Visualizing and Analyzing Street Crimes Using Personalized Security Information Service PRISM

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ABSTRACT

In our previous research, we proposed a security information service, called PRISM, which personalizes the incident information based on living area of individual users. PRISM computes the severity of a given incidents based on distance, time, and type. It then visualizes the incident with the severity on a heat map. In this paper, we extend the functionality of PRISM, in order to analyze street crimes around living area in more details. More specifically, we add three new features to PRISM: showing a past heat map, showing a heat map focused on specified type of incidents, and showing statistics of incidents for every type. Using the extended features, we visualize the dynamic transition of street crimes in a specific area and the whole region. The visualization also reveals the ecology of wild boars. Finally, we also show that PRISM can be used to compare different districts by statistics of street crimes.

CCS CONCEPTS

• **Human-centered computing** → **Heat maps**; *Visual analytics*; • **Information systems** → Web crawling;

KEYWORDS

security information service, smart city, Web service, street crimes, visualization

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1 INTORODUCTION

Many local governments in Japan recently start providing *security information service* for residents. The service distributes information of street crimes and incidents occurred in the region to residents using the Internet. The residents can make use of the information for avoiding crimes. A typical security information service provides a list of recent incidents and a security map within a Web site. Or, it delivers the incident information by e-mail. For example, Hyogo Prefectural Police in Japan provides "Hyogo Bouhan Net" [2]. The service publishes incident information that Hyogo prefectural Police recognize on the Web. By registering an e-mail address, a user can receive the information by e-mail. Similarly, Tokyo Metropolitan Police Department provides the e-mail delivery service, called "Mail Keishicho". The Department also publishes "Tokyo Crime Map" [9]. It is a security map showing where and when every suspicious person appeared.

In these existing security information services, every incident information is uniformly delivered to all users. Various types of incidents occur every day at various locations in the region. However, user's living area varies from one person to another. Therefore, even if an incident is critical for a user, it may not be so serious for another user who is living at distant place. Thus, how the incident is severe depends on individual users. However, this fact is not taken into account in the existing security information services. All information of incident is distributed uniformly to all users. Hence, when much information is delivered in a day, a user may miss important information.

In our previous research, we proposed and implemented a new security information service, called *PRISM (Personalized Real-time Information with Security Map)*, which personalizes the incident information based on living area of individual users[3]. For every incident information provided by the existing security information services, PRISM computes severity of the incident according to the living area of a user. More specifically, based on the distance between the living area and the incident, the time elapsed from the occurrence, and the type of the incident, PRISM adds a weight to the incident, so that closer and newer incidents become more serious for the user. It then visualizes the weighted incidents on a heat map. Since the weight of severity varies depending on user's living area, the resultant heat map becomes a personalized and real-time security map.

The current version of PRISM visualizes the latest incident information only. It does not have features to look back on past incident information, or perform statistical analysis. Although PRISM is useful to capture the current incident status, it cannot be used for deeper analysis or visualization considering past incidents.

In order to visualize and analyze street crimes in more details, we add three new features to PRISM in this paper. The first feature is showing a past heat map. A user can display the heat map at any date in the past. By using this feature, the user can see how the incidents around the area have been changing as the time went. The second feature is narrowing down by the type of incident. This allows the user to display only interesting type of incidents on the

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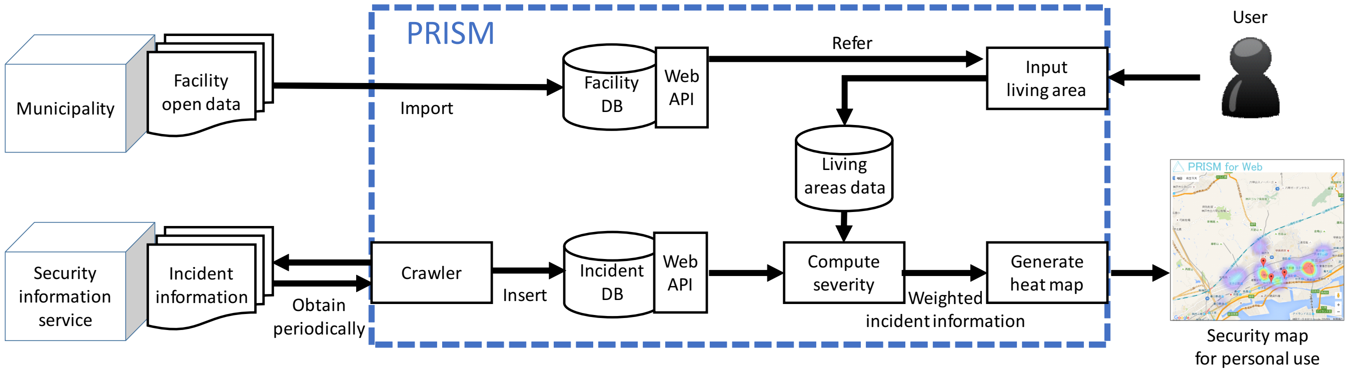


Figure 1: Architecture of PRISM

heat map. The third feature is displaying statistics of the number of occurrences for each type of incident. The user can see the number of incidents around the living area as statistical data.

Using new three features, around Kobe city in Japan, we visualize the transition of street crimes in a certain living area and the whole region. We also investigate ecology of wild boars, and compare statistics of crimes for different living areas. Using extended functionality of PRISM, the user can understand more characteristics of incidents around the registered living area.

2 PREVIOUS RESEARCH: SECURITY INFORMAITON SERVICE PRISM

In [3], we have proposed PRISM (Personalized Real-time Information with Security Map), which personalizes the incident information based on living area of individual users.

2.1 Overview of PRISM

To provide personalized incident information, PRISM exploits two key ideas. The first idea is to put a weight of *severity* on every incident. The severity is computed based on the distance to the living area, the elapsed time, and the type of the incident. The second idea is to visualize the weighted incidents on a *heat map*.

A user of PRISM first registers his/her living areas. The living areas represent places where the user often visits in the daily life, such as a house, a station, a working place, a school of children, and a shopping center. Every user can register multiple places as living areas.

Then, for each incident information delivered, PRISM calculates the distance between the point of incident occurrence and the living area of the user. PRISM also calculates the elapsed time from date and time of occurrence to the current time. Based on the distance and the elapsed time, PRISM adjusts a weight of the default severity pre-determined for each type of incident. The resultant weight is the severity of the incident personalized for the user. Finally, PRISM generates a heat map based on the personalized severity, which achieves a personalized and real-time security map.

2.2 Architecture

Figure 1 shows the system architecture of PRISM. In the figure, the dotted rectangle represents the system boundary of PRISM. A *crawler*, at the bottom left of the figure, periodically obtains incident information from an existing security information service. Then, the crawler analyzes the retrieved text, extracts attributes, and inserts the attributes into an *incident DB*. A user at the top right of the figure registers his/her *living areas data*. In the registration, the user can refer to a *facility DB*, where facility open data of the local government is imported. Based on the incident DB and the living areas data, PRISM *computes the severity* of every incident. Finally, PRISM generates a heat map based on the weighted incident information, and presents the map to the user.

In the current version of PRISM, we use "Hyogo Bouhan Net" as a security information service and Kobe city facility open data [5]. Using PRISM, a user can browse personalized and real-time information within Hyogo prefecture.

2.3 Severity

Severity is a degree of how the incident is serious for a user. Based on keywords contained incident information, PRISM first defines the default severity of incidents by the following four categories:

Alert (severity 3) The most serious incident that can threaten life of citizens.

Warning (severity 2) Incidents that may cause physical damage to citizens.

Caution (severity 1) Incidents to be paid attention, not directly linked to life or physical damage.

Notice (severity -1) Other information from the police.

Next, PRISM weights the above default severity based on following two viewpoints:

Distance: The closer the distance between the place of incident and user's living area is, the more serious the incident is for the user, since a new incident may happen again nearby. Thus, higher weight is given to the incident. On the other hand, the longer the distance is, the smaller the severity is.

Time: The shorter the elapsed time from the incident occurrence, the more serious is for the user, since a new incident may happen again soon. Thus, higher weight is given to the incident. On the other hand, the longer the time is, the smaller the severity is.

Now, for an incident x and a user u, let d be the distance from living area of u to the place where x occurred. Also, let t be the elapsed time from the time when x occurred. Then, we define the severity of x for u, denoted by $severity(x, u)$, as follows:

$$severity(x, u) = 1/3 * (WD(d) + WT(t) + severity(x) * 1/3)$$

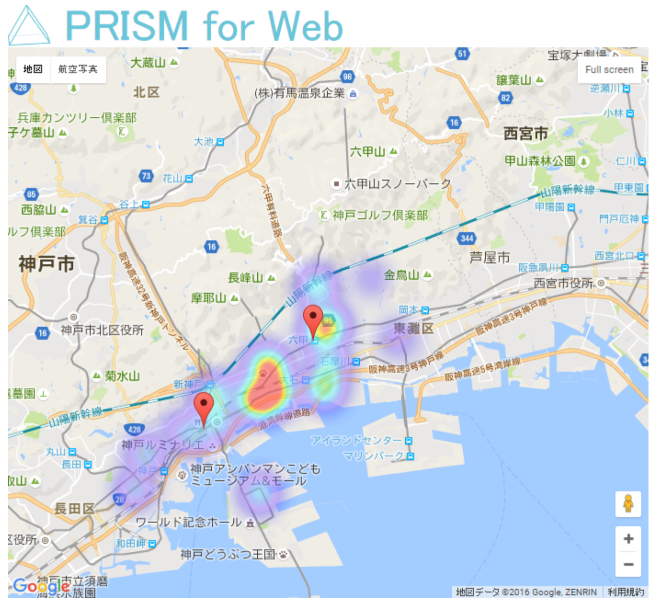
where $WD(d)$ and $WT(t)$ are weight functions with respect to distance d and time t, respectively. $severity(x)$ represents the default severity of x (ranging over -1, 1, 2 or 3) calculated by incident information. Since $severity(x)$ takes the maximum value 3, PRISM first multiplies it by 1/3 in order to normalize the maximum value to 1. After that, $severity(x, u)$ is calculated by taking the average value of $WD(d)$, $WT(t)$, and $severity(x)$.

Currently, we use a function that maintains the weight 1.0 until d reaches 2km and decrease the weight linearly from 1.0 to 0.0 up to 4km as $WD(d)$. Similarly, $WT(t)$ maintains the weight 1.0 until t reaches 7 days and decrease the weight linearly up to 14 days. However, they are freely customized according to characteristics of the area as well as the crime situation of the region.

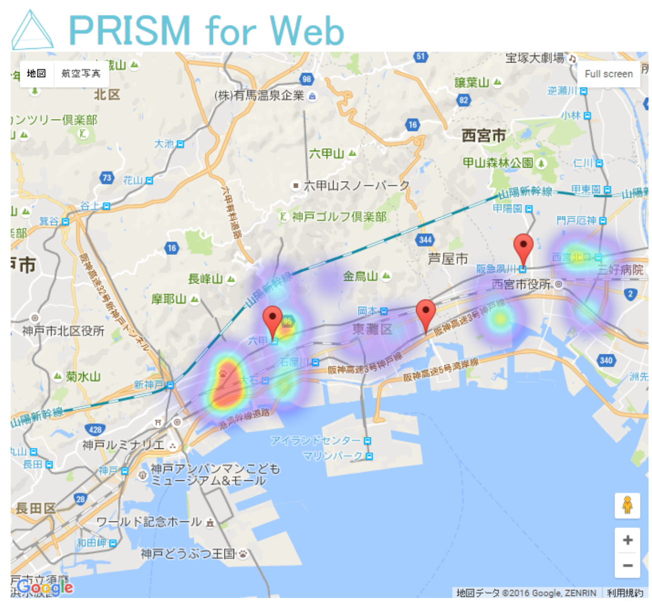
2.4 Heat Map

PRISM visualizes the incident data with personalized severity on heat map. The value of $severity(x, u)$, which is the severity of incident x for user u, is between 0.0 and 1.0. PRISM creates a heat map such that the severity value is scaled into the seven colors, [purple, indigo, blue, green, yellow, orange, red]. For each incident x, PRISM puts a data point on coordinates (lat, lng) of x using a color associated with $severity(x, u)$. This generates a heat map adapted to individual living area and the current time.

