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Opioid ED-DT Propagation Model based on Linear Programming

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Abstract: In this paper, based on the national crisis of opioids in the United States, a communication model based on the influence degree and drug recognition threshold level was established, and the possible development trend of opioids was successfully predicted, and the effectiveness of the strategy against opioid crisis was tested. The boundaries of the parameters it depends on.

Keywords: Principal component analysis; 0-1 distribution; Influence degree; Sensitivity analysis

1. Introduction

The United States is experiencing a second national crisis on opioids, and the number of opioid deaths in the United States has exceeded the combined number of deaths from shooting and traffic accidents. In cases of death from excessive drug use, more than half of the deaths were caused by opioids. The US Centers for Disease Control is fighting the opioid overdose epidemic to save lives and prevent the negative health effects of the epidemic.

2. Establish a Propagation Model

To describe the spread of synthetic opioids and heroin incidents between five states and states, between counties in each state. We set up the ED-DT propagation model to analyze, ED represents the degree of influence, DT represents the drug recognition threshold level, with the impact degree as an important indicator of measurement. The incidence of opioid crime will spread with the movement of the population, and the spread will gradually weaken with the increase of distance and the growth of time.

We define the propagation index as a variable of the degree of influence, the propagation index of a particular opioid in a state (county):

$$S_{ci}=\frac{m_i n_i}{m_{total} n_{total}} \tag{1}$$

Define another variable associated with the impact degree as the selection probability,

$$\mathrm{P}=\frac{m_j}{m_{total}-\sum_{i=1}^{n} m_i} \tag{2}$$

The standard impact degree $e_{ij}^{*}=\frac{s_{ci}\times p}{d_{ij}}$, that is, the impact of the high crime rate State (county) on its surrounding states (counties).

The degree of impact $e_{ij=}e_{ij}^{*}\times\Delta t=\frac{s_{ci}\times p}{d_{ij}}\times\Delta t$, Δt is the time experienced. As time goes by, the high crime rate of the state (county) has a deeper influence on the j state (county) around it.

In actual circumstances, state (county) cannot be affected only by one state (county) of state (county), so we modify the degree of influence and the influence of state (county):

$$e_j=\sum_{i=1}^{n} e_{ij} \tag{3}$$

The spread of any type of opioid case meets the impact index. We take the heroin incident as an example to analyze the spread between states (counties), as shown in Figure 1

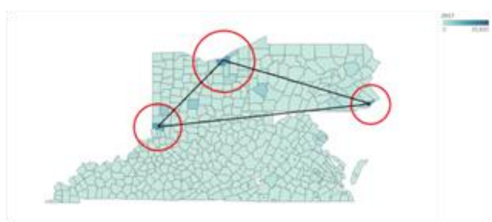

Figure 1. The spread of heroin incidents

In the picture, as the color deepens, it represents an increasing number of cases of crime in the county as a result of excessive heroin use. In the analysis of the dissemination process, we use the latest state for analysis, that is, to predict the possible location of a particular type

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of opioid drug in the 2018, we only study the 2017 data, regardless of previous years of data.

The impact of high crime counties on other surrounding counties is circular diffusion, the closer to the high crime rate counties, then the probability of being affected and transmitted is higher, and the farther away, the less likely to be affected. As shown in Figure 7, we selected three representative high-crime cities for analysis, except in the circular affected areas around the city, where the probability of being affected is extremely high in the enclosed area of the three connections.

If the patterns and features we have identified continue to exist, there will be a sense of crisis in the US government, a fear of the size and quality of the US workforce, a worrying economic burden of growth, a lack of important positions in important parts of the United States, and so on.

3. Determination of Drug Recognition Threshold Level

The degree of influence we have identified in the above model is：

$$e_j=\sum_{i=1}^{n}e_{ij}=\sum_{i=1}^{n}\frac{S_{ci}\times P}{d_{ij}}\times\Delta t \qquad (4)$$

The threshold level of the drug:

$$\frac{e_j}{P\Delta t}=\frac{\sum_{i=1}^{n}S_{ci}}{d_{ij}} \qquad (5)$$

Because there is a j state (county) that affects the n states (counties), the distance between two states (counties) must have a minimum value $[d_{ij}]_{min}$, a maximum value $[d_{ij}]_{max}$, There is a range interval for $\frac{e_j}{P\Delta t}$, that is,

$$\frac{\sum_{i=1}^{n}S_{ci}}{[d_{ij}]_{max}}\le\frac{\sum_{i=1}^{n}S_{ci}}{d_{ij}}\le\frac{\sum_{i=1}^{n}S_{ci}}{[d_{ij}]_{min}} \qquad (6)$$

