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A simulation-based emergency force planning method for social security events

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Abstract: The occurrence of social security events is uncertain, and the distribution characteristics are highly complex due to a variety of external factors, posing challenges to their rapid and effective handling. The scientific and reasonable requirement evaluation of the emergency force to deal with social security events is very urgent. Based on data analysis, this paper uses the neural network, operational research, modelling and simulation to predict and analyze social security events, studies the usage rule of emergency force and deployment algorithm, and conducts simulation experiments to evaluate and compare the different force deployment schemes for selection.

Keywords: social security, emergency force, simulation, force deployment.

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1. Introduction

Social security events are uncertain in terms of time, place, type, scale, and intensity, and are affected by multiple external factors such as geography, climate, population, culture, transportation, and ethnicity. Their distribution characteristics are highly complex [1−6]. The suddenness of social security events poses a challenge to their quick and effective disposal [7−10]. With the help of historical data, we can predict the social security event, design the deployment scheme of emergency force for social security events with simulation, and promote professional and scientific emergency force planning [11−17]. Emergency force planning evaluates the emergency force requirement and mainly determines the quantity and deployment of the emergency force, to make it as scientific and reasonable as possible.

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The first case of applying data analysis methods to police data occurred in the United States in the mid-1990s. In 2013, PredPol, a case prediction system, was introduced in the United States to guide and assist civilian police. The prediction system was developed for five years by a team of data scientists, social psychologists, government officials, and criminal investigators, mainly used to analyze the collected data to predict future occurrence time of the possible crime events in a certain area. In 2015, about 60 police departments in the United States were using this system. In some areas with the insufficient police force, this system is effective in relieving the pressure on police officers and can help the reasonable deployment of force to a certain extent, stop crimes, and improve the execution of police [18−24]. In 2010, the United States police also implanted a monitoring program in a financial company specializing in cross-border business, which was used to monitor trading volume and abnormal trading behavior. It studied police data based on machine learning and made real-time alarms, effectively preventing fraud and other criminal activities [25−29]. These foreign studies and application cases imply the concepts of "active policing" and "predictive policing" proposed by Chinese police institutions and show us more clearly some practical problems existing in data analysis [30−34].

In recent years, Chinese police institutions have also been exploring data analysis application in practice. Since 2012, Suzhou Public Security Bureau has introduced a crime prediction system from the United States and conducted crime prediction experiments within the city. Local governments have also followed the trend by developing various prediction methods in public opinion surveys, social management, railway transportation, livelihood services, agriculture, forestry, and animal husbandry.

There are also some evolution models and process simulation software for specific problems and event types, which can simulate the process and disposal effect of certain types of events from the beginning to the end, but they are usually limited to specific scenes and single event disposal, such as venue evacuation and fire rescue. Complex situations such as large-scale events, simultaneous disposal in multiple places, and nationwide multi-level force scheduling are rarely considered. The existing research results of force planning and event simulation cannot meet the demand demonstration of emergency force for social security events.

This paper uses neural network and modeling and simulation (M&S) methods to conduct exploration. In the second section, we develop the framework about the evaluation of emergency force requirement. In the third section, according to the character of problem domain data, we construct the social security event predictive model. Then, we design the emergency force deployment scheme algorithm. In the last section, we do experiments on the emergency force deployment scheme, and select a better scheme based on the comparison of experimental results.

2. General framework

The evaluation of the emergency force requirement is expressed by a hierarchical process, which mainly includes the following steps: Firstly, we formulate the predictive model of social security events by using the historical data and neural network method, and form the simulation task set, to provide the task quantity basis for the subsequent force evaluation. Then, based on the historical data, we analyze the rule of force, study the indicators of task, design the algorithm of force deployment, and formulate different schemes according to different strategies. Finally, we compare and assess different results of simulation experiments, to pick out a better scheme.

The general framework of emergency force planning is shown in Fig. 1.

