Design of Aircraft Accident Case Base Construction based on Frame Representation Method

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***Abstract*—Professional knowledge and relevant experience are required in different levels of events though aircraft accident rarely occur. Based on the characteristics of civil aviation emergencies, this paper constructs an aircraft accident scenario construction factor model based on four elements: causing subject, bearing subject, fighting subject and system state. It also studies the structural expression and storage of aircraft accident case base based on the frame representation. The paper takes the 2019 Ethiopian Airlines air crash as an example, the case base storage model is established. The analysis results verify the rationality and feasibility of the model in the construction of the aircraft accident case base. This model helps to standardize aircraft accident case bases and lays the foundation for improving emergency command and decision-making levels.**

Keywords—aircraft accident, emergency case base, case-based reasoning, scenario building, frame representation

I. INTRODUCTION

The safety situation of China's civil aviation is stable and controllable, and the level of safety management system is constantly improving. By the end of 2018, aviation transportation achieved continuous safe flight for 100 months and 68.36 million hours. However, the complexity of China's civil aviation security situation in recent years has led to inadequate emergency response in certain unsafe incidents. There are as many as eight unsafe typical aircraft incidents in 2018. The emergency response reflect many deficiencies, such as professional disposition ability, coordination and communication ability, and situational judgment ability. At the same time, a large amount of emergency response experience and lessons have been accumulated in each emergency response.

Historical emergency cases have important reference value in real emergency decision-making. They can not only help to remind the development trend of the situation, the decision makers can utilize the intelligent knowledge information from emergency case base as well. However, the information degree of emergency case base is low in China. There are some shortcomings such as inconsistent expression structure and incomplete expression (Gu Y., 2012[1]; Zhang M.L., 2015[2]; Zhang, M.H., 2016[3]). Therefore, based on case-based reasoning theory and framework representation, this paper constructs a basic model of a structured aircraft accident case base. It analyzes the information storage and use technology of aircraft accident cases, which will help to improve the rationality and scientificity of aircraft emergency response command and decisions.

II. RESEARCH METHODOLOGIES

A. Emergency Scenario Construction Principle

This paper establishes the emergency scenario based on the characterization of the disaster system (Shi, P.J., 2002[4]; Wu, Q., 2016[5]). It builds an emergency scenario construction factor model based on four elements: causing subject, bearing subject, fighting subject, and system state, as shown in Figure 1. The causing subject refers to the disaster itself that causes the emergency event; the bearing subject refers to the person or thing that is adversely affected by the occurrence of the causing subject. The fighting subject refers to the person who makes decisions and disposes in order to reduce the various types of losses in the affected area, as well as the various material resources and information resources they use; the system state refers to the impact of the organization in the event of a disaster.

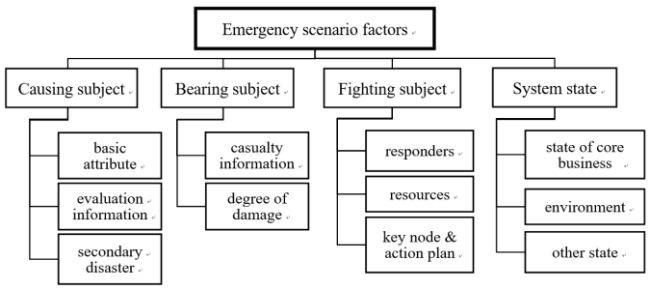

Fig. 1 Emergency scenario factors model and framework

The four main stages of emergency response are emergency monitoring, response and rescue, recovery, and post-reconstruction. The emergency scenario is the evolution process of the occurrence and development of the emergency (Jiang, H., 2009[6]). There are key disposal nodes at different stages, and the expansion of these scenario slices in space and time constitute the scenarios (Jiang, H., 2012[7]), as shown in Figure 2.

As shown in Figure 2, each scenario slice is characterized as a collection of multiple events and states. The event mentioned here refers to the interaction activities that are formed in different regions, different personnel, and for different purposes during the development of an emergency.

The state refers to the form that different subjects exhibit during the development of an emergency.

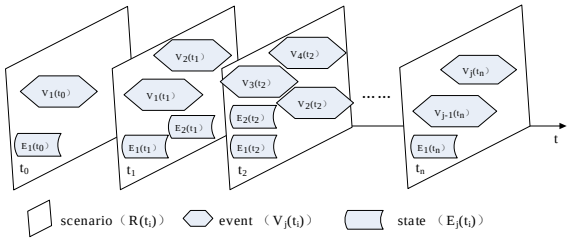

Fig. 2 Emergency scenario evolution model based on key nodes

The occurrence and termination of each event is relatively independent. There are usually several events on a scenario slice. The important work of the scenario construction model analysis is to study the subjects interaction activities of each event in different scenario slices, and the development trend of those events based on the interaction activities. The interaction activities of a single event is shown in Figure 3.

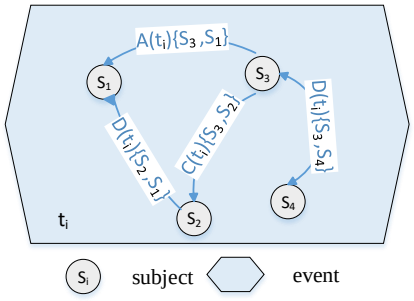

Fig. 3 Interaction Subjects in a single event

As shown in Figure 3, each event contains one or more interrelated subjects. There is a certain relationship between the subjects. The relationship refers to an attribute, an action, a command, a making decision, etc.. The case base needs to record the relationship characteristics between different subjects in the events in each scenario slice.

B. CASE-BASED REASONING

Case-based Reasoning (CBR) is a sub-discipline of artificial intelligence, which can simulate the thinking process of expert association, intuition, analogy, induction, learning and memory in a good way. The core idea of CBR is to use the previous experience and knowledge acquired to solve the similar problems. And to make corresponding adjustments to the differences between the old and new situations. Therefore, it can get solutions to new problems and form new cases into the case base. As the case base grows, the "experience" of the system will become more and more abundant. The working principle based on CBR is the cognitive psychology process of people, that is, people assume that people always use existing experience and knowledge to solve similarities new problems.

The Structured case expression in CBR is as follows.

1) emergency scenario description;

2) emergency action plan;

3) emergency results and evaluation of the emergency action plan.

C. FRAME REPRESENTATION

The framework representation is a knowledge representation on the internal structure of things, which is based on the framework theory. It was first proposed by the famous American artificial intelligence scholar Minsky in 1975 and has now developed into a widely used knowledge representation method. The frame representation represents an empirical knowledge, a data structure that describes the attributes of objects (things, events, or concepts), and can express various relationships between related objects through a framework network. The top layer of the frame represents a fixed concept, object or event, and the lower layer consists of slots that describe various aspects of the object. Each slot has a slot value of a specific data type; the slot can have several facets, and each facet has its facet value for a particular data type (Yu, F., 2013[8]).

(<frame>(<slot>(<facet>(<value>))))

According to the emergency scenario, the case storage framework structure is established for the causing subject, bearing subject, fighting subject and system state.

Frame 1 < causing subject >:

Slot 1: time of occurrence
Slot 2: location of occurrence
Slot 3: category
Slot 4: reason of occurrence
Slot 5: impact scope
Slot 6: hazard rating
Slot 7: secondary disaster

Frame 2 < bearing subject >:

Slot 8: personal health indicators
Slot 9: casualty number
Slot 10: damage of the facilities

Frame 3 < fighting subject >:

Slