Description, Analysis, Forecasting, and Evaluation of Opioids' Spread

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Abstract: We build a Drug Spread Model to describe the spread path of top-ten popular drugs. Firstly, we operate on the data to select the top-ten drugs with the total cases over 5000 between 2010 and 2017. We also collect data about each drugs' use cases in each county. Next we find each county's adjacent regions to construct the adjacency matrix. After that we make the drugs' spread principles which help to determine the each drug's birthplace and which counties are more easily to be affected. Finally we use the Depth-first algorithm to find the spread path and obtain possible locations where the ten drugs use might have started in the five states.

To predict the drug identification threshold levels, we calculate ratio of the number of cases of heroin use per year (call it NH) in each county to the total number of drugs use incidents (call it TN) in these places to find the regulation. We regard the ratio (NH) of infected counties as the standard for evaluating the threshold of drugs. Take heroin as an example we find that its identification threshold levels is 0.15. Then we build a Prediction Model based on the Gray prediction algorithm to find where and when the drug use will breakthrough the threshold. In order to find what contributes significantly to the growth in opioids use and addiction, we build an Influencing Factors of Drug Use Model based on the Analytic Hierarchy Process and the data provided by the U.S. Census Bureau. During this process we take 5 factors: PIH, MYO/FYO, PAE, TOP, PAO (Their meaning can be found in the "Notation" part) into consideration and finally obtain the separated weights for each factor.

1. Introduction

Opioids are important drugs and they have many positive impacts. Due to its powerful effects on relieving pain, opioids are often used in medical community. But there are also many illegal trades in the world for recreational purposes. Nowadays, the illegal opioids trades and some drug abuse dramatically endanger people's safety and destroy social stability. We build a Drug Spread Model to describe the spread path of some popular drugs, and we also clearly show the spread path with colorful pictures. Then we use the ratio of the number of cases about a drug use per year to the total number of drugs use incidents in counties to find the threshold level (as for heroin, the threshold is approximately 0.15).Next, we build a Prediction Model based on the Gray prediction algorithm to find where and when the drug use will breakthrough the threshold. In order to find what contributes a lot to the increase in opioid use and addiction, we build an Influencing Factors of Drug Use Model based on the Analytic Hierarchy Process and the data provided by the U.S. Census Bureau. During this process we take 5 factors into consideration and finally obtain the separated weights for each factor.

We make some general assumptions to simplify our model. These assumptions together with corresponding justification are listed below:(1)A county suffered by infectious illness may lead to the massive use of a certain kind of drug. Meanwhile, the dangerous illness is likely to infect the adjacent counties, which may lift the use of the drug in the surrounding area too.(2)Every year each state has many counties use a certain kind of drug, and it is easy to find out that the county with the most uses of the drug has the strongest power to infect other locations.(3)We consider the area is infected, if the number of drugs used in the area suddenly rises in a year. And in order to improve the accuracy of our model, we choose the first two counties with the largest growth as infected

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regions.(4)As we discussed above, a county suffered by illness has the ability to spread the virus to its neighbors.

2. Drug Spread Model

To discuss the spread and characteristics of synthetic opioids and heroin cases in the five states and their counties, we select information about drug cases from the NFLIS data, calculate the total count of the indicated substance from 2010 to 2017 in five states and sort them according to the number of incidents. To reduce the amount of calculation, we only consider the top-ten drugs with the total cases over 5000 between 2010 and 2017, since they have contributed more than 50.8% of the total synthetic opioids and heroin cases in the five states. To simply our model, for a type of drug, we consider the city with the most cases and the largest number of cases as the source of infection. We also find the adjacency between each county via google map[1]. In order to find this drug's spread path, we take the location and the increase of incidents between two years into consideration, which means the surrounding areas with the great increase in drug use are considered being infected. We use the Depth-first search algorithm to find the spread and characteristics of the top-ten drugs.

2.1. Judgement Process

Our model aims to find the top-ten drugs' spread path and their characteristics, and we will take herion for example to explain the process of modeling. Basically, we divide the modeling process in to three stages: Firstly, we consider the county which use herion first and with the largest amount as the birthplace and it has the ability to affect the nearby region. Secondly, in the next year, we believe the top-two surrounding counties with the largest increase in the use of herion is infected. Finally, we use Depth-first search algorithm to conduct the spread of herion, the modeling process of our Drug Spread Model is shown in Figure 1.