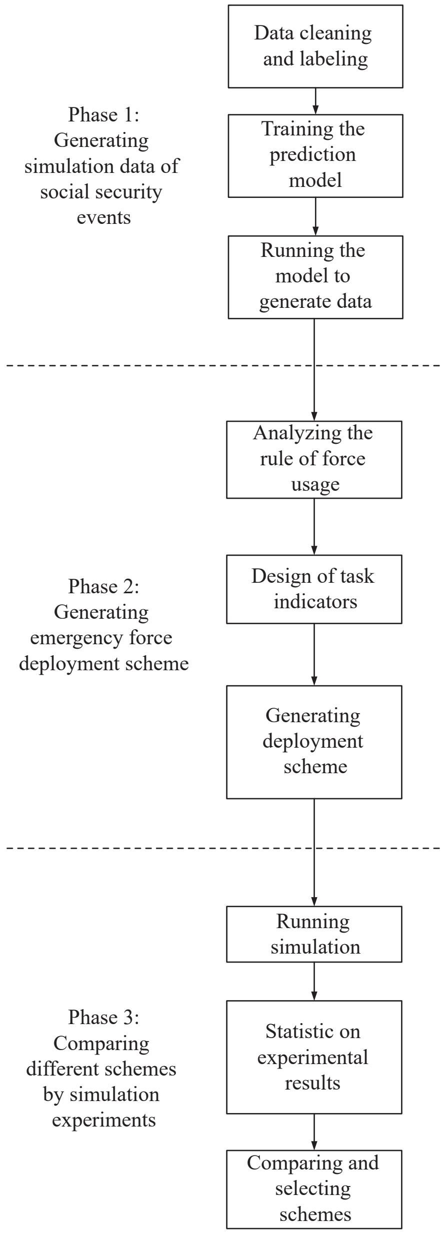


Fig. 1 General framework of emergency force planning

3. Social security event predictive model

More and more data related to social security events are available, such as information on persons involved in the event, mass events data, anti-terrorism data, individual extreme events data, organized crime data, and emergency disposal time, location, duration, force quantity, and other data of various events. In the past, information with high potential value is processed mainly based on experience and traditional data statistical methods, which are only suitable for a small range of data and take a lot of time when massive data is involved, with inaccurate results and inefficiency. The rapid development of machine learning makes it possible to analyze massive data. Using long short-term memory (LSTM) neural network model to analyze the data of social security events, we can get the guiding results, assist the intelligence department to make scientific and reasonable decisions, and improve the efficiency of force deployment. For example, the model can be used to predict the key areas to be subject to significant situations, strengthen the force deployment in this area, increase the patrol force, increase the police visibility rate, form a strong deterrent effect, and effectively reduce the occurrence rate and crime rate.

The predictive model of social security events mainly includes data cleaning, annotation, neural network training model, and model evaluation.

3.1 Classification of social security events

Social security events can be divided into two types: mass events and terrorist events. Each type can be divided into some sub-types. Based on the number of persons involved, each sub-type contains four levels: small-scale, medium-scale, large-scale and extra-large-scale. This paper takes mass events as an example, and other security events are analyzed in the same way. The classification of social security events is shown in Table 1.

Table 1 Illustration of classification of social security events

Event type	Sub-type	Persons involved	Level
Mass event	General mass event	Less than 100	Small
		101−1 000	Medium
		1 001−10 000	Large
		Over 10 000	Extra-large
	Mass gathering to block traffic	Less than 100	Small
		101−1 000	Medium
		1 001−8 000	Large
		Over 8 000	Extra-large
	Gang violence	Less than 100	Small
		101−1 000	Medium
		1 001−6 000	Large
		Over 6 000	Extra-large
	Riot	Less than 100	Small
		101−1 000	Medium
		1 001−5 000	Large
		Over 5 000	Extra-large
Terrorist event	⋮	⋮	⋮

3.2 Data processing

The data acquisition channels of social security events are diverse, with different structures and attributes, covering various fields such as transportation, commerce, banking, security, and railway. This leaves disparate, fragmented, and incomplete data with a lot of useless information.

According to the classification of social security events, the key factors involved in event handling include time, location, type, level, duration of the event, as well as the force level and quantity applied. In this paper, the collected data are pre-processed, deleted, generalized, sorted out, and saved by the designed standardized data model, to prepare for predicting specific events in the future. An illustration of the processed data is shown in Table 2.

Table 2 Illustration of processed social security event data

Time	Location	Event type	Event level	Duration/day	Force level	Force quantity
10/5/2018	City A	General mass event	Small	1	Local	20
12/23/2017	City B	General mass event	Medium	1	City-level	200
7/17/2014	City C	Mass gathering to block traffic	Small	1	Local	20
10/9/2009	City D	Gang violence	Medium	1	City-level	500

3.3 Neural network predictive model of social security events

LSTM is a special type of recurrent neural networks (RNNs). It can learn long-term dependencies and is suitable for processing and predicting significant events with relatively long intervals and delays in time series. It has obtained good results in a series of applications such as natural language processing and language recognition. Therefore, LSTM is suitable for analyzing data on social security events.