Figure 2 shows two heat maps generated for two users A and B, where the incident information within Kobe City at a certain date is visualized. The pins in the map indicate locations of living areas registered by the users. The colored points indicate the places where incidents occurred. In this example, user A registered Kobe Sannomiya Station and Hankyu Rokko Station as living areas. On the other hand, user B registered Hankyu Rokko Station, Shukugawa Station, and Hanshin Fukae Station. We can see that completely different heat maps are generated depending on the living area, even though the map area and the time are the same.



(a) User A's heat map



(b) User B's heat map

Figure 2: Example of outputting heat map

3 EXTENDING PRISM FOR DEEPER ANALYSIS

3.1 Extended Features

In order to achieve the safety and security, it is important for every citizen to grasp when, where, and what kind of incident occurs frequently around yourself. In this section, we propose a method to analyze street crimes in your own living area by extending PRISM.

PRISM we have proposed in Section **2** is a tool for visualizing *real-time* incident information. It cannot look back on the past incidents, or perform statistical analysis. Thus, the previous methods cannot be used for deeper analysis or visualization that considers both past incidents and individual living areas.

To cope with the limitation, we add the following three features to PRISM in this paper. Using these additional features, a user can analyze temporal and statistical characteristics of incidents around his/her own living area.

F1 (Visualizing past heat map): This feature shows the heat map on any given date and time specified by the user. It

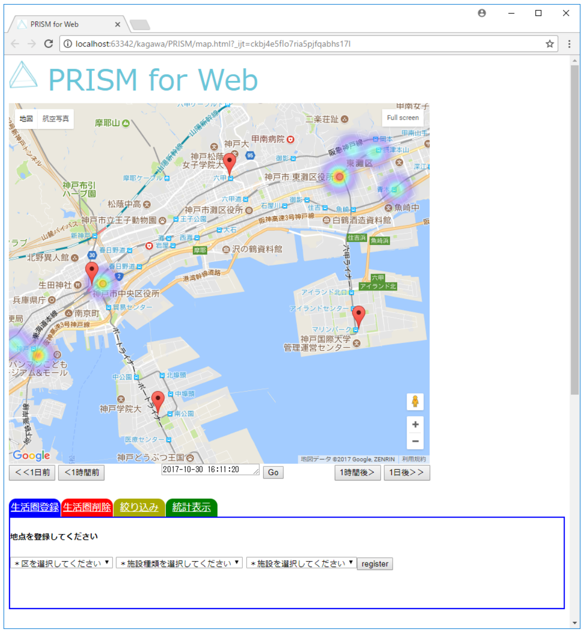


Figure 3: Feature F1: Showing previous heatmap

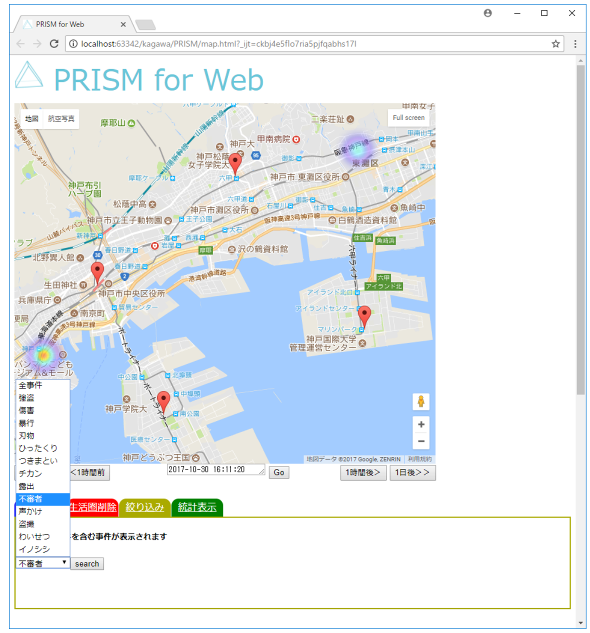


Figure 4: Feature F2: Filtering incidents by type

allows the user to see the heat map at any point of time in the past.

F2 (Narrowing down by type of incident): This feature filters only specified type of incident on the heat map. It allows the user to focusing on special types of incidents that he/she wants to analyze.

