human Body Model, and tracks position and movement of each body part such as head, torso, and limb, so that this method assumes posture of moving person. Tracking using 2D or 3D human body model, [12]-[18], detects characteristic posture of human body from the watched person's behavior, and recognizes human motion. The method, which finds motion trajectory of body part such as arms, understands gesture as [19][20]. This research paper consists of 6 chapters. Chapter 2 represents a method of human behavior measurement, which abstracts Motion Region on moving human body, and finds Motion Quantity. Chapter 3 pinpoints the detecting point of suspicious activity on human behavior, and detects suspicious activity. Chapter 4 finds the degree of risk of suspicious activity. Chapter 5 shows experimental result. Chapter 6 is conclusion.

II. MEASUREMENT OF HUMAN MOVEMENT

A. Motion Region

This study measures human movement using Motion Region occurring with a human behavior. The experiment in this study divided a dynamic image of human behavior into image frames for each 0.2 seconds. Total of these frames are denoted as $N = \{n|1, 2, \cdots\}$, and image frame number is n. proposal method uses time-series data, which shot human motion, $\{fr_1, fr_2, \cdots, fr_{n-1}, fr_t, \cdots\}, n \in N$, and extracts Motion Region. Motion Region, MR, is extracted by spatiotemporal difference, $|fr_n - fr_{n-1}|$, between current frame, fr_n, and previous frame, fr_{n-1}. Motion Region on each image frames, $MR(x, y)$, is found as $MR_n(x, y) =$

$|fr_n(x,y) - fr_{n-1}(x,y)|, x \in X, y \in Y$, by frame width, X, and frame height, Y. The experiment uses an image frame of 640×480 size, and $x \in X = \{0,1,2,\cdots,639\}$ on X-axis, and $y \in Y = \{0,1,2,\cdots,479\}$ on Y-axis. Motion Region is extracted as $\{\cdots, MR_n, MR_{n+1}, \cdots\}$ from each image frame, $\{\cdots, fr_{n-1}, fr_n, fr_{n+1}, \cdots\}$. And, Object Region is extracted as $Obj_n(x,y) = |fr_n(x,y) - fr\_back(x,y)|$ by background image frame, fr_back, using Background Subtraction.

This study finds the geometric size of <mark>Motion Region</mark>, MR_size_n, and the geometric size of <mark>Object Region</mark>, Obj_size_n, on each image frame, n. The proportion of Motion Region to Object Region, $MR\_proportion$, is found by $MR\_proportion_n = MR\_size_n / Obj\_size_n$.
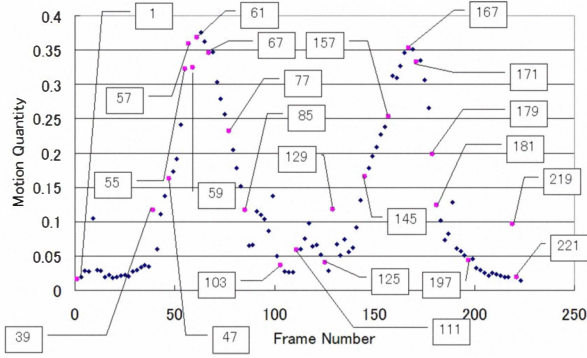
B. Motion Quantity

Fig1(a) The dots in Motion Quantity in a human behavior, putting a hand up and down.
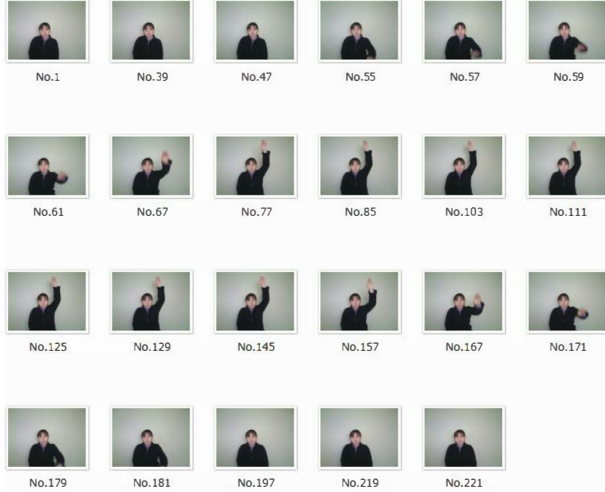

Fig1(b) Characteristic postures detected for each 0.1 in Motion Quantity.

