Mathematical Modelling for Interpretation of HCV Infection

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Abstract: - This note explains about HCV (Hepatitis C virus). Here the analysis around the symptoms of hepatitis C virus. Concept of Fuzzy Cognitive Maps had been used to interpret the symptoms of hepatitis C virus. For this purpose, focus is on the most likely explanation for the relationship between the symptoms.

Key words: - Fuzzy Cognitive Maps, Induced Fuzzy Cognitive Maps, Symptoms of HCV infection, Interpretation of infection.

I. HEPATITIS C VIRUS

Hepatitis C virus (HCV) infection with the dangerous spread around the world (2.15%) is a public health problem. Hepatitis C virus (HCV) is one of the major problems of liver disease in world. It is usually through blood and blood products. In 1989, it was determined, and hepatitis C virus-infected blood products increased likelihood of HCV screening. Unfortunately, the virus has spread to most of the world's population and established itself as the leading cause of acute liver disease. HCV infection is hard to combat as a large fraction of all infected individuals become chronic carriers of the virus.

Unprotected sex and perinatal transmission from infected mother to offspring are frequent ways of spreading of this virus as compared to other ways. The incubation period is about 50 days for HCV. Acute hepatitis C is usually a mild disease with mortality of 1%. However, in severe cases, over 50% develop chronic, and some of them will eventually develop into liver cirrhosis or cancer, or both. Acute infection, fatigue is the most common symptom. However, in most cases (90%) are asymptomatic. This makes it very difficult for hepatitis C to diagnose.

II. SYMPTOMS OF HCV INFECTION

About 75% of people have no symptoms and remaining 25% complain of fatigue, loss of appetite, muscle aches and fever. Eyes or yellowing of the skin (jaundice) is at the early stage of infection. Finally, the inflammatory immune response to the virus to people affected by the continuation of a chronic infection with the liver can start. Blood test levels of enzymes indicating liver damage, elevated liver may appear, and the first sentence of the infection may exist which are often. Patients get tired easily or may complain of non-specific symptoms. Some major symptoms are weakness, loss of appetite, weight loss, enlarged breasts, including the blood vessels at the skin on the palms of the hands, difficulty in blood clotting, pruritus and spider rash. Patient suffers from advanced liver means the liver begins to fail. It is a life-threatening problem.

III. FUZZY COGNITIVE MAP

Fuzzy Cognitive Maps of researchers are signed procedure & may include different kinds of knowledge to draw and analyze complex operating system. During the process of learning and understanding mapping system between particular favours, in which the process of representation and public buildings researchers FCM certain perception of the obstacles created reason. A SEI consists of many elements / concepts / nodes / factors and their influences on one another, the chances of the weighted are depicted with arrows between the elements. The

analysis of the relationship between the goal of beings found in a SEI detecting and interpreting the map and by understanding its structural properties and the dynamism. The structured ways of collecting and data coding enables comparison studies have been reused.

Definition: 1
An FCM is a directed graph with concepts like policies, events etc. as nodes and causalities as edges. It represents causal relationship between concepts. If increase (or decrease) in one concept, leads to increase (or decrease) in another, then give the value 1. If there exists no relation between two concepts, then the value 0 is given. If increase (or decrease) in one causalities decreases (or increases) another, then give the value –1. Thus FCMs are described in this way.

Definition: 2
When the nodes of the FCM are fuzzy sets then they are called as fuzzy nodes.

Definition: 3
FCMs with edge weights or causalities from the set {–1, 0, 1}, are called simple FCMs.

Definition: 4
Consider the nodes or concepts $C_1, C_2, C_3, ..., C_n$ of the FCM. Suppose the directed graph is drawn using edge weight $e_{ij} \in \{0, 1, -1\}$ .The matrix E be defined by $E = e_{ij}$, where e_{ij} is the weight of the directed edge $C_i C_j$. E is called the adjacency matrix of the FCM, also known as the connection matrix of the FCM. It is important to note that all matrices associated with an FCM are always square matrices with diagonal entries as zero.

Definition: 5
Let $C_1, C_2, C_3, ..., C_n$ be the nodes of an FCM. $A = (a_1, a_2, a_3, ..., a_n)$, where $a_i \in \{0, 1\}$. A is called the instantaneous state vector and it denotes the on-off position of the node at an instant.

$$a_i = 0 \quad \text{if } a_i \text{ is off and}$$
$$a_i = 1 \quad \text{if } a_i \text{ is on}$$
$$\text{for } i = 1, 2, 3, ..., n$$

Definition: 6
Let $C_1, C_2, C_3, ...C_n$ be the nodes of a Fuzzy Cognitive Map. Let $\overrightarrow{C_1C_2}, \overrightarrow{C_2C_3}, \overrightarrow{C_3C_4}, ..., \overrightarrow{C_iC_j}$ be the edges of the FCM $(i \neq j)$. Then, the edges form a directed cycle. An FCM is said to be cyclic if it possesses a directed cycle. An FCM is said to be acyclic if it does not possess any directed cycle.

