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Analysis and Countermeasures of the Opioid Crisis in the United States

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ABSTRACT. *In recent years, opioid abuse has become one of the most severe social events in the United States. The number of deaths caused by opioid overdose in the United States has exceeded that of deaths caused by traffic accidents that led to the economic loss as high as 78.5 billion dollars. The opioid crisis has seriously hindered the socio-economic development of the United States, posing a great threat to the lives of the American people. Therefore, the most direct and scientific way to solve the opioid crisis is to study the factors that cause opioid abuse and formulate policies to prevent it. The paper establishes the discrete image model, the entropy model, the time series prediction model and the regression model and uses MATLAB, SPSS, Excel and other software, so as to formulate the strategies to prevent opioid abuse and conduct the test of their effectiveness.*

KEYWORDS: *MATLAB, ArcGis, entropy model, weight value*

1. Data Analysis

According to the data provided by NFLIS, the States, the Names of the Substances and the Total Drug Reports of Each State are taken as the statistical indexes, and the correlation between the indexes is analyzed through the method of Frequency Distribution Analysis. With the help of Excel, the data are analyzed and the drugs distribution frequency of each state is represented in the bar chart as Figure 1 shows. According to the references, the synthetic opioid drugs can be identified as Methadone, Pentazoc Ine, and Pethidine as well as Tramadol, Fentanyl and the derivatives of Fentanyl[1]. In the analysis, the total number of the reported synthetic opioid and heroin incidents were jointly counted and represented in Figure 1.

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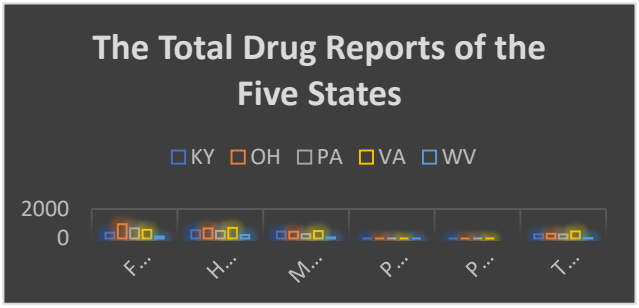

Fig. 1 The total number of the reported synthetic opioid and heroin incidents

According to Figure 1 and the overall distribution frequency of drug incidents of each type in the states represented, the characteristics of the drug distribution in the five states are evaluated, and the state of the drug distribution can be an evaluation index[2]. The ranking of the drug distribution level from the highest to the lowest is Ohio, Virginia, Kentucky, West Virginia, Pennsylvania, and is represented in the map of the United States of America as Picture 2 shows, indicating the extent with the depth of the color, that is to say, the darker the color, the higher the distribution level, and vice versa.

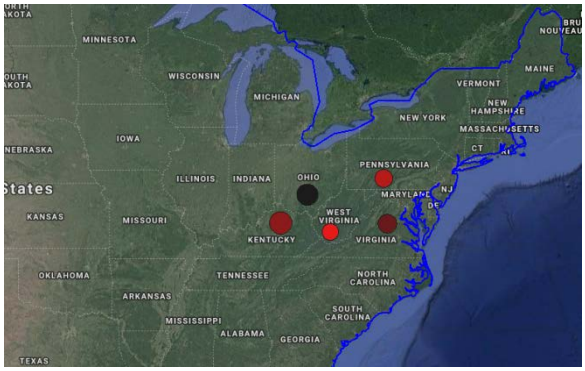

Fig. 2 The map of the United States of America

2. Establishment of Discrete Model

According to the factors including Drug Reports, County Total Drug Reports and State Total Drug Reports provided by NFLIS to construct the Discrete Model, the Distribution Diagram of Three-Dimensional Space of the overall distribution of drug reports in five states and their counties are drawn by SPSS software.

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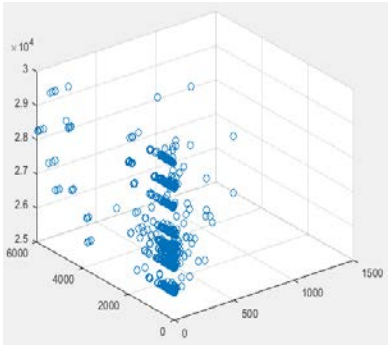