LSTM neural network model is used to encode the data of social security events. The input is the coding of security event data of a certain place in the past period, and the output is the coding of security event prediction data of the place in the future period. The time granularity can be day or month, and the duration of input and output can be selected through comparative experiments. The neural network predictive model of social security events is shown in Fig. 2.

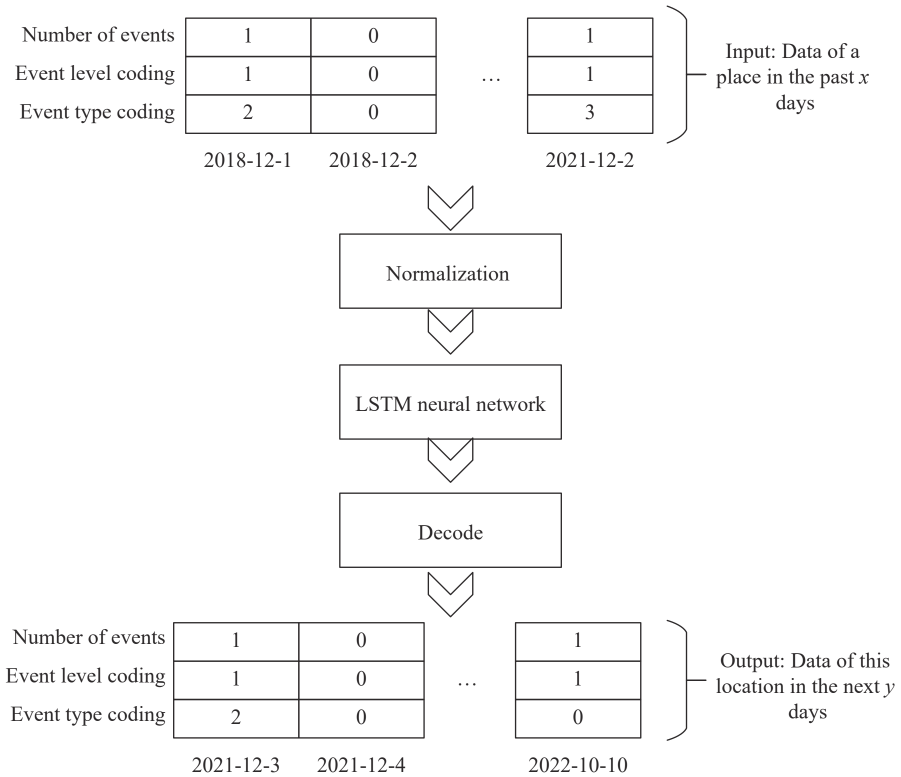


Fig. 2 Neural network predictive model of social security events

After the model is created, the mean absolute error (MAE) is used to calculate the loss function of the regression model. MAE is the sum of the absolute values of the difference between the target value and the predicted value. The calculation result of MAE is more accurate, easy to understand, and without the consideration of direction, to make better evaluation of the model.

3.4 Generating simulation data of social security events

After importing the existing annual data of each place into the social security event predictive model, it can output the prediction of the level, quantity, and time of security events in this place in the future, and the prediction data can be generated into simulation data for force requirement demonstration. If the time granularity of the prediction result is in a month, the event time can be set on a specific day of the month by random distribution. A random distribution can be used to generate persons involved for the predicted event level.

4. Generation of emergency force deployment scheme

This method is mainly used to analyze the history of force usage to get the quantity rules, calculate the deployment position of emergency force as well as the location of events at a different level, and calculate the force quantity.

4.1 Analysis of the rule of force usage

The analysis of the rule of emergency force usage mainly refers to the statistical analysis of historical data to obtain the relationship between the types and levels of different events, emergency force usage, and force quantity and level, to provide a quantitative reference for the calculation of force demand, as shown in Table 3.