To determine the approximate location of a particular opioid that is specifically used in five states, we compare this threshold with the specified threshold we have obtained, divided into the following three scenarios:

$$\begin{cases}\frac{\sum_{i=1}^{n}S_{ci}}{[d_{ij}]_{max}}\ge\frac{e_j}{P\Delta t}\\ \frac{\sum_{i=1}^{n}S_{ci}}{[d_{ij}]_{min}}\le\frac{e_j}{P\Delta t}\\ \frac{\sum_{i=1}^{n}S_{ci}}{[d_{ij}]_{max}}\le\frac{e_j}{P\Delta t}\le\frac{\sum_{i=1}^{n}S_{ci}}{[d_{ij}]_{min}}\end{cases} \qquad (7)$$

When the maximum value of the threshold is less than or equal to the specified threshold we have obtained, the specific opioid is not starting to be used in the state (county), and when the maximum value of the threshold is greater than or equal to the specified threshold we have obtained, it is stated that the particular opioid has been used in the state (county) ; If the specified threshold we are seeking is between the maximum and minimum values of the threshold, a statistic needs to be constructed to determine. Analogy 0-1 distribution, construct the following statistics.

Making $\Delta 1=\frac{e_j}{P\Delta t}-\frac{\sum_{i=1}^{n}S_{ci}}{[d_{ij}]_{max}}$, $\Delta 2=\frac{\sum_{i=1}^{n}S_{ci}}{[d_{ij}]_{min}}-\frac{e_j}{P\Delta t}$, The amount of statistics we construct is $\frac{\frac{\Delta 2}{\Delta 1}-1}{\sqrt{0.5\times 0.5}}$, when $\frac{\frac{\Delta 2}{\Delta 1}-1}{\sqrt{0.5\times 0.5}}\ge 1$, we can think that this particular opioid has begun to be used in the state (county).

Taking heroin as an example to determine any possible location where heroin has begun to be used, using the above model to determine a specific threshold, followed by an analysis of heroin, we identified 215 counties where heroin might begin to be used, as shown in Figure 2.

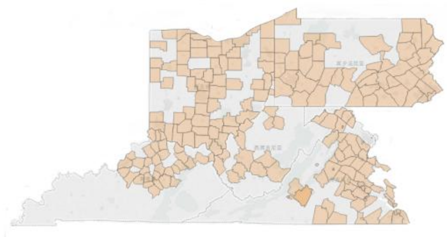

Figure 2. Possible county locations to start using heroin

Under the premise of determining the drug identification threshold level e_0, calculate the standardization degree of influence e^* in the feasible domain, and calculate the of the county to reach the drug identification threshold by calculating the following formula, that is:

$$\Delta t=\frac{e_0}{e^*} \qquad (8)$$

When $\Delta t\ge 1$, It is believed that the use of specific opioids will occur in this area after .

When $\Delta t<1$, It is believed that the use of specific opioids has occurred in this area.

4. Looking for Important Factors Driving the Growth of Opioid Use and Addiction

First, the social and economic data provided by the United States Census in the annex are preprocessed, the invalid data is deleted, the missing value is removed, and the redundant data is deleted. In the first part of the analysis of the problem, we found that in each of the year there will always be several counties due to excessive use of opioids resulting in higher crime rates, such as Hamilton County and Philadelphia County.

When analyzing the annual data, select several counties with higher crime rates for the year and average the variables in these counties. Then the remaining counties are also summed up to take the average process, and eventually the 461 counties into two different situations to compare the mean values of their variables.

By taking care, select variables with larger gaps, because the greater the gap between high-crime cities and ordinary cities, suggests that it is likely that these indicators led to an increase in opioid use addiction, and eventually we extracted a total of 34 variables.

Then we treat these 34 variables in descending dimension, and the principal component is extracted by principal component analysis method. The resulting gravel map is shown in Figure 3.

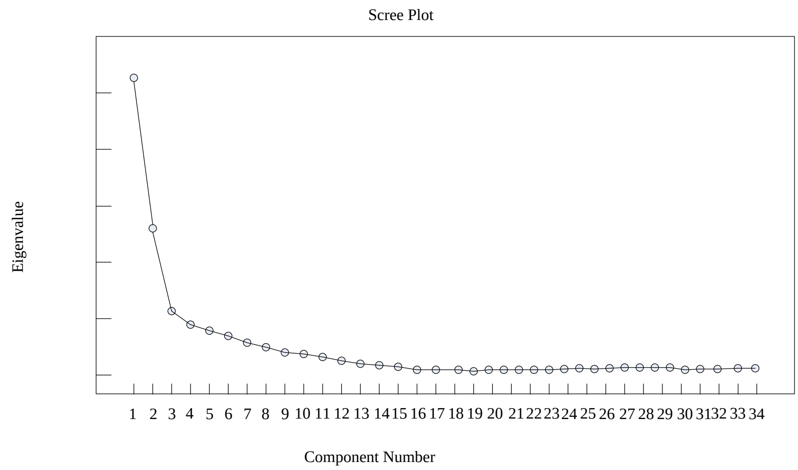

Figure 3. Main component gravel diagram

Eight main components were extracted, that is, in the socio-economic data of the United States Census, these eight principal components have a great impact on promoting opioid use and addiction growth.

