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Determining Variable Factors of Risk and Calculating Risk to Public Safety

Donghyok Suh[1], Jeonghwa Song

Namseoul University, Korea
{absuh,[1] songjh}@nsu.ac.kr

Abstract. This study aimed to determine the variable factors involved in risky situations by performing an analysis on data from specific crime incidents. Factors related to the occurrence of the specific crime were determined and risk of occurrence was calculated using these factors with a multi-factor convergence scheme. The analysis and risk calculation performed in this study are expected to contribute to the development of a more efficient and intellectualized prevention service, as these can help provide information about real-time risk levels for particular public safety situations.

Keywords: crime prevention, data convergence, situation deduction

1 Introduction

It is important to understand the risk factors that must be perceived by the sensors and network system when preparing an intelligent detection system that can detect crime occurrence risk in urban spaces. More effective and efficient crime prevention can be expected when intelligent detection functions that include factors for computing risk level are integrated with the facilities of high-risk physical environments.

This study focused on predetermining the dynamic factors related to specific high-risk situations by analyzing specific incidents of violent crime. More specifically, the crimes analyzed for the purpose of this study were roadside kidnapping and sexual assault cases occurring in Cheonan-si, Chungcheongnam-do, Korea. Cheonan-si is an industrial city with a population of 0.6 million. The city has shown a marked increase in sexual crimes over the past five years. The present study analyzed these incidents and extracted potential environmental and dynamic factors that may have had an impact on the occurrences of these incidents. This study also aimed to determine which sensors could detect these factors in daily life, and based on these results, a scheme was proposed for calculating the risk levels for violent crimes using the values detected and reported by each sensor. This kind of calculation scheme can help simplify the process of obtaining information by evaluating different trends in the signals detected by the sensors over time. The information obtained from the changing values detected by the sensors can be used for the calculation of real-time crime risk, thus resulting in the possibility of prompt responses to high-risk situations.

[1] Corresponding author.

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This paper is organized as follows. Following the Introduction, Chapter 1 and Chapter 2 summarize the related literature. Chapter 3 reports on the use of an actual incident analysis to determine dynamic factors related to that specific incident. Chapter 4 determines which sensors can detect the dynamic factors determined in Chapter 3 in a real-world situation, and these sensors are used to calculate the risk-level indicated by each factor and to investigate the effectiveness. Chapter 5 presents an evaluation of the study and the conclusion.

2 Determining risk factors and calculating risk to public safety

2.1 Extraction of dynamic factors

Risk factors that either increase or decrease the risk of crime occurring over time are defined as dynamic factors. Time itself is one example of a dynamic factor. This study analyzed cases of sexual assault and sexual harassment committed by strangers that occurred in Cheonan-si and the surrounding area. Three dynamic factors were found to play roles in the occurrence of sexual assault and sexual harassment in these areas: floating population, time, and spatial characteristics.

1) Floating population: The existence of a floating population where the victim resides, as well as the size of that floating population, seems to be related to the occurrence of sexual harassment and assault. The cases below are all examples of incidents that occurred in an area with a very small floating population. It should also be noted that none of these incidents occurred in typically crime-ridden districts.

Most of the incidents occurred in places that periodically experience drastic drops in floating population. Although these places were all open to the public and were perceived as being relatively safe, the few members of the nearby floating populations made these places more susceptible to crime.

2) Time: In the cases listed below, time is suspected to have played a certain role in the occurrence of the crime, despite the crime occurring in what was considered to be a relatively safe area.

In many cases, the incident took place near a main road or in a public place. Although the spatial characteristics of these locations indicates that the probability of a crime occurring should be low, these places became more susceptible to crime late at night. Changes in time thus played a role in the rate of crime occurrence.

3) Spatial characteristics: One of the factors observed in some of the cases was that the victims became targets when they moved from a wide road to a narrow road. In the cases listed below, the victims moved from a brightly lit area on a wide road to a poorly lit area on a narrow road.

- Case 3-1) August 13, 2013—In the alley near Saemannam Church, Bongmyung-dong, Dongnam-gu, Cheonan-si, Chungcheongnam-do, Korea
- Case 3-2) July 6, 2010—In the alley beside Hoseo Wedding Hall, Baebang-eup, Segyo-li, Asan-si, Chungcheongnam-do, Korea
- Case 3-3) July 16, 2010—In front of Doojeong Housing, Dujeong-dong, Seobuk-gu, Cheonan-si, Chungcheongnam-do, Korea

These incidents all share one common feature: in every case, the victim was spotted by the perpetrator in the main road before she moved to a narrow alley, where the perpetrator then chased her to commit the crime. Hence, it is necessary to consider the moving path of the victim as a factor that may influence the occurrence of sexual assault or harassment.

3 Real-time risk calculation and evaluation

The next section outlines the actual scheme used to calculate risk based on the previously extracted variable risk factors.