Table 3 Illustration of relationship between event level and force usage

Event type	Sub-type	Level	Force usage/day	Force level
Mass event	General mass event	Small	100	Local
		Medium	1 000	City-level
		Large	10 000	Regional
		Extra-large	20 000	Global
	Mass gathering to block traffic	Small	150	Local
		Medium	1 500	City-level
		Large	10 000	Regional
		Extra-large	12 000	Global
	Gang violence	Small	200	Local
		Medium	2 000	City-level
		Large	10 000	Regional
		Extra-large	12 000	Global
	Riot	Small	300	Local
		Medium	3 000	City-level
		Large	12 000	Regional
		Extra-large	15 000	Global
Terrorist event	⋮	⋮	⋮	⋮

4.2 Design of task indicators for forces at all levels

Task indicators include the tasks that forces at all levels need to undertake, the types and levels of security events that can be controlled, and the arrival time, which are the basis of following evaluation of emergency force requirement [35].

The local force mainly focuses on early warning and response to small-scale events, with limited disposal capacity. The city-level force is the first-line early disposal force, with the ability to deal with small-scale and medium-scale events; the regional level is the main force for security event response, which can effectively deal with large-scale general mass events under its jurisdiction. Global force is the force that is used in the national scope. The task indicators of forces at all levels are shown in Table 4.

Table 4 Illustration of task indicators of forces at all levels

Force level	Arrival time/h
Local	1
City-level	2
Regional	4
Global	5

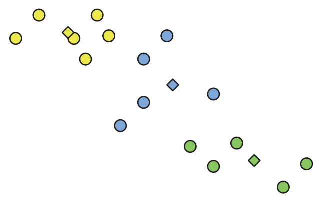
4.3 Algorithm of force deployment

The algorithm of force deployment is based on the above rules, and operational research to deploy and calculate the force quantity at all levels.

Step 1 Measure the quantity and location of local forces used in small-scale events over the next year.

(i) Import the location of small-scale social security events within the same city-level and find out the distance $k1$ of the two points with the largest distance among these event locations.

(ii) According to the task indicator of forces at all levels in Table 4, calculate n=k1/ (1-hour emergency distance of local force), divide these event positions into n classes by the K-means algorithm, and calculate n central positions. Then, the local emergency force can be allocated to these n positions in this city-level region to meet the demand of emergency range for dealing with small-scale events. When n =3, the deployment positions of local forces are shown in Fig. 3. To meet the arrival time requirements, the security event positions are divided into three categories, and forces are deployed in three positions respectively.



◇: Position of emergency force deployment;
○: Location of security event.

Fig. 3 Illustration of calculation of force deployment position based on event location

(iii) The force quantity of each local emergency force deployed at the city-level can be calculated according to Table 3.

Step 2 Calculate the quantity and location of city-level forces used for medium-scale events in the next year and supplement the local forces.

(i) Find out medium-scale events at locations where the local forces cannot reach within two hours. Conduct the first-step calculation on these events to determine the location and quantity of new city-level emergency force.

(ii) For the medium-scale events at locations where the local force can reach in two hours, first determine whether to choose a single unit or select force from each local unit when selecting the local force.

(iii) If it is selected from a single unit, the local forces that meet the conditions are sorted by distance or force quantity first. Sorting by the force quantity means that priority should be given to local forces with more quantity.

(iv) Check whether the current local force meets the medium-scale event task according to the relationship between event level and force usage. If the combined available forces of all alternative counties cannot meet the task requirement, additional forces are needed; the rule of force replenishment can be a proportional increase from alternative units and a prior increase of a single unit.

Step 3 Calculate the quantity and location of regional forces for large-scale events in the coming year and supplement the forces at the city and local levels.

(i) Find out large-scale events at locations where the local and city-level forces cannot reach within four hours. Conduct the first-step calculation on these events to determine the location and quantity of new regional emergency force.

(ii) For large-scale events at locations where local and city-level forces can reach within four hours, select a single unit or select by proportion from each subordinate level for the current task forces.

(iii) If selecting a single unit, determine the priority based on the distance, level (local, city-level, regional), or force quantity.

(iv) Check whether the current alternative force meets the large-scale event task requirement according to the relationship between event level and force usage. If the combined available forces of all alternative units cannot meet the task requirement, additional forces are needed; the rule of force replenishment can be a proportional increase from alternative units and a prior increase of a single unit.

Step 4 Calculate the quantity and location of global forces for extra-large-scale events in the coming year, and supplement the forces at the region, city, and local levels.

(i) Find out large-scale events at locations where the local, city-level, and regional forces cannot reach in five hours. Conduct the first-step calculation on these events to determine the location and quantity of new regional emergency force.