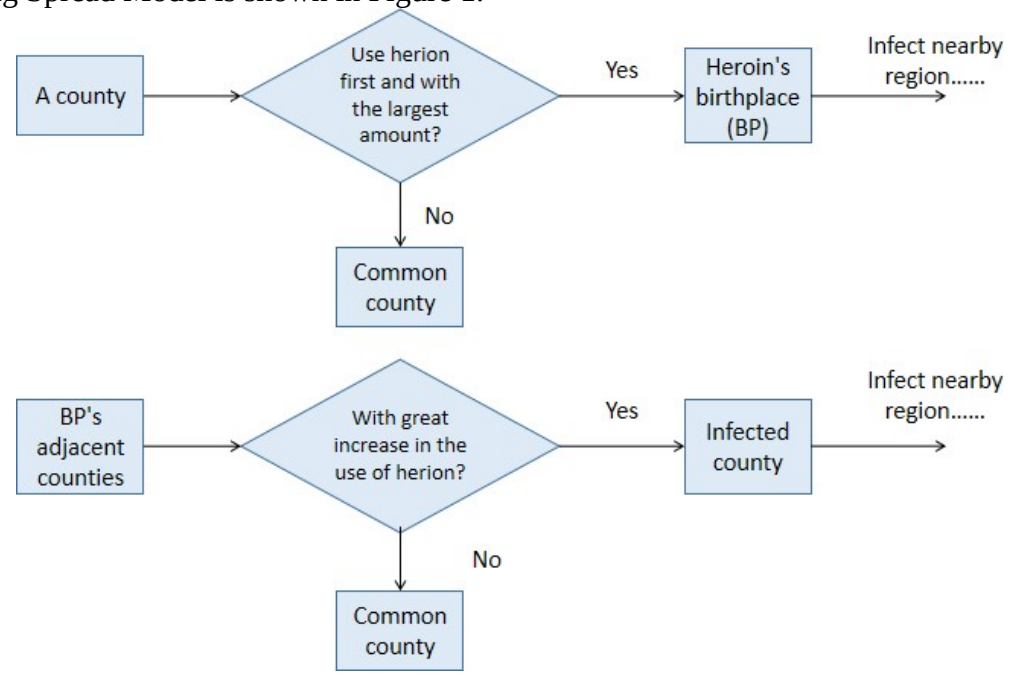

Figure 1. Judgement process of Drug Spread Model

Many countries are suffering the crisis of the use of synthetic and nonsynthetic opioids which are extracted from opium (opium poppy). They have many uses either for the treatment and management of pain in medical community or for recreational purposes (illegal). There are countless kinds of opioids and we can find 70 kinds of opioids in the data provided by NFLIS. However, to simplify our model, we only consider the top-ten drugs with the largest total cases from 2010 to 2017. We use the provided NFLIS data to calculate the total number of each reported drugs' use cases in 2010-2017. Then we sort them, and select the top 10 medicines to analyze.

To make the analysis feasible, we discussed five states separately. When considering the changes in drug use, we take geographical factors into ac- count, that is, drug use between adjacent counties will affect each other. In order to make it possible to find the spread of drugs, We believe that the county which use drug earliest and with the largest amount as the birthplace and it can affect the nearby region.

2.2. The top-ten drugs' spread path

According to our Drug Spread Model, we conduct the ten popular drugs' spread path, and display it with pictures. We list the 10 drugs' corresponding colors (each color represents a different kind of drug) and use different colors to draw the spread graphs. What's more, the dots in the pictures represent the possible locations where specific opioids use might have started. Those pictures can clearly show the infection path of each drug in 5 states, and we can also find out the characteristics of the drugs cases, that means which counties use the most types of drugs or have the strongest infectious ability.

2.3. Influencing Factors of Drug Use Model

The Centers for Disease Control and Prevention (CDC) [2]reported that 63% increase in heroin use and a three-fold increase in deaths among people over 12 years of age happened in the United States between 2012 and 2017. The United States is the world's largest drug consumer, more than 60% of the world's drug production is exported to the United States. Not only America but also many countries in the world are experiencing a national crisis regarding the use of synthetic and nonsynthetic opioids. So it is important to know which factors can significantly affect the drug use.

We gain the weights of each section by calculating eigenvalue and normalizing the corresponding eigenvector. The five major sections we consider together with their weights are shown in Figure 2 below.

