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A Study on the Attributes That Causes Passenger Aircraft Accidents Using Combined Disjoint Block Fuzzy Cognitive Maps

Mohan, Assistant Professor, Kalaimagal College of Arts and Science, India,

mohansubbaraya15@gmail.com

Abstract **Air transportation systems are designed to ensure that aircraft accidents are rare events. To minimize these accidents, factors causing or contributing to accidents must be understood and prevented. Previous research has studied accident data to determine these factors. The low rate of accidents however, makes it difficult to discover repeating patterns of these factors. In this research we employ Combined Disjoint Block Fuzzy Cognitive Maps (CDBFCMs) to determine the most important attribute that causes passenger Aircraft accidents. Combined Disjoint Block Fuzzy Cognitive Map is an efficient method which analyses the data by directed graphs and connection matrices. This research paper has four sections. First section gives the information about development of Fuzzy Cognitive Maps and brief explanation about the attributes, (i.e., Pilot Error, Mechanical Error, Weather, Sabotage, other human Errors) which causes Passenger Aircraft Accidents. Second section gives preliminaries of Fuzzy Cognitive Maps and Combined Disjoint Block Fuzzy Cognitive Maps. In section three, we explain the concepts of problem and the method of determining the hidden pattern. Final section gives the conclusion based on our study.**

Keywords — **Fuzzy Cognitive Maps (FCMs), Combined Disjoint Block Fuzzy Cognitive Maps (CDBFCMs), Aircraft Accidents.**

I. INTRODUCTION

A Mathematical Model called Fuzzy Cognitive Maps was introduced by Lofti.A.Zadeh in 1965. After a decade a Political scientist R.Axelord used this fuzzy model to study decision making in social and political systems in the year 1976. And the power of cognitive maps considering fuzzy values for the concepts of the cognitive map and fuzzy degrees of interrelationships between concepts was enhanced by B.Kosko. Fuzzy Cognitive Maps are fuzzy structures that strongly resemble neural networks, and it is a powerful and far reaching consequences as a mathematical tool for modeling complex systems [1,3,4,5,6,7]. Neutrosophic Cognitive Maps are generalizations of FCMs, and their unique feature is the ability to handle indeterminacy in relations between two concepts thereby bringing greater sensitivity into the results.

Levels of safety are typically measured by the number of accidents and its rates. An aircraft accident is defined as an occurrence associated with the operation of an aircraft in which people suffer death or injury, and/or in which the aircraft receives substantial damage. Throughout the history of air transportation, along with the continuous growth in air travel, remarkable improvements have been made in lowering of accident rates. Nevertheless, further improvements are needed. For our research paper, we have collected opinions from Experts. In our collected data, we focus on five important attributes that causes Passenger Aircraft Accidents, which are explained below.

(i)Pilot Error

Pilot factors are more frequent in accidents. Two qualified pilots should be present in the ground control station (GCS) prior to switching control of the aircraft from one console to the other. The pilots must always follow the procedures outlined in the checklist. Failure to follow the checklist can lead to missing critical steps. The pilot should declare an emergency in a timely fashion to allow for a rapid contingency response.

(ii)Mechanical Error

Mechanical problems are problems with landing gears, flight control systems, and wings. Ensure the proper settings of switches on control panels in order to avoid loss of mode awareness. Battery power conservation systems should leave mission critical systems operating when shutting down noncritical systems.

(iii)Weather

Severe weather also becomes an accident factor. Wind, Thunderstorm, Ice plays a major role in the aircraft accidents. *Air Traffic Control (ATC)* must provide weather information to the pilot. Air Algerie Flight 5017 crashed in the Sahara in July 2014, killing all 118 people on board, there had been reports of bad weather. Very powerful

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storms might be able to seriously damage the wings on a aircraft.

(iv)Sabotage

Plane crashes that are caused by sabotage draw the most media attention [2]. Some sabotaged flights crash because of hijackers, and of course the most notable examples are the three flights that were hijacked on September 11th 2001. Mentally ill passengers have been known to attack both pilots and passengers, and some have even detonated bombs in an attempt to commit suicide while in flight.

(v)Other Human Errors

Some plane crashes are inadvertently caused by *Air Traffic Controllers (ATCs)*. Air traffic control mistakes have caused planes to crash into mountains, to land on occupied runways and even to collide in midair. When a plane is loaded, fueled or maintained incorrectly, that's human error too. Air Traffic Control communications refer to factors such as controllers issuing traffic advisories, and controllers checking for systems and wings.