F3 (Showing incident frequency): This feature shows statistics of the number of incidents of each type as a stacked bar chart. It allows the user to analyze which type of incidents occurred how often.

We will describe the details of each feature in the following subsections.

3.2 F1: Visualizing Past Heat Map

PRISM proposed in Section **2** only displays the current incident information, and cannot look back the past information. In this feature, therefore, we extend PRISM so that the user can analyze street crimes with respect to the time axis. Specifically, we allow the user to input any date and time. Regarding the given date and time as the current date and time, PRISM re-computes the severity, and re-draws the heat map as described in Section **2.4**. As a result, the past heat map can be generated.

Figure 3 shows a screenshot of PRISM with the extended features. At the bottom of the map, there is a textbox for specifying the date and time The user inputs the past date and time he/she want to analyze in the text box, and presses Go button. Then, PRISM displays the heat map on the specified date and time.

On the left side of the text box, there are also buttons to look back one hour ago, or one day ago. Similarly, on the right side, there are buttons to forward the time to one hour, or one day. By using these interfaces, the user can display the heat map at any past time and analyze the situation of street crimes.

Using this feature, it is also possible to visualize the *transition* of incidents as an animated movie, where time-series snapshots of the heat map are linked together. Thus, the user can dynamically analyze where and when incidents occurred frequently.

3.3 F2:Narrowing Down by Type of Incident

In PRISM proposed in Section **2**, all types of incident were displayed on the heat map. Therefore, in this feature, we extend PRISM so that street crimes can be filtered by the types of incident. Specifically, when the user designates a keyword, PRISM searches only the incidents including the keyword with API and generates heat map.

We will explain F2 using Figure 4. When the user clicks on a tab of "narrow down" at the bottom of the screen, a dropdown list for selecting keywords appears. The user selects the type of incident he/she want to analyze from the list and presses the search button. PRISM visualizes only incidents which have the selected keyword on the heat map.

3.4 F3: Showing Incident Frequency

This feature displays the statistics of the number of incidents of each type, which we call the incident frequency. The incident frequency is represented for each registered living area, in a form of a stacked bar chart.

More specifically, for each location point p of the registered living areas, PRISM retrieves incidents that occurred within a R-kilometer radius of p and within the last D days. PRISM then counts the frequency of incidents for each incident type (see Section **3.3**),

Figure 5: Feature F3: Statistics of incidents for each point of living area

and displays the statistics as a stacked bar chart. In the default setting, R is set to 2.0 km and D is set to 365 days. Thus, it is possible to take statistics of the incident frequency in the last one year within a two-kilometer radius of each point.

We explain F3 using Figure 5. When the user clicks "statistics" tab at the bottom of the screen, and presses "show statistics" button. Then, PRISM shows stacked bar charts of all locations registered as living area. In each chart, a user can see which type of incidents occur how often. Thus, the user can visually analyze features of street crimes at each location point with a stacked bar chart.

4 VISUALIZING AND ANALYZING STREET CRIMES USING PRISM

Using the extended features of PRISM, we conduct deeper analysis of street crimes within Kobe city in this section.

4.1 Transition of Street Crimes in Living Area

We analyze how the street crimes in the living areas change throughout the year. In this analysis, we adopt the Hankyu Imazu station (Nishinomiya city) and the Hankyu Rokko station (Kobe city) as personal living areas. These stations are used by the author on a daily basis. Next, using the feature F1, we displayed a series of heat maps from January 1st, 2016 to December 31st, 2016. We captured each heat map into an image file using a screen capture software. Then, we created a movie file by joining 366 pieces of the image files together.

We used "Mado Photo"[1] and "UWSC"[2] in order to make the movie file. After capturing the screenshot using Mado Photo, we forward the heat map to the next day using the feature F1. Using UWSC, it is possible to repeat fixed operations by a specified number of times automatically. We generated 366 pieces of image data by repeating capturing the screen and forwarding to the next day for 366 times. Mado Photo also has a feature to create GIF animation by joining multiple image files together. We created an animation GIF file utilizing this feature, and converted it into the MP4 format.