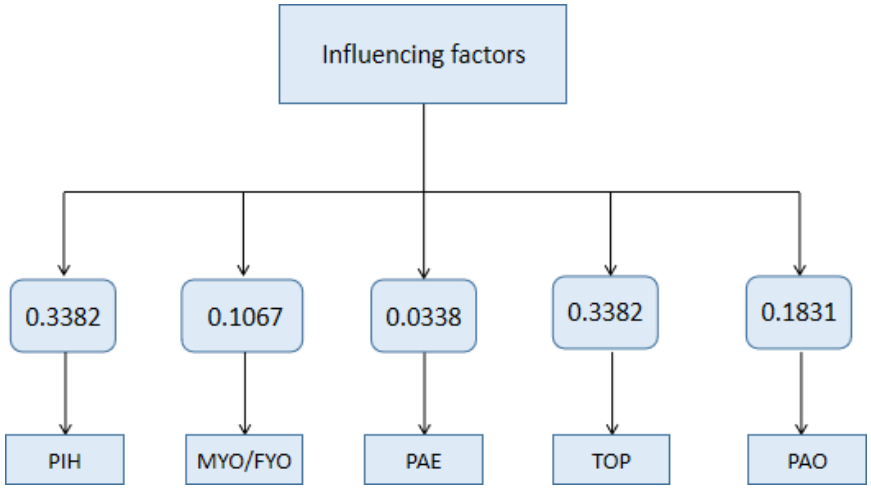

Figure 2

To test the consistency of the matrix, we calculate the Consistency Ratio(CR), which is defined as the ratio of Consistency Index(CI) to Average Random Consistency Index(RI). Since n=5, RI=1.12, and CI=0.0672, we get CR= CI =0.0600<0.1, so the consistency of the matrix is confined.

3. Sensitivity Analysis

In general, based on the analysis of a large number of data and the Depth-first search algorithm, we get the general route transmission of 10 most infectious drugs during 2010- 2017. According to this spread path of the drugs, we can intuitively understand the trend characteristics of different drugs over time.

On this basis, using AHP, we make the primary and secondary analysis about socio- economic factors of some typical areas where a large number of drugs are rampant. We observe that PHI,

MYO/FYO, PAE, TOP and PAO (five major factors whose meaning can be found in the "Notation" part) have the great impact on the spread of Heroin drugs.

We also define the drug identification threshold levels. If there is a region, with the ratio (NH) about a drug is more than its threshold, it indicates that the drug abuse stands a good chance to happen in this place. So, the government need to take some appropriate measures, such as strengthening education supervision, increasing government propaganda, to make sure the stability of the society. It is assumed that in the specific model, if heroin drug cases in VA state increase sharply, some actions need to be taken to strengthen the supervision of people. Because it is always possible for people who feel disappointed or lack warmth from society and family to seek temporary pleasure in drugs. To a large extent, this result is consistent with reality, and in the meantime, it also proves that our model is feasible.

4. Strengths and Weaknesses

Due to the accurate data we collect and sort and the Depth-first search algorithm, the Drug Spread Model can conduct the spread path of drugs in the five states in America. We also carefully draw the path on the map which can clearly show our results. In order to gain useful information and make reliable prediction, we make the fore- casting for each state, which can better help the administrative committee in each state to cope with the matter about the abuse of synthetic and nonsynthetic opioids. The Prediction Model is quite useful and can help people predict the use of different drugs, so that it can alert the government and make it pay more attention to the use of some drugs. Based on AHP method, the Influencing Factors of Drug Use Model fully consider the impact of many possible factors on the drug use, including PIH, MYO/FYO, PAE, TOP and PAO. Therefore, the result of the model is highly credible. To simplify the calculation, we believe a county which has the most cases of a drug discovery in a given year, has the strongest infectious ability to its neighbors. But obviously, there are many other countries can be the birthplace of a drug.

5. Conclusion

Drug abuse is a serious problem in US as well as other countries. To deter this bad trend and predict when and where the drug use will breakthrough the threshold, we build a Prediction Model by using the Gray Prediction Algorithm. Because heroin takes the largest part of the total drugs use, analysing it to predict the drug identification threshold levels is proved to be more universal. To simplify our model, we take Virginia as an example. According to the Drug Spread Model, we know the birthplace of heroin(HIGHLAND) and the 14 infected counties during 2010 to 2017.We use the ratio of the number of cases of heroin use per year(NH) in each infected county to the total number of drugs use incidents(TN) in these places to find the regulation.

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