II. 2 Basic Definitions and Notations

Fuzzy cognitive maps (FCMs) are more applicable when the data in the first place is an unsupervised one. The FCMs work on the opinion of experts. FCMs model the world classes and causal relations between classes.FCMs are fuzzy signed directed graphs with feedback. The directed edge $e_{ij}$from causal concept Ci to concept Cj measures how much Ci causes Cj. The time varying concept function Ci(t) measures the non-negative occurrence of some fuzzy event, perhaps the strength of political sentiment , historical trend . The edges eij take values in the fuzzy causal interval [–1, 1]. eij= 0 indicates no causality, eji> 0 indicates causal increase, Cj increases as Ci increases (or Cj decreases as Ci decreases). eji< 0 indicates causal decrease or negative causality. Cj decreases as Ci increases (or Cj increases as Ci decreases) simple FCMs have edges values in {–1, 0, 1}.

2.1. Definition

An FCM is a directed graph with concepts like policies, events etc. as nodes and causalities as edges. It represents causal relationship between concepts they are called as fuzzy nodes.

2.2. Definition

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

2.3. Definition

Consider the nodes/ concepts C1, …, Cn of the FCM. Suppose the directed graph is drawn using edge weight eij ∈{0, 1, –1}. The matrix E be defined by E = (eij) where eij is the weight of the directed edge CiCj . 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.

2.4. Definition

Let C1, C2,…, Cn be the nodes of an FCM. A = (a1, a2,…,an) where ai∈{0, 1}. A is called the instantaneous state vector and it denotes the on-off position of the node at an instant

ai = 0 if ai is off and

ai= 1 if ai is on for i = 1, 2, …, n.

2.5. Definition

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

2.6. Definition

If the FCM settles down with a state vector repeating in the form A1 → A2 → … →Ai→A1 then this equilibrium is called a limit cycle.

2.7. Definition

Finite number of FCMs can be combined together to produce the joint effect of all the FCMs. Let E1, E2,…, Ep be the adjacency matrices of the FCMs with nodes C1, C2, …,Cn then the combined FCM is got by adding all the adjacency matrices E1, E2, …, Ep. We denote the combined FCM adjacency matrix by E = E1 + E2 + … + Ep.

Suppose A = (a1, … , an) is a vector which is passed into a dynamical system E. Then AE = (a'1, … , a'n) after thresholding and updating the vector suppose we get (b1, … , bn) we denote that by (a'1, a'2, … , a'n) → (b1, b2, … , bn). Thus the symbol '→' means the resultant vector has been thresholded and updated.

2.8. Definition

Let C1, C2, …, Cn be n distinct attributes of a problem n very large and a non- prime.

If we divide n into k equal classes i.e., k/n and if n/k=t which are disjoint and if we find the directed graph of each of three classes of attributes with t attributes each then their corresponding connection matrices are formed and these connection matrices are joined as blocks to form a n x n matrix. The n x n connection matrix forms the combined disjoint block FCM of equal classes If the classes are not divided to have equal attributes but if they are disjoint classes we have n x n connection matrix called the combined disjoint block FCM of unequal classes / size. Here we approach the problem through attributes using Combined Disjoint Block Fuzzy Cognitive Maps (CDBFCMs) that are basically matrices which predict the feelings of all the attributes under certain conditions. Before

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we proceed to apply Combined Disjoint Block Fuzzy Cognitive Maps (CDBFCMs) to this problem, we define a set of 5 attributes given by experts. We work with analyzing them using directed graph and its connection matrices.

III. DESCRIPTION OF THE HIDDEN PATH USING COMBINED DISJOINT BLOCK FUZZY COGNITIVE

Maps

By expert opinion and explanation we take following as attributes related to Passenger Aircraft accidents

C1: Pilot Error

C2: Mechanical Error

C3 : Weather

C4: Sabotage

C5: Other human Errors

We take three experts opinion on the three disjoint classes so that each class has three attributes. Let the disjoint classes be classes be E1, E2, E3 be divided by the following

E1= { C1 , C3 , C5 }

E2= { C2, C4, C3} and

E3 = { C1 , C4 , C5 }

The directed graph given by the first expert C1 , C3 , C5 which forms the class B1

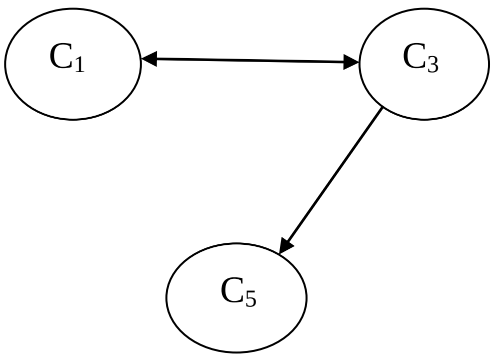

Figure 1

The related connection given by first expert opinion on C1 , C3 , C5 which forms the class B1

E_1 =

	C_1	C_2	C_3	C_4	C_5
C_1	0	0	1	0	0
C_2	0	0	0	0	0
C_3	1	0	0	0	1
C_4	0	0	0	0	0
C_5	0	0	0	0	0

The directed graph given by the expert C2, C4, C3 which forms the class B2.