Definition: 7
An FCM with cycles is said to have a feedback.

Definition: 8
When there is a feedback in an FCM, i.e., when the causal relations flow through a cycle in a revolutionary way, the FCM is called a dynamical system.

Definition: 9
$\overrightarrow{C_1C_2}, \overrightarrow{C_2C_3}, \overrightarrow{C_3C_4}, ..., \overrightarrow{C_{n-1}C_n}$ be a cycle. When C_i is switched ON and if the causality flows through the edges of a cycle and if it again causes C_i we say that the dynamical system goes round and round. This is true for any node C_i for $i = 1, 2, 3, ..., n$. The equilibrium state for this dynamical system is called the hidden pattern.

Definition: 10
If the equilibrium state of a dynamical system is a unique state vector, then it is called a fixed point.

IV. ALGORITHM FOR INDUCED FUZZY COGNITIVE MAPS (IFCMs)

Induced Fuzzy Cognitive Maps is up-gradation of Fuzzy Cognitive Maps. IFCMs has some modifications in algorithms as per requirement of the model. To interpret solution of the problem go through the following steps:-

Step: 1
For the given model collect the unsupervised data that is in determined factors called nodes. In this model few symptoms of HCV infection are taken as arbitrary atributes.

Step: 2
According to the expert opinion, draw the directed graph.

Step: 3
Obtain the connection matrix, 'B' from the directed graph (FCMs). Here the number of rows in the given matrix is equal to number of arbitrary atributes.

Step: 4
Consider the state vector C_1 which is in ON position. Find $C_1 \times B$. The state vector is updated and threshold at each stage.

Step: 5
Threshold value is calculated by assigning 1 for the relation between any two symptoms or arbitray atributes otherwise 0. The symbol $\rightarrow$ represents product of the result.

Step: 6
Now each component in the C_1 vector is taken separately and product of the given matrix is calculated. The vector which has maximum number of one`s which occurs first is considered as C_2.

Step: 7
C_2 vector is again multiplied with matrix and the result will be considered as output of the model.

V. ANALYSIS OF THE MATHEMATICAL MODEL

A model for HCV infected people to find out most probable symptoms is explained. At the first stage following seven aribitrary attributes $(A_1, A_2, A_3, A_4, A_5, A_6, A_7)$ are taken for the study.

A_1 = Fatigue & loss of appetite,

A_2 = Nausea & vomiting,

A_3 = Abdominal & stomach pain,

A_4 = Joint & muscles pain,

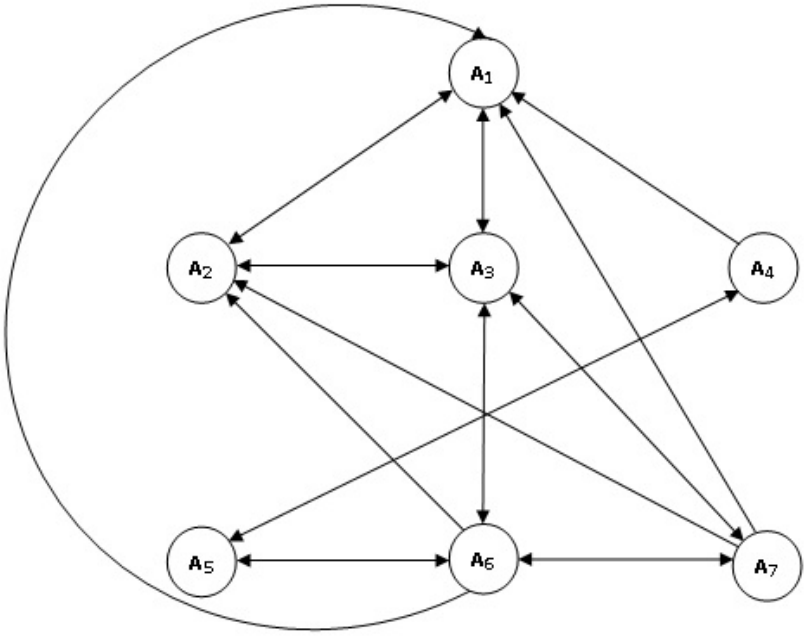
A_5 = Pruritus (Itching),

A_6 = Jaundice (Yellowing of eyes & skin),

A_7 = Liver Cirrhosis.