Fig. 3 KY

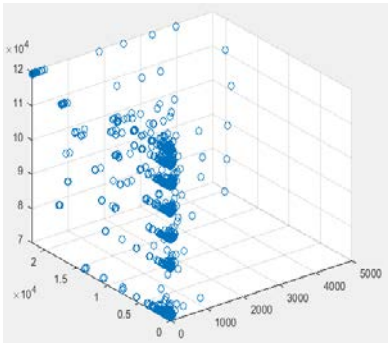

Fig. 4 OH

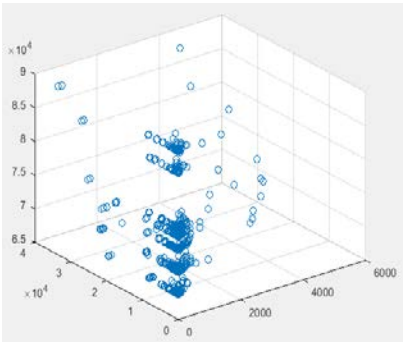

Fig. 5PA

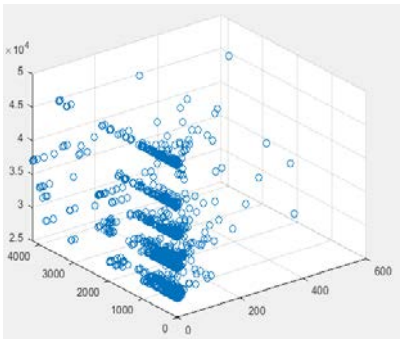

Fig. 6VA

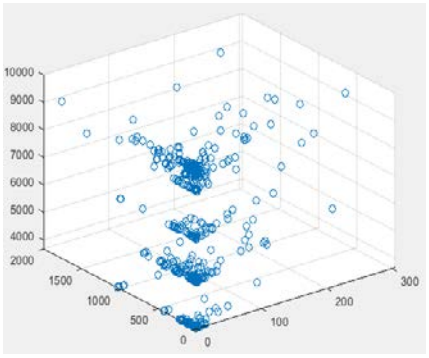

Fig. 7 WV

Through the analysis of the overall distribution of drug reports in the five states and their counties, it can be concluded that their distribution is concentrated in KY and PA, and dispersed in OH, VA, and WV[3]. The number of county drug reports in

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the other four states except WV, ranges mostly between 1000 and 2000, while that of county drug reports in WV, does between 0 and 1000. The number of state drug reports in KY, OH, and VA is fairly evenly distributed, while that of state drug reports in PA and WV is not partially missed. According to the previous analysis, the frequency corresponding to different intervals and the changes in the number of drug incidents can reflect the spread and characteristics of drug use in each state[4-5].

2. Establishment of Entropy Model

In the information theory, entropy can measure uncertainty, and the value of entropy depends on the amount of information. According to the results of entropy, the randomness and disorder of events can be evaluated, and the indicators can also be evaluated by the degree of dispersion. By establishing the Entropy Model, the correlation between the opioid-related cases and their locations (five states and their counties) can be obtained, and the places where specific opioids have stated in each states can be determined.

Assume that n is the county's code, m the name of the drug, then x_{ij} is the value of the *j-th* drug of the *i-th* county.*(i=1,2,⋯, n, j=1,2,⋯,m);*

1) The proportion(p_{ij})of the *j-th* drug among those drugs in the *i-th* county can be represented as follows:

$$p_{ij} = \frac{X_{ij}}{\sum_{i=1}^{n} X_{ij}}, \ (i = 1, \ 2....., n, \ j = 1, \ 2....., m);$$

2) The Entropy values of the $i\text{-}th$ county are as follows:

$$e_i = -k\sum_{j=1}^{n} p_{ij} \ln(p_{ij}) \quad \text{,plus } k > 0, \ \ k = 1/\ln(n) \ \ e_i \geq 0;$$

3) The Coefficient of difference for the $i\text{-}th$ county is as follows:

$$g_i = \frac{1 - e_i}{m - E_e}, \quad E_e = \sum_{i=1}^{m} e_i, \quad 0 \leq g_i \leq 1, \quad \sum_{i=1}^{m} g_i = 1;$$

4) The Weights can be represented as follows:

$$w_i = \frac{g_i}{\sum_{i=1}^{m} g_j}, \qquad (1 \leq i \leq m).$$

4. Solution of the Models

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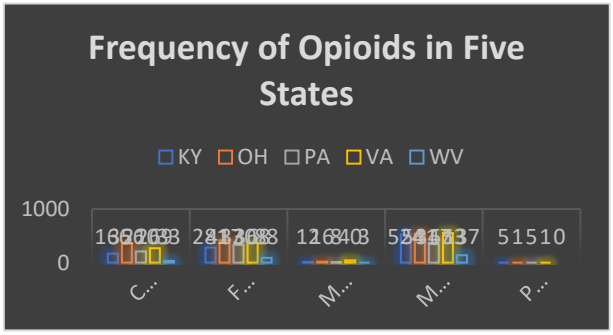