This study proposes Motion Quantity for measuring active state on human motion. Motion Quantity is found by

$MQ_n = -MR\_proportion_n \cdot \log_{10}(MR\_proportion_n) + MR\_proportion_n, n \in N$. This study measures human behavior numeric value between 0.0 and 1.0 using Motion Quantity. If a person works active movement, Motion Quantity denotes closer to 1.0. And, if a person is inactive, Motion Quantity is in the neighborhood of 0.0. Fig1(a) measures a human behavior, putting a hand up and down, at each image frame, and pinpoints image frames in regular intervals, approximately 0.1, in Motion Quantity as characteristic postures, No.1-No.221. And, the characteristic postures are shown in Fig1(b).

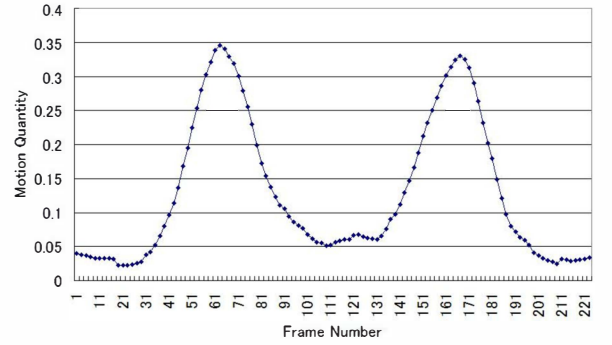The experiment measures putting a hand up and down,

Fig2 Lind of the smoothed Motion Quantity in a human behavior, putting a hand up and down.

and makes the smoothed Motion Quantity line using Smoothing Filter. The smoothed Motion Quantity line, $smooth\_MQ$, is made by the interval for smoothing, smt, 18 image frames, 1.8 seconds, as $smooth\_MQ(n) = \sum_{m=n-s}^{n+s} MQ_m / smt, s = smt/2, m \geq 0$. Fig2 shows Motion Quantity and the smoothed Motion Quantity line, which measures a human behavior, putting a hand up and down.

III. DETECTION OF SUSPICIOUS ACTIVITY

A. Detecting point

In the experiment, Fig3(a) shows Motion Quantity, (1)-(2), which measures a human behavior, entering the room, acted by different persons, in each image. And, Fig3(b) shows the smoothed Motion Quantity line, (1)-(2). If fixed Web camera shoots from same angle and distances, each dots in Motion Quantity, which measure different persons act same behavior, denote similar distributions in Fig3(a), and the smoothed Motion Quantity lines show similar shapes in Fig3(b). The experiment measures entering the room behavior, finds the dots in Motion Quantity, and the smooth Motion Quantity line, and <mark>pinpoints the characteristic postures</mark> detected for each 0.1 in Motion Quantity, No.1-No.287, in Fig4(a). And, the characteristic postures are shown in Fig4(b). This study proposes a detection method of suspicious activity using
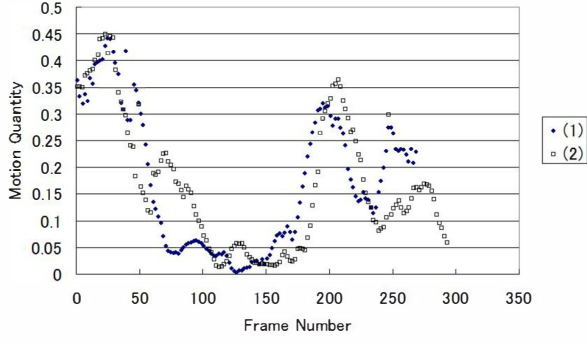
Fig3(a) Comparing the distributions in Motion Quantity, which measures a human behavior acted by difference persons, (1), and (2).
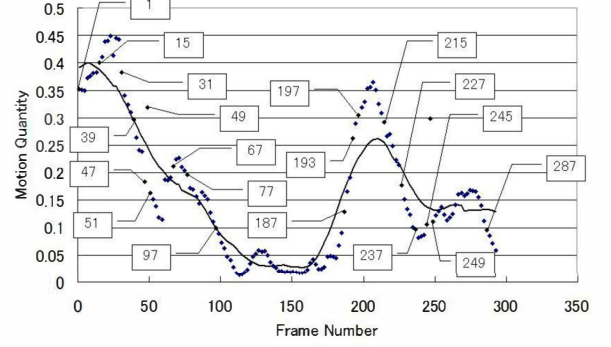

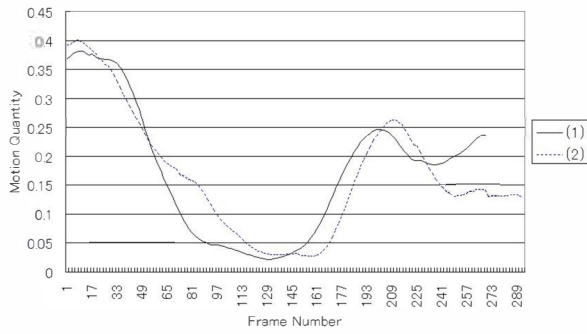Fig4(a) The dots in Motion Quantity in a human behavior, entering the room.