Here a directed Graph is mentioned by using Symptoms (arbitrary attributes) of HCV Infection,

Fig (1) : Directed graph by using symptoms of HCV infection



VI. IMPLEMENTATION OF MATHEMATICAL MODEL

According to the study we found symptoms for being infcted by HCV. Now here is implementation of the model, for this, a matrix 'B' is created by using fig (1),

$$B=\left[b_{ij}\right]=\begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ A_4 \\ A_5 \\ A_6 \\ A_7 \end{array}\begin{array}{c} \begin{array}{ccccccc} A_1 & A_2 & A_3 & A_4 & A_5 & A_6 & A_7 \end{array} \\ \begin{bmatrix} 0 & 1 & 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 & 0 & 1 & 1 \\ 1 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 1 & 0 \\ 1 & 1 & 1 & 0 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 & 0 & 1 & 0 \end{bmatrix} \end{array} \quad \text{.....(1)}$$

To interpret the HCV infection here Induced Fuzzy Cognitive Maps method has been used. Initially A_4 (Joint & muscles pain) and A_5 (Pruritus) are taken to interpret the problem. Here we supposed that only A_4 (Joint & muscles pain) and A_5 (Pruritus) states are ON and others are OFF. Then,

$$C_1=\begin{pmatrix}0 & 0 & 0 & 1 & 1 & 0 & 0\end{pmatrix} \quad \text{.....(2)}$$

Multiply C_1 with matrix 'B',

$$C_1B=\begin{pmatrix}1 & 0 & 0 & 1 & 1 & 1 & 0\end{pmatrix}$$

i.e.,

$$C_1^1 B = (1 \quad 0 \quad 0 \quad 1 \quad 1 \quad 1 \quad 0) \qquad \text{.....(3)}$$

It is known that the threshold value is calculated by assuming one (1) for individual relation between symptoms and zero (0) if there is no relation.

Now, calculation for threshold values by iteration method, in this process we suppose in ON position one by one all A_i`s as we supposed for A_1, So,

$$C_1^1 B \sim (1 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0) B \to (0 \quad 1 \quad 1 \quad 0 \quad 0 \quad 0 \quad 0) \qquad \text{.....(4)}$$

$$C_1^1 B \sim (0 \quad 1 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0) B \to (1 \quad 0 \quad 1 \quad 0 \quad 0 \quad 0 \quad 0) \qquad \text{.....(5)}$$

$$C_1^1 B \sim (0 \quad 0 \quad 1 \quad 0 \quad 0 \quad 0 \quad 0) B \to (1 \quad 1 \quad 0 \quad 0 \quad 0 \quad 1 \quad 1) \qquad \text{.....(6)}$$

$$C_1^1 B \sim (0 \quad 0 \quad 0 \quad 1 \quad 0 \quad 0 \quad 0) B \to (1 \quad 0 \quad 0 \quad 0 \quad 1 \quad 0 \quad 0) \qquad \text{.....(7)}$$

$$C_1^1 B \sim (0 \quad 0 \quad 0 \quad 0 \quad 1 \quad 0 \quad 0) B \to (0 \quad 0 \quad 0 \quad 1 \quad 0 \quad 1 \quad 0) \qquad \text{.....(8)}$$

$$C_1^1 B \sim (0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 1 \quad 0) B \to (1 \quad 1 \quad 1 \quad 0 \quad 1 \quad 0 \quad 1) \qquad \text{.....(9)}$$

$$C_1^1 B \sim (0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 1) B \to (1 \quad 1 \quad 1 \quad 0 \quad 0 \quad 1 \quad 0) \qquad \text{.....(10)}$$

Let

$$C_2 = (1 \quad 1 \quad 1 \quad 0 \quad 1 \quad 0 \quad 1) \qquad \text{.....(11)}$$

Because the threshold having maximum 1`s will assumed as C_2, then repeat the above process again, So,

$$C_2 B = (3 \quad 3 \quad 3 \quad 1 \quad 0 \quad 2 \quad 1)$$

i.e.,

$$C_2^1 B = (3 \quad 3 \quad 3 \quad 1 \quad 0 \quad 2 \quad 1) \qquad \text{.....(12)}$$

Here equation (12) will be considered as the result of the mathematical model to interpret HCV infection by using Fuzzy Cognitive Maps.

VII. CONCLUSION

On completion of the process following are the interpretations:-

- When we put A_4 (Joint & muscles pain) and A_5 (Pruritus) in ON position, we found that the result is (3 3 3 1 0 2 1) which is shown in equation (12).
- Here first three symptoms have maximum value. It means if anybody is suffering from these problems for a long time then he needs to go for clinical advice or test.
- In this model A_4 and A_5 has been taken as major symptoms, if they present simultaneously even though the result of A_4 (Joint & muscles pain) and A_5 (Pruritus) have values 1 & 0 respectively. The reason behind this is, these symptoms will come out after a long time when liver become infected if patient suffering in initial stage then probability of these symptoms will be rare.

- In this result symptom A_6 (Jaundice) has value 2. Jaundice is curable but if it has been over looked or previously mentioned symptoms are also present then patient and physician need attention clinical advice and pathological test.

- Finally, if any jaundice patient suffering from first three symptoms with symptom A_4 (Joint & muscles pain) or A_5 (Pruritus) or both then it is a high risk and it will be converted in to liver cirrhosis due to lack of treatment or awareness.

VIII. FUTURE SCOPE OF THE RESEARCH

By the study it has been analysed that first three symptoms are very initial if they come again and again or for a long time. Usually people ignore them and then it makes problem in future. Here authors tried to say by the help of mathematical modelling an intelligent system can be developed to aware the people which can save many lives.

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