Risk factor 1: Nearby floating population
Members of the floating population were detected with infrared sensors placed in the moving paths of pedestrians.
The following case assumes that *n* infrared sensors are installed in nearby area *S*, among which *m* infrared sensors detect objects (vehicles, walking floating population members, etc.). First, the fundamental risk level at the current time is assigned as $\alpha_t = 1 - \frac{m}{Sn}$. Risk level decreases when there are more detected infrared sensors per unit area. According to the increases and decreases in risk level, the following computation was implemented. Each set of data detected by the infrared sensor in unit area S at time t was defined as:

$$S_t = < a_1, a_2, a_3, \cdots, a_m >$$

Based on the method suggested by Deypir, Hadi Sadreddini, and Hashemi (2012), which emphasized a method "towards a variable size sliding window model for frequent item set mining over data streams," a change of frequent items set was defined as:

$$FChange_T(T') = \frac{|F_T^+(T')| + |F_T^-(T')|}{|F_T| + |F_T^+(T')|}$$

Here, the newly received data area was defined as:

$$S_t^+ = S_t - S_{t-1}$$

Data that were no longer received in the next time period were defined as:

$$S_t^- = S_{t-1} - S_t$$

Changes in the data that were detected and reported by the infrared sensors were defined as follows:

$$SC_t = \frac{n(S_t^+) + n(S_t^-)}{n(S_t) + n(S_t^+)}$$

The equation above reflects the changes in the nearby floating population. The calculated results have values within the range of [0,1]. These values became close to zero considering the region with the larger floating population.

Following these calculations, the fundamental risk levels established earlier were multiplied. This was done to take into account both the fundamental risk level and the changes in floating population. The value of the floating population factor was defined as follows:

$$P(t) = \alpha_t SC_t$$

Risk factor 2: Time

The statistical frequency of the incidents was considered according to time period. The times for each occurrence were as follows:

Late night (00:00–04:00) — 0.358957
Dawn (04:00–07:00) — 0.119218
Morning (07:00–12:00) — 0.104719
Afternoon (12:00–18:00) — 0.121600
Early evening (18:00–20:00) — 0.134298
Night (20:00–24:00) — 0.161209

The values given above indicate the frequency of incidents occurring during each time period, rather than the usual values, which involve using a simple sum of occurrence numbers. The above values were calculated as follows:

Frequency by time = Number of incidents / Length of time

The function of the occurrence time variable can be estimated based on the values above.

The periodic function of the time factor *T(t)* was calculated as follows:

$$T(t) = \begin{cases} -0.190819t + 1.38163 & t = (2, 5.8772) \\ 0.008667t + 0.209217 & t = (5.8772, 21.6186) \\ 0.137724t - 2.58088 & t = [21.6186, 24), [0, 2] \end{cases}$$

$$T(t + 24) = T(t)$$

Where, t means current time and the domain of the definition of t was calculated at the left of each linear function. *T(t)* indicate a scaling, such that the graph above has a maximum value of one.

Risk factor 3: Spatial characteristics

There are several spatial characteristics that are commonly observed in crime occurrence that can be examined. For example, in some of the cases listed above, the perpetrator spotted the victim in a bright area and committed the crime by chasing the victim after she had moved to a darker area. Factors such as the victim moving from the main road to a narrow alley or moving from a brightly lit area to a dark area can play significant roles in the occurrence of crime. Hence, the following are considered sub-factors of the spatial characteristics factor:

a. Decrease in illuminance (moving from a bright place to a dark place)
b. Decrease in road width detected on the map (moving from a main street to a narrow alley)
c. Existence of video surveillance in the area
d. Accidental crime region

The decrease-in-illuminance value was defined as follows:

$$l = l_t - l_{t-1}$$

The illuminance of the previous time was subtracted from the current illuminance value (simple difference).
The change-in-road-width value was defined as follows:

$$r = (r_t - r_{t-1})/r_{t-1}$$

The simple difference between the two road widths was calculated and then divided by the original width. By combining the two factors above, the value was calculated based on the equation below. Function M of the spatial characteristics is defined by the M processes receiving the 1 value and the *r* value.

$$M(l,r) = \frac{\sum_{l \in T, l < 0} l}{\sum_{l \in T} l} \times \frac{\sum_{r \in T, r < 0} r}{\sum_{r \in T} r}$$

The equation above includes an equation for the l value and an equation for the *r* value. The equation for the l value is the sum of the l values that are reported when the illuminance decreases within the current time slot, divided by the sum of all l values within the current time slot. Hence, this value becomes close to one when the victim moves to a dark area, and it becomes close to zero if the victim moves to a bright area.

The equation for *r* is the sum of the *r* values reporting decreases of the road width within the current time slot, divided by the sum of all *r* values within the current time slot. Hence, this value becomes close to one when the victim moves toward a narrow alley, and it becomes close to zero if the victim moves toward a wide road. Hence, the role played by M on the different factors of spatial characteristics also has values between [0,1].

Because the three factors all have values between zero and one, the sum of the three factors must have a value between zero and three. When the four sub-factors are considered equivalent to one another, the risk level as influenced by spatial characteristics can be divided into one to four stages.

Hence, the final level of risk can be expressed as follows:

$$D = T(t) + P(t) + M(l,r)_t$$

D = 0–1: low riskiness
D = 1–2: medium riskiness
D = 2–3: high riskiness

4 Conclusion

With the aim of improving public safety and crime prevention, this study attempted to find dynamic factors that may increase or decrease the risk of certain crimes in certain contexts. Static factors based on existing statistical analyses were also examined. The study also attempted to calculate real-time risk levels by analyzing these variable risk factors. Three of these risk factors— floating population, temporal characteristics, and spatial characteristics—were extracted as a result of the analysis, and risk calculation was performed for each factor. Measuring and monitoring real-time risk level in everyday life may be made possible based on the data from this analysis and risk calculation. This study may thus contribute significantly to the implementation of services for preventing crime.

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