Fig3(b) Comparing the lines of the smoothed Motion Quantity, which measures a human behavior acted by difference persons, (1), and (2).
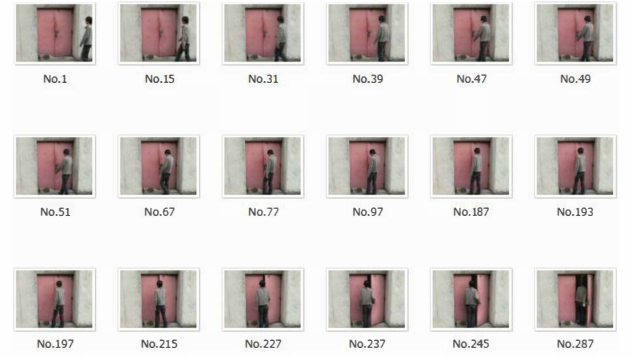

Fig4(b) Characteristic postures detected for each 0.1 in Motion Quantity. Motion Quantity.

the difference in Motion Quantity between watched person's behavior and unsuspicious behavior. The detection method finds range difference between the dot in Motion Quantity, which measures watched person's behavior, MQ_n, and line of the smoothed Motion Quantity in unsuspicious behavior, $smooth\_MQ(n)$, at each image, n. The range difference is found by $|MQ_n - smooth\_MQ(n)|$. And, this method finds the detecting point of suspicious activity, $point$, using threshold amount, η, as Formula(1).

Fig5 The range difference between the dot in MotionQuantity, and line of the smoothed Motion Quantity at No.225.

$$\begin{cases} point = n & IF \quad |MQ_n - smooth\_MQ(n)| \geq \eta \\ point \neq n & IF \quad < \eta \end{cases}$$
(1)

As the example, Fig5 compares the dots in Motion Quantity in watched person's behavior, which a person looks on the door, and passes over the entrance, and the smoothed Motion Quantity line in unsuspicious behavior, which is entering the room in Fig4. This example sets $\eta = 0.15$ for finding the detecting point of suspicious activity. At No.225, the range difference between dot in Motion Quan-
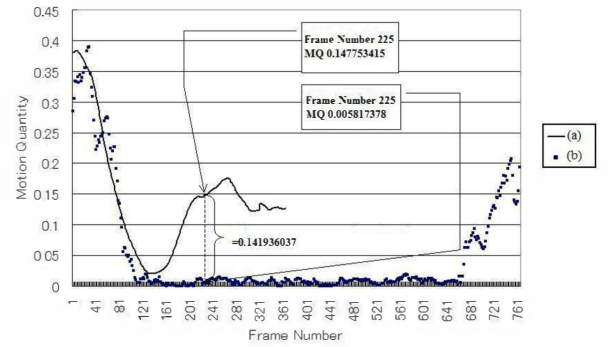
tity, which is found from watched person's behavior, and line of the smoothed Motion Quantity in unsuspicious behavior, is 0.141936037. This condition shows that the detecting point of suspicious activity can't be detected from watched person's behavior, and watched person's behavior doesn't include unsuspicious activity until No.225.
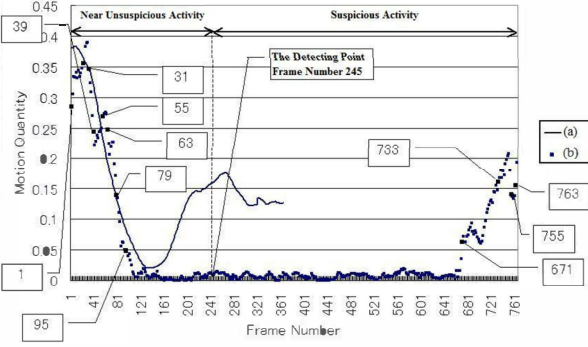
300