(ii) For extra-large-scale events at locations where local, city-level, and regional forces can reach within five hours, select a single unit or select by proportion from each subordinate level for the current task forces.

(iii) If selecting a single unit, determine the priority based on the distance, level (local, city-level, regional), or force quantity.

(iv) Check whether the current alternative force meets the task requirement according to the relationship between event level and force usage. If the combined available forces of all alternative units cannot meet the task requirement, additional forces are needed; the rule of force replenishment can be a proportional increase from alternative units and a prior increase of a single unit.

In this algorithm, there are a total of nine steps involving in priority options, which can be selected during the generation of the force deployment scheme.

5. Simulation evaluation of force deployment scheme

According to the combination of force quantity calculation rule, we get different force deployment schemes. The final scheme is determined by comparing the total task distance consumption and the force quantity of different schemes using the simulation experiment method.

The discrete event modeling method is used to conduct simulation experiments. The simulation system includes the input of social security events, input of force usage rules, the input of force task indicators at all levels, and selection of force quantity calculation rules, and the output includes the position of forces at all levels, force quantity, each task distance consumption, and force quantity. Fig. 4 shows the simulation flow chart of the force deployment scheme.

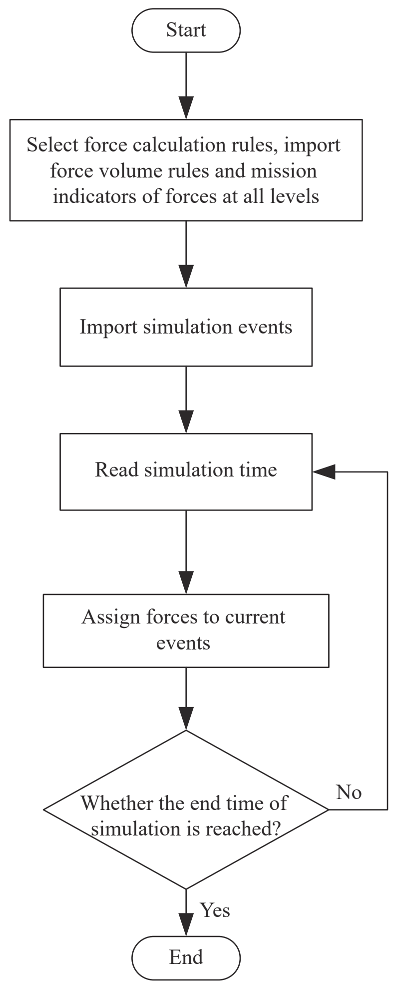


Fig. 4 Simulation flow chart of force deployment scheme

After the simulation, we do a statistical analysis of the force and the required distance and time of each task. The experimental results are shown in Table 5.

Table 5 Illustration of simulation results of a force deployment scheme

Result	Scheme 1	Scheme 2
Total distance time consumption/h	10000	19000
Total force	50000	45000
Total local force	20000	15000
Total city-level force	10000	10000
Total regional force	10000	10000
Average distance time consumption for small-scale events/h	0.7	0.8
Average distance time consumption for medium-scale events/h	1.8	1.6
Average distance time consumption for large-scale events/h	2.9	3.1
Average distance time consumption for extra-large-scale events/h	3.6	3.7

It can be seen from the design principle of the emergency force deployment scheme and the simulation experiment results that, if selecting the distance with less time consumption from the algorithm rule, the force quantity deployed will be larger and the economic cost will be higher. A combination of different rules can be used to get a quick response with less force. In addition, rules of different stages can be combined, or different rules can be selected for different regions. The scheme with fewer force allocated can be selected for the area with a low probability of security events, and the rule with less distance time consumed can be used for the area with a relatively high probability of security events so that the emergency force can quickly reach the event site and strive for the time to handle it.

6. Conclusions

Rapid response and effective disposal of social security events are important parts of national security in the new era. Studying the emergency force requirement is an important means to improve scientific and effective security construction and is also a frontier and new research field.

In this paper, focusing on the problem of estimating the requirement of emergency force for social security events, a calculation method combining event prediction, simulation deduction, and evaluation optimization is proposed, which is based on the neural network to predict the level of security events, form the standard scheme and alternative scheme of force deployment, and use simulation deduction method to evaluate and optimize the force measurement scheme. It is proved that this method can form a scientific and reasonable quantity and deployment of the emergency force.

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