[1] https://www.otsoftware.net/software/madophoto.html
[2] http://www.uwsc.info/

Figure 6: Showing incidents around Imazu and Rokko stations (February 1, 2016)

Figure 6 shows a scene of the animation. From this, the following facts were observed:

- More incidents occurred around Imazu station than around Rokko station.
- Street crimes occur throughout the year.
- Incidents occurs various places around both stations.

The generated movie file can be watched in https://youtu.be/y2wbIJSGgXk.

4.2 Transition of Street Crimes in the Whole Region

We analyze the transition of the street crimes in the whole region of Kobe, by applying the same method described in the previous subsection.

Specifically, we place points of living areas throughout Kobe in a mesh shape. Here, we register nine points covering each ward of Kobe city, centering on Shin-Kobe station. Then, we created a movie file in the same way we described in the Section **4.1**. Analyzing the animation, you investigate in which part within Kobe city incidents often occur. Figure 7 shows a snapshot of the movie. From the animation, the following facts were observed:

- Incidents occurred along three train lines (Hankyu, JR, and Hanshin) running through Kobe city.

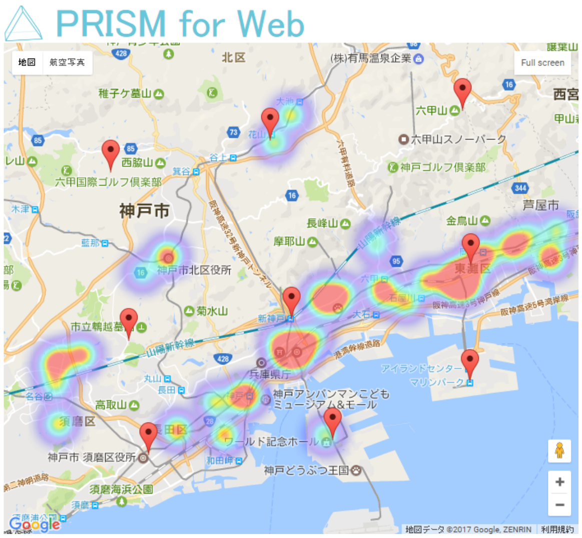


Figure 7: Showing incidents in all Kobe area (June 7, 2016)

Figure 8: Showing witness information of wild boars (June 7, 2016)

- As it goes to the north, the number of incidents decreases.
- There are no incidents observed in mountains.

The generated movie file can be watched in https://youtu.be/Ngr3mQ-Hijw.

4.3 Ecology of Wild Boars

Since there are many mountains in Kobe city, wild boars frequently appear. Wild boars sometimes cause harm to people. Therefore, when a wild boar is observed, the location and time where the boar is found are reported to the police. Then, the witness report is delivered as an incident by Hyogo Bouhan Net. Here, we analyze the ecology of the wild boars that appeared in Kobe city in 2016, using the feature F2.

First, as similar to Figure 7 and Section **4.2**, we registered nine points centered on Shin-Kobe station. Then, we specified "wild boar" as a keyword with the feature F2. As a result, only witness information of wild boars is shown in the heat map. Finally, we generated a movie file in the same way as Section **4.1** and Section **4.2**. Figure 8 shows a snapshot of the movie. From the animation, the following facts were observed:

- Most wild boars are observed within a mountain belt from Shin-Kobe station and Hankyu Okamoto station.
- Wild boars are frequently observed from June to September.
- Wild boars are not observed during the winter season.

The generated movie file can be watched in https://youtu.be/YkdfsZZ8hrc.

4.4 Comparing Statistics of Crimes

One of the biggest concerns for inhabitants is to know whether or not their living place and around are actually secure. Moreover, such security information becomes a criterion for in-bound people to decide where to live. In this subsection, we analyze statistics of

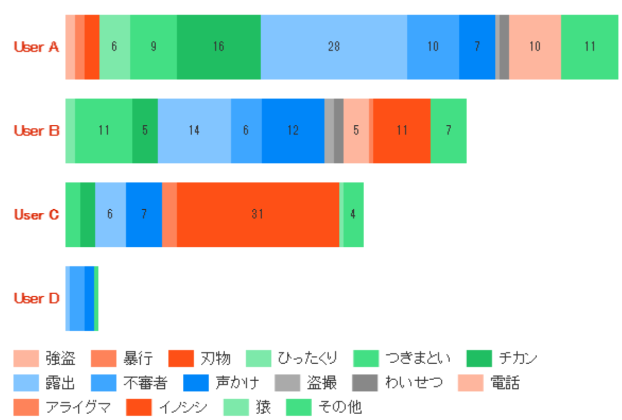


Figure 9: Showing stacked bar charts of incident statistics

incidents frequency for several locations within Kobe city using the feature F3. Then, we compare the security of the locations from the viewpoint of the frequency of street crimes.