Fig6(a) The detecting point at No.245, and Near Unsuspicious Activity, No.1-244, and Suspicious Activity, No.145-763.
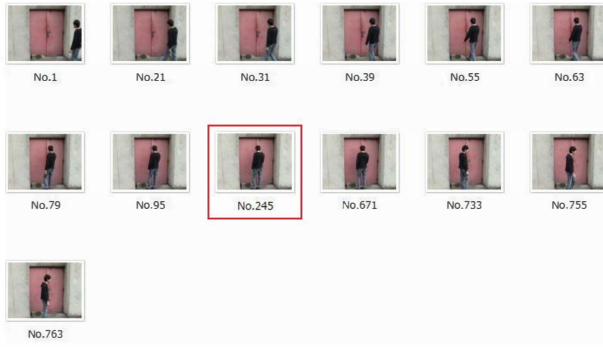

Fig6(b) Characteristic posture at the detecting point, No.245, in a human behavior.

At No.245 in Fig6(a), the range difference between watched person's behavior and unsuspicious behavior is in 0.15, or more. And, the detecting point of suspicious activity is found at MQ_{245} in watched person's behavior. No.245 in Fig6(b) is pinpointed as the starting posture of suspicious activity at the detecting point. And, No.245-763 are detected as the characteristic postures in suspicious activity.

B. Suspicious Activity

This study finds the degree of risk using a point of suspicious activity detected from watched person's behavior. Fig7 shows the smoothed Motion Quantity line in unsuspicious behavior, and the dots in Motion Quantity in watched person's behavior including suspicious activity. The detection method of suspicious activity compares line of the smoothed Motion Quantity in unsuspicious behavior, and each dot in Motion Quantity in watched person's behavior, and finds the detecting point of suspicious activity using the range difference between them. Then, this study defines first activity, Near Unsuspicious Activity, between the starting point of watched person's behavior, and short

of the detecting point of suspicious activity, and second activity, Suspicious Activity, between the detecting point of suspicious activity, and the current point in observation. Fig7 shows Near Unsuspicious Activity between the starting point, No.1, and short of the detecting point, No.244, and Suspicious Activity between the detecting point, No.245, and the current point, No.765, on watched person's behavior.
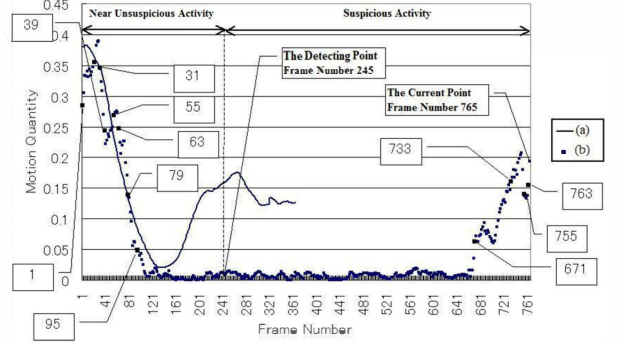

Fig7 The detecting point, No.245, and Near Unsuspicious Activity, No.1-244, and Suspicious Activity, No.245-765.

IV. ESTIMATE OF RISK

This study finds the degree of risk of suspicious activity from watched person's behavior. The watched person's behavior including suspicious activity can be divided into Near Unsuspicious Activity and Suspicious Activity by the detecting point. Frame number of the detecting point is denoted as dn, and frame number of short of the detecting point is as $dn - 1$. And, frame number of the starting point is sn

This study assumes that near unsuspicious activity has low degree of risk because the watched person's acts almost unsuspicious activity. The implementation term of Unsuspicious Activity shows as image frames, $sn < n < dn$. And, suspicious activity can be presumed as high degree of risk to commit the crime. Frame number of the current point, cn, represents the point of blocking action, which observer notices the detecting point of suspicious activity in watched person's behavior, and works to block from crime. The implementation term of Suspicious Activity is $dn \leq n \leq cn$.

If the watched person moves activity to commit a criminal act, this study presumes that suspicious person inflicts heavy damage on such as human body, and physical matters. Then, if Motion Quantity in watched person's behavior shows large value in suspicious activity, the person's action takes high risk of crime because the person deals a heavy blow to the oversight area. If Motion Quantity is small, the behavior denotes low risk for the area because the person's behavior

remains nearly stationary.