We use the proportion of the eigenvalue of each principal component as the weight of the variable to modify the model in the first part.

In the model established in the first part, the impact degree is $e_{ij}=\sum_{i=1}^{n}\frac{s_{ci}\times p}{d_{ij}}\times\Delta t$.

Now we know that these eight variables have a certain impact on the increase in crime rates due to the excessive use of opioids, so we have improved the impact model established in the first part:

$$e_{ij}=\sum_{i=1}^{n}\frac{s_{ci}\times p}{d_{ij}}\times\Delta t+\sum_{k=1}^{8}W_kF_k \tag{10}$$

$$F_i=\sum_{j=1}^{32}u_{ji}\cdot x_j \tag{11}$$

Where u_{ji} is the element of column J of the eigenvectors Matrix, and the elements of the n columns.

Where F_k is the eight variables affected, and W_k is the weight corresponding to each of the eight variables. $W_1=0.40$, $W_2=0.20$, $W_3=0.11$, $W_4=0.08$, $W_5=0.07$, $W_6=0.05$, $W_7=0.05$, $W_8=0.04$.

The eight socio-economic variables that influence the impact can be divided into three types: family background, education level, and number of immigrants in the region and the variables controlled by these three types are shown in table 1.

Table 1. Socio-economic factors

Socio-economic type	variable
Family background	F_1、F_2、F_3、F_5
Education level	F_4、F_6
Immigration in the area	F_7、F_8

Because of the uncertainty affecting opioid variables, there is still a known risk of opioid use.

5. The Following Suggestions are Made to Combat the Opioid Crisis:

Using the model established above, we propose the following suggestions for combating the opioid crisis:

Research on data. When there are many crime cases in a certain county, the US government should also strengthen the crackdown on the counties that may be spread around the county.

Investigate the checkpoints between the state and the state, county and county, and reduce the impact on the surrounding counties as much as possible.

Governments and local officials should care more about the people, formulate policies related to the public or special family preferences, and increase the public's happiness.

Promote higher education and maximize the education of the population in the region.

The number of immigrants in a region within one year should be controlled, and the background of immigrants should be strictly investigated.

In the model, the degree of influence on the surrounding area is reduced, and the weight of each socio-economic factor in the impact model is reduced to curb the use and growth of opioids.

However, the adjustment of the weight should also have a degree. After this degree, the validity of the policy may identify failure. When we use the determined threshold to calculate the limit of a certain variable, we control the weight of other parameters unchanged. Based on this, the adjustment range of each factor weight is obtained, as shown in Table 2.

Table 2. Table of weight variation ranges of each parameter

Weight corresponding to each variable	Initial weight	Threshold minimum	Threshold maximum
w_1	0.4	8.98	10.04
w_2	0.2	8.82	10.2
w_3	0.11	8.91	9.13
w_4	0.08	8.94	9.1
w_5	0.07	8.95	9.09
w_6	0.05	8.97	9.07
w_7	0.05	8.97	9.07
w_8	0.04	8.98	9.06

6. Inconclusion

The model is derived under theoretical derivation and can guarantee theoretical correctness. By reducing the degree of influence to be calculated in an interval, the model reduces the number of times the distance between states is sought, thereby reducing the time complexity.

References

[1] Mo Huanmin. Mathematical model of virus propagation. Journal of Engineering Mathematics. 2003, 20 (08), 45-48.

[2] Sun Li. Opioid abuse in the united states and its control measures. China Journal of Drug Abuse Control. 2018, 24 (04), 219-224.

[3] Wang Jie, Li June, Su Senyi, Korean Army. A summary of opioid abuse prevention. Chinese Journal of Biochemical Drugs. 2015, 35 (07), 178-181.

[4] Rudd, Rose A, Aleshire, Noah, Zibbell, Jon E, Gladden, R Matthew. Increases in drug and opioid overdose deaths - united states. 2000-2014. MMWR. Morbidity and Mortality Weekly Report. 2016, 64(50/51).

[5] Romesh P. Nalliah. Opioid abuse and dependence in those hospitalized due to head and neck cancers. Journal of Oral and Maxillofacial Surgery. 2018