Algorithm design and analysis of fire rescue problems

Mengshuang Fu*

College of materials science and engineering, Shandong University of Technology, Zibo 255049, China

*Corresponding author e-mail: fumengshuang@stu.shmtu.edu.cn

Abstract. With the rapid economic development, the urban space environment is becoming more and more complex, various accidents and disasters occur frequently, and safety risks are increasing. The rescue tasks involved in the fire brigade are showing a trend of diversification and complexity. The fire rescue team always puts the people first and insists on serving the people wholeheartedly. It is the guardian of maintaining social stability in our country and safeguarding the health and safety of people's lives and property and various disaster affairs. The society needs the participation in the fire rescue team. Aiming at the fire rescue problem, this paper uses the fire rescue call data onto 2016 to 2019 to predict the number of fire rescues / rescued calls based on the difference equation to improve the rescue efficiency of the fire brigade. Taking into account the impact on the domestic epidemic in 2020 on people's lives, the adjustment value was introduced to adjust part of the alarm data onto 2020 to ensure the accuracy and reliability of the data. Finally, the second-order difference equation is used to predict the alarm data onto 2021 through the least square method, which verifies the accuracy of the model.

Keywords: difference equation, predictive model, fire fighting, rescue.

1. Introduction
With the rapid development of China's social and economic progress, the speed of urbanization in China is accelerating, and the frequency of fire accidents is increasing. As the fire brigade, which is the first unit responsible for safeguarding people's lives and property, preventing fires and providing rapid rescue and rescue, it has taken on an important responsibility, which makes the rescue work of the fire brigade a huge challenge and also makes the number of rescue calls by the fire brigade more and more frequent. It is therefore essential to make forecasts based on the number of police calls over the years.
2. Model building and solving

2.1. Description of symbols

Table 1. Description of symbols

| Symbols | Significance | Unit |
|---------|--------------|------|
| \( \lambda \) | Value of condition changes | |
| \( \beta_{mn} \) | Year \( m \) | Year \( n \) | Number of fire calls for the month | times |
| \( \beta_{rn} \) | 2020 \( n \) | Number of fire calls for the month | times |
| \( \beta_{rn} \) | Adjusted number of fire calls by month | times |

2.2. Model building

By numbering the months from January 2016 to December 2021 as \( t=1,2,\ldots,72 \), you can set the number of fire calls in month \( t \) as \( y_t \).

Based on the data in Appendix 2, a predictive model was developed using MATLAB software using difference equations.

A predictive model is constructed using a first-order difference equation that

\[
y_t = a_1 y_{t-12} + a_2.
\]

A predictive model was constructed using a second-order difference equation that

\[
y_t = a_1 y_{t-12} + a_2 y_{t-24} + a_3.
\]

A predictive model was constructed using a third-order difference equation that

\[
y_t = a_1 y_{t-12} + a_2 y_{t-24} + a_3 y_{t-36} + a_4.
\]

The three detection models derived from ① were used to calculate the number of fire calls for each month in 2020 and to test the accuracy of the models compared to the adjusted actual data.

Based on the final model of ②, the number of fire calls is predicted for each month in 2021.

2.3. Solving the model

Here, we first adjust the data for the 2020 part of the year. Since the outbreak of the domestic epidemic in January 2020, the spread of the epidemic was largely controlled in roughly July of that year. Socio-economic normalcy has largely returned and people are getting out of their homes and getting some fresh air. During this period, people stayed at home to fight the epidemic and did not go outside easily, and it is reasonable to assume that this is the reason for the steep drop in fire calls in 2020 in the annexed data. Therefore, we have adjusted the deviation values for January-July 2020 data and left August-December unchanged. Based on the idea of linear interpolation, the adjusted values are set to \( \lambda \), \( n=2016,2017,2018,2019, f=1,2,3,\ldots,12 \)

\[
\lambda_m = \frac{\sum_{m=2016}^{2019}(\beta_{mn} - \beta_{rn})}{4}
\]

The adjusted values are \( \tilde{\beta}_{rn} \) (as shown in Table 1), the \( \tilde{\beta}_{rn} = \beta_{rn} + \lambda_m \)

Table 1. Actual vs. adjusted (2020') number of police trips by month, 2016-2020

| month year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|------------|---|---|---|---|---|---|---|---|---|----|----|----|
| 2016       | 79| 95| 98| 51| 275| 67| 63| 40| 31| 38| 43 |
| 2017       | 58| 28| 44| 14| 148| 87| 23| 42| 49| 33| 65| 68 |
| 2018       | 54| 129| 68| 71| 107| 119| 59| 50| 46| 44| 40| 63 |
| 2019       | 67| 76| 73| 44| 138| 146| 72| 30| 41| 26| 35| 36 |
| 2020       | 28| 23| 28| 46| 62| 55| 25| 29| 36| 25| 51| 62 |
| 2020'      | 65| 82| 71| 45| 167| 105| 54| 29| 36| 25| 51| 62 |
As an example, take the second order difference equation and ask for $a_1$, $a_2$, $a_3$, calculate the sum of squares of the residuals of.

$$Q(a_1, a_2, a_3) = \sum_{t=1}^{48} [y_t - (a_1 y_{t-12} + a_2 y_{t-24} + a_3)]^2$$

The smaller the $Q$, the more accurate and stable the prediction model.