In addition, this study compares Motion Quantity in watched person's behavior to unsuspicious behavior. If the range difference between the dot in Motion Quantities in watched person's behavior , and line of the smoothed Motion Quantity in unsuspicious behavior, $|MQ_n - smooth\_MQ(n)|$, denotes large values, the watched person's behavior denotes at high risk of crime. And, if the range difference is small, the watched person's behavior works low risk because watched person acts similar behavior to unsuspicious behavior. Risk of Near Unsuspicious Activity, $near\_unsuspic\_act$, is found by Formula(2).

$$near\_unsuspic\_act = \sum_{n=sn}^{dn-1} |MQ_n - smooth\_MQ(n)| \cdot MQ_n/(dn - sn - 1) \tag{2}$$

Risk of Suspicious Activity, $suspic\_act$, is found by Formula(3).

$$suspic\_act = \sum_{n=dn}^{cn} |MQ_n - smooth\_MQ(n)| \cdot MQ_n/(cn - dn) \tag{3}$$

The whole watched person's behavior consists of near Unsuspicious Activity, and Suspicious Activity. The degree of risk of Suspicious activity to the whole behavior, $suspic\_deg$, is found by Formula(4).

$$suspic\_deg = \frac{suspic\_act}{near\_unsuspic\_act + suspic\_act} \tag{4}$$

The experiment finds the degree of risk of Suspicious Activity, which is a person looks on the door, and passes over the entrance, as Table I, The Degree of Risk of Suspicious Activity. This watched person's behavior has the detecting point of Suspicious Activity at No.245. The experiment divided into Near Unsuspicious Activity, No.1-244, and Suspicious Activity, No.245-763.

Table I
THE DEGREE OF RISK OF SUSPICTION ACTIVITY

Near Unsuspicious Activity	0.004187
Suspicious Activity	0.003354
The Degree of Risk	0.444781

V. EXPERIMENTAL RESULT

This study pinpoints the detecting point of Suspicious Activity, and finds the degree of risk in a human behavior. The experiment measures that watched person approaches the opening door, and goes into the room as CASE-1. This experiment result pinpoints the detecting points, and detects Suspicious Activity from watched person's behavior. If range difference between each dot in Motion Quantity in watched
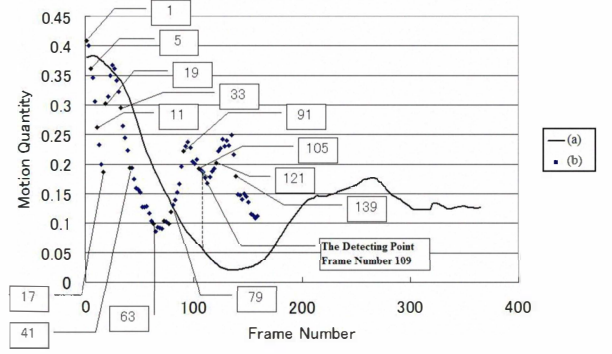

Fig8(a) The detecting point, No.109, and Near Unsuspicious Activity, No.1-108, and Suspicious Activity, No.109-139.
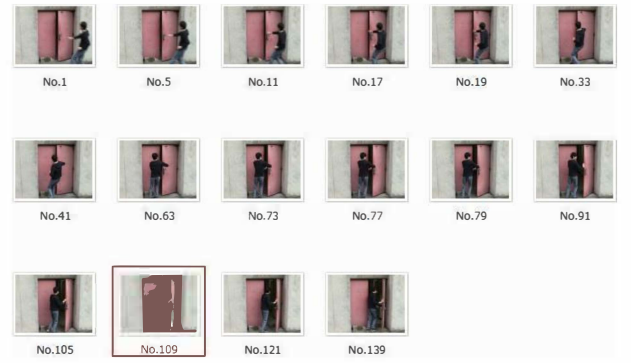

Fig8(b) Characteristic postures at the detecting point, No.109, in a human behavior.

person's behavior, and line of the smoothed Motion Quantity, is 0.15, or more, the experiment pinpoints the detecting point of Suspicious Activity.

In Fig8, this proposal method divides CASE-1 into Near Unsuspicious Activity, No.2-108, and Suspicious Activity, No.109-139, by the detecting point, No.109, because watched person doesn't unlock the opening door. And, the starting point of human behavior is No.1, and the current point is No.139. This experiment compares the smoothed Motion Quantity line, which is found from unsuspicious behavior, (a), and the dots in Motion Quantity, watched person's behavior, (b).

If the current point is No.159, this method divides CASE-1 into Near Unsuspicious Activity, No.2-108, and Suspicious Activity, No.109-159, by the detecting point, No.109. This experiment compares the line of the smoothed Motion Quantity in unsuspicious behavior, (a), and the dots in Motion Quantity in watched person's behavior, (b).