Fig. 8 The opioids include Codeine, Fentanyl, Morphine, Meperidine and Pethidine with the much consulting of the related materials and literature

As shown in Figure 8, the opioids include Codeine, Fentanyl, Morphine, Meperidine and Pethidine with the much consulting of the related materials and literature. Before using the entropy method to solve the problem, the frequency of the number of specific opioid reports in the states is carried out and the histogram of its frequency is drawn by Excel software. By observing the histogram, it can be concluded that the great demand for Codeine, Fentanyl and Morphine, is discovered in the states, KY, OH, PA, and VA, while the small demand for Meperidine and Pethidine is done in all states.

Taking the state and county codes, the names of the five drugs selected, the County Total Count of all Substances Identified provided by the NFLIS as the statistical indicators, and the frequency of state and county codes as the general rule of the selection, the counties with the largest number of opioid incidents are found out. The statistical data are shown in Table 1.

Table 1

FIPS_Combined	Codeine	Fentanyl	Meperidine	Morphine	Pethidine	Total Drug Reports County
21111	38865	38865	8471	38865	5426	130492
39049	59915	54412	23994	59915	0	198236
42101	187314	187314	125119	187314	0	687061
51087	12658	12658	2486	12658	0	40460
54039	7360	4387	1790	6877	0	20414

To get the proportion of the *j-th* drugs in the *i-th* county firstly requires the total sum of each of the columns (as Table 2 shows), and then the results of the value of

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each row compared to each total sum of the columns to form a new matrix (shown as Table 3).

Table 2

SUM	306112	297636	161860	305629	5426

Table 3

P matrix(The original matrix)	0.648668948	0.714272587	0.353046595	0.648668948	1
	0.195729014	0.182813907	0.148239219	0.196038334	0
	0.611913287	0.629339193	0.773007537	0.612880322	0
	0.041350878	0.042528458	0.015358952	0.041416227	0
SUM	0.024043487	0.01473948	0.01105894	0.022501137	0

Turn each element of the previously generated matrix into the product of each element with the ln, as shown in Table 4.

Table 4

P matrix(The new matrix)	-0.281	-0.24	-0.368	-0.281	0
	-0.319	-0.311	-0.283	-0.319	0
	-0.3	-0.291	-0.199	-0.3	0
	-0.13	-0.135	-0.06	-0.13	0
	-0.09	-0.06	-0.05	-0.087	0
SUM	-1.12	-1.037	-0.96	-1.117	0

Work out the constant *k*,*k=1/1n(quantity)* and k=0.6215.And then work out the product of the total sum of each column with the new matrix, so, the five products obtained are the proportion of the *j-th* drugs in the *i-th* county. Now, all values of E_j are worked out. With d_j as the degree of consistency of the contribution of each scheme of the *j-th* attribute, Since $d_j=1-E_j$, d_j can be obtained with the value of E_j.

Table 5

Ej	0.69608	0.6444955	0.59664	0.6942155	0
Dj	0.30392	0.3555045	0.40336	0.3057845	1
Wj	0.128313762	0.150092524	0.170296918	0.129100947	0.422195849

Each weight is the quotient of corresponding d_j divided by the total sum of d_j as the following formula of: $W_j = \frac{d_j}{\sum d_j}$.

Plus, d_j *=2.368569* thus, the weights can be obtained are 0.13, 0.15, 0.17, 0.13, 0.42. So, the first counties in the five states that started using opioids are: Jefferson (KY), Franklin (OH), Philadelphia (PA), Henrico (VA), Kanawha (WV).

Here, frequency distribution analysis is conducted on the data provided by

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NFLIS, and the plane distribution image is drawn by ArcGis to evaluate the spread and characteristics of drug misuse in the five states. The discrete image analysis model is established to construct a three-dimensional spatial distribution diagram and analyze the trend of specific opioids.Then the entropy model is established to obtain the weight value and the correlation between the number of drug reports and the counties.

5. Strategies for Countering the Opioid Crisis

1)Amending the relevant laws and regulations and strengthening the opioid management; 2) Supervising specific opioids for different age groups at the different levels; 3) With the education on preventing opioid misuse provided, citizens have a deeper understanding of the harm of opioids because opioid misuse is closely related to the factors, such as place of birth, residence 1 year ago, relationship, and language spoken at home, according to the data analysis;4) Strictly standardizing the procedures for prescribing the relevant drugs and eradicating the illicit channels for opioids; 5) Strengthening professional training and public health education, and providing scientific and comprehensive treatment for patients with addiction.

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