In this analysis, we compare the security around actual living houses of four users. User A's house is located in Nishinomiya city. User B's house is located in a downtown area of Nada ward, Kobe city. User C's house is located near mountains in Nada ward, Kobe city. Finally, User D's house is located in Sanda city, which is a countryside of Hyogo prefecture. We registered addresses of the four houses in PRISM, then displayed statistical information using the feature F3. We took frequency of incidents that had occurred within a two-kilometer radius in the year 2016.

Figure 9 shows four stacked bar charts generated by PRISM, each of which corresponds to statistics of a user. For clear reading, we also summarize the number of occurrences for each type of incident in Table 1.

Table 1: Number of incidents every type around each house of users

	User A	User B	User C	User D
robbery	2	0	0	0
assault	2	0	0	0
knife	3	0	0	0
snatching	6	2	0	0
stalk	9	11	3	0
groping	16	5	3	0
exposure	28	14	6	0
suspicious person	10	6	0	3
act of speaking	7	12	7	2
spy photo	1	2	0	0
obscenity	2	2	0	0
phone	10	5	0	0
racoon	0	0	3	0
wild boar	0	11	31	0
monkey	0	0	1	0
others	11	7	4	1
total	107	77	58	6

In the neighborhood of User A's house, there are many exposures and groping. Therefore, a woman need to be careful when she walks alone. Moreover, a few serious incidents such as robbery, assault, and knife occurred. Thus, it is necessary to pay attention to these incidents. On the other hand, in the neighborhood of User B's house, there are several incidents of exposure and groping. Also, there is no incident that can threaten life of residents. However, more wild boars are observed compared to the downtown area. Thus, it is necessary to prepare for the wild boars. Fewer incidents are observed in the neighborhood of User C's house, compared to Users A and B's. However, more wild bores are witnessed, because the house is near a mountain. Thus, User C should be more careful of wild boars than User B. Since User D lives in the countryside, only six incidents are reported around his house within the year of 2016. Therefore, it can be said that User D lives in a relatively safe area compared to the other users.

5 RELATED WORK

Previously, many studies have been conducted to clarify factors relevant to street crimes. Hipp and Kane focused on the relationship between population and crime[1]. They state that cities with more population will experience larger increases in crime. They also state that cities with increasing population will experience larger decreases in crime. Morenoff and Sampson[6] mentioned about the relationship between decrease of population and violent crime. They also visualized changes in the population. Roncek[7] examined how the characteristics of the area affect where crimes occur using the actual data of San Diego and Cleveland. Stults and Hasbrouck[8] focused on the relationship between commuting and crime rates. Kester[4] visualized and analyzed crime patterns using Formal Concept Analysis. Their findings are interesting, however, these previous studies mainly focus on interesting regions as a whole, but do not consider individual's living area. Using the extended features of PRISM, it is possible to analyze street crimes according to individual's living area.

6 CONCLUSION

In this paper, we have extended a personalized security information service PRISM, in order to perform deeper analysis of street crimes and incidents within a city. Using the new three feature, a user of PRISM can refer to the past heat map, focus on specified type of incidents, and see the statistics of incident frequency for each type of incidents. These new features allow the user to know more deeply the characteristics of the incidents around his/her living area.

Using the extended version of PRISM, we have conducted deeper analysis of Kobe city. Transitions of street crimes within a year 2016 were analyzed for specific living area of an author as well as a Kobe city. It was also interesting to see the ecology of wild boars, unveiled from incident information. Finally, we compare the security of different locations quantitatively with the incident frequency.

In our future work, we will verify the validity of the value of the severity, as well as the weight functions described in Section **2.3**. In addition, although only security information in Hyogo prefecture can be browsed as it stands, we plan to implement security map in other areas, and analyze characteristics of incidents.

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