In Table II, this experiment finds the degree of risk of Suspicious Activity.

Table II
THE DEGREE OF RISK OF SUSPICION ACTIVITY IN CASE-1

Near Unsuspicious Activity	0.015961
Suspicious Activity	0.028968
The Degree of Risk	0.644751

The experiment measures the watched person's behavior, which doesn't unlock the door, and treads in someone's footsteps into the room as CASE-2. In Fig9, this method divides CASE-2 into Near Unsuspicious Activity, No.2-
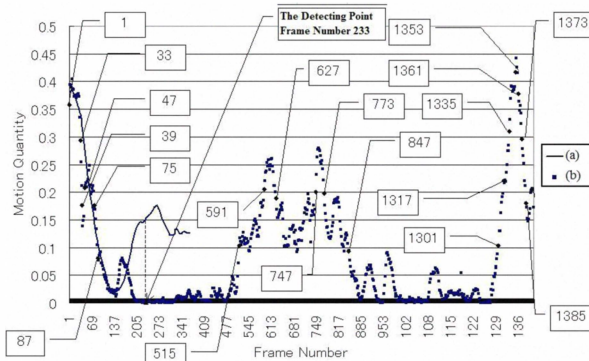

Fig9(a) The detecting point, No.233, and Near Unsuspicious Activity, No.1-232, and Suspicious Activity, No.233-1385.
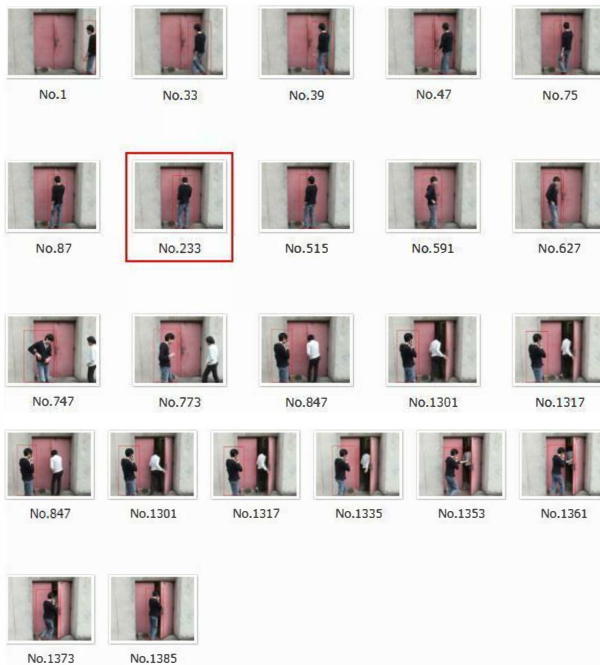

Fig9(b) Pinpointing the human postures, which show suspicious activity, Frame number 233-1385.

232, and Suspicious Activity, No.233-1385, by the detecting point, No.233, because watched person doesn't open the door. The starting point is No.1. And, the current point is No.1385. This experiment compares line of the smoothed Motion Quantity in unsuspicious behavior, (a), and the dots in Motion Quantity in watched person's behavior, (b) in Fig9.

The experiment finds the degree of risk of Suspicious Activity, CASE-2. This watched person's behavior has the detecting point at No.233. The experiment divides CASE-2 into Near Unsuspicious Activity, No.2-232, and Suspicious Activity, No.233-1385, finds the degree of risk of Suspicious Activity as Table III.

Table III
THE DEGREE OF RISK OF SUSPICION ACTIVITY IN CASE-2

Near Unsuspicious Activity	0.003477
Suspicious Activity	0.015488
The Degree of Risk	0.816649

VI. CONCLUSION

In the experiment, this proposal method is possible to detect Suspicious Activity from the watched person's behavior, and to measure the degree of risk of Suspicious Activity due to finding the detecting point. This surveillance camera system can identify unsafe oversight area and suspicious person, and bring observer's attention to them using this proposal method. And, an observer is relieved of the burden of mind and body occurred from the matter, which is an observer must watch enormous quantity of image data shot by multiple Web cameras constant monitoring of remote control. Then, this system occurs serious problem, which an observer misses important predictor of crime in area under surveillance.

This proposal method pinpoints the detecting point of Suspicious Activity, and finds the degree of risk of Suspicious Activity so that observer can lessen physical and mental burden in monitoring. As research challenge, this study tries to understand gesture using Motion Quantity so that companion robots can have natural and extremely precise communication with human.

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