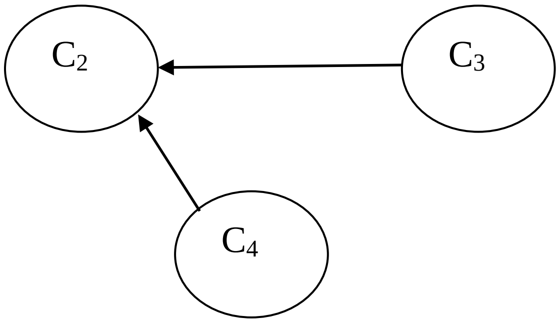

Figure 2

The related connection given by second expert opinion on C2, C4, C3which forms the class B2.

E=

	C_1	C_2	C_3	C_4	C_5
C_1	0	0	0	0	0
C_2	0	0	0	0	0
C_3	0	1	0	0	0
C_4	0	1	0	0	0
C_5	0	0	0	0	0

The directed graph given by the third expert C1 , C4 , C5 which forms the class B3

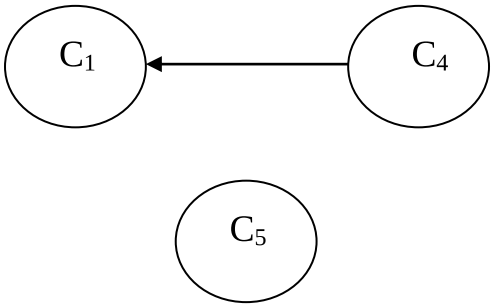

Figure 3

The related connection given by third expert opinion on C1 , C4 , C5 which forms the class B3.

E_3=

	C_1	C_2	C_3	C_4	C_5
C_1	0	0	0	0	0
C_2	0	0	0	0	0
C_3	0	0	0	0	0
C_4	1	0	0	0	0
C_5	0	0	0	0	0

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Combined Disjoint Block Fuzzy Cognitive Map From Figure 1,2 & 3 , we get

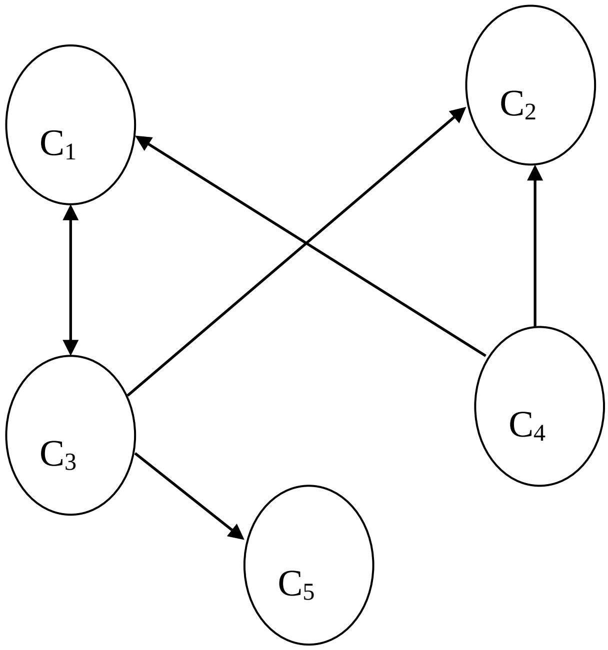

Figure 4

The combined FCM adjacency matrix is

$$E = \begin{array}{c} \\ C_1 \\ C_2 \\ C_3 \\ C_4 \\ C_5 \end{array} \begin{array}{c} \begin{array}{ccccc} C_1 & C_2 & C_3 & C_4 & C_5 \end{array} \\ \begin{pmatrix} 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 & 1 \\ 1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{pmatrix} \end{array}$$

Now using the matrix A of the combined overlap block FCM, we determine the hidden pattern. Suppose the concept C1 is in the ON state and all other nodes are in the OFF state.

Let the initial input vector be X = (1 0 0 0 0), where Pilot Error is taken as the ON state and all other nodes are in the OFF state.

The effect of X on the dynamical system E is given by:

$XE = (0\ 0\ 1\ 0\ 0) \rightarrow (1\ 0\ 1\ 0\ 0) = X_1$

$X_1E = (1\ 1\ 1\ 0\ 1) \rightarrow (1\ 1\ 1\ 0\ 1) = X_2$

$X_2E = (1\ 1\ 1\ 0\ 1) \rightarrow (1\ 1\ 1\ 0\ 1) = X_3 = X_2$.

$\therefore$ X_2 is the hidden pattern, which is the fixed pattern.

IV. Conclusion & Suggestions

From our study we conclude that while analyzing FCM, when the concept C_1, "Pilot Error", is in the on state, the other concepts C_2, C_3, C_5, are also in the on state. i.e., when we keep Pilot Error in on state, Mechanical Error, Weather, Other human Errors are also become on state. Therefore "Pilot Error" is the major attribute for Passenger Aircraft Accidents. To avoid aircraft accidents pilots must not get fatigue and should take rest properly. Pilot should not misjudge the weather and misread the equipments that will lead to a safe and peaceful journey.

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