Using the Matlab software difference equation, it can be found that

$$a_1 = z(1) = 0.1520, a_2 = z(2) = -0.0478, and a_3 = z(3) = 32.7502$$

$$y_t = 0.8683 y_{t-12} - 0.4647 y_{t-24} - 22.5239$$

(a) The following are some of the most important features of the new system:

Similarly, using a first-order difference equation prediction model, it is obtained that

$$y_t = 1.0631 y_{t-12} - 10.8036$$

and

Using a third order differential equation prediction model, this gives

$$y_t = 0.8186 y_{t-12} + 0.3767 y_{t-24} + 0.0741 y_{t-36} - 19.9197$$

The results of the predicted number of fire calls for each month in 2020 based on the above equations are shown in Table 3.

Table 2 Comparison of the actual number of police trips with the forecast for 2020

| Month    | Number of times adjusted to account for deviations | Number of first-order model predictions | Number of second order model predictions | Number of third-order model predictions |
|----------|---------------------------------------------------|----------------------------------------|-----------------------------------------|----------------------------------------|
| January  | 65                                                | 60                                     | 61                                      | 60                                     |
| February | 82                                                | 70                                     | 103                                     | 93                                     |
| March    | 71                                                | 67                                     | 72                                      | 69                                     |
| April    | 45                                                | 36                                     | 49                                      | 44                                     |
| May      | 167                                               | 136                                    | 147                                     | 144                                    |
| June     | 105                                               | 144                                    | 160                                     | 151                                    |
| July     | 54                                                | 66                                     | 67                                      | 63                                     |
| August   | 29                                                | 21                                     | 27                                      | 27                                     |
| September| 36                                                | 33                                     | 34                                      | 35                                     |
| October  | 25                                                | 17                                     | 20                                      | 20                                     |
| November | 51                                                | 16                                     | 18                                      | 20                                     |
| December | 62                                                | 27                                     | 38                                      | 38                                     |

We compared the data in Table 3 through images to make it more visual, as shown in Figure 2 below.

Fig. 1 Folding line diagram comparing first, second and third order models with the actual situation
By calculating the sum of squared residuals, the second-order prediction model is relatively accurate and stable, i.e.

\[ y_t = 0.8683y_{t-12} - 0.4647y_{t-24} - 22.5239 \]

After the above tests, the second order difference equation model was the most accurate, so we predicted the number of fire situations for 2021 by using the fire call data for each month from 2016-2019 and adjusted for deviation values for 2020. The final predicted number of fire calls for each month in 2021 is shown in Table 4.

**Table 3** Forecasted police attendance for each month in 2021

| Month | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|-------|---|---|---|---|---|---|---|---|---|----|----|----|
| Forecast (times) | 61 | 103 | 72 | 49 | 147 | 160 | 67 | 30 | 34 | 20 | 18 | 38 |

### 3. Conclusion

In this paper, we use a difference equation prediction model for the number of fire and rescue calls, while taking into account the impact of the domestic epidemic outbreak on people's lives in 2020, the number of calls in 2020 deviates significantly from previous years, so we introduce adjustment values to adjust some of the calls in 2020, increasing the accuracy and reliability of the final data. Finally, the accuracy of the model was verified by least squares, and the number of police calls in 2021 was predicted using a second order difference equation. Based on the predicted values we can make reasonable arrangements for firefighters to maximise staff utilisation.

### References

[1] HongGuang Zhang, ZiHan Liang, HuaJian Liu, Rui Wang, YuanAn Liu. Ensemble framework by using nature inspired algorithms for the early-stage forest fire rescue - A case study of dynamic optimization problems [J]. Engineering Applications of Artificial Intelligence, 2020, 90:

[2] M I Ramli, H Yatmar, M Pasra. An optimum route analysis of fire rescue according to fire station location (Case study: Residence area in Makassar's central business district) [J]. IOP Conference Series: Earth and Environmental Science, 2019, 235(1):

[3] Božović Marijola, Živković Snežana, Mihajlović Emina. Integrated system of occupational safety and health and fire protection of the fire rescue brigades members. [J]. International journal of injury control and safety promotion, 2018, 25(2):

[4] Marijola Božović, Snežana Živković, Emina Mihajlović. Integrated system of occupational safety and health and fire protection of the fire rescue brigades members [J]. International Journal of Injury Control and Safety Promotion, 2018, 25(2):

[5] Aleksandrs Politika, Māris Ziemelis, Inese Vilcāne, Vladimirs Jemeljanovs, Valentina Urbāne. Problems and Solutions in Technical Capabilities of State Fire and Rescue Service [J]. Safety of Technogenic Environment, 2017, 8(1):

[6] Jian Wang, Han Liu, Shi An, Na Cui. A new partial coverage locating model for cooperative fire services [J]. Information Sciences, 2016, 373:

[7] Feng He, Rui Chun He, Sheng Nan Sun, Jiong Di Chen. Research on the Model of Emergency Fire Rescue Vehicle Routing Selection and Resource Allocation [J]. Applied Mechanics and Materials, 2014, 3488:

[8] Dowdall-Thomae Cynthia, Culliney Sean, Piechura Jeff. Peer Support Action Plan: Northwest Fire and Rescue. [J]. International journal of emergency mental health, 2009, 11(3):

[9] B. Kardels, K.H. Beine. Problem awareness and support - Stress and posttraumatic stress disorder in fire brigades and in rescue organizations [J]. Notfall & Hausarztmedizin, 2006, 33(1):

[10] Kardels B., Beine K.H.. Problem awareness and support - Stress and posttraumatic stress disorder in fire brigades and in rescue organizations [J]. Notfall & Hausarztmedizin, 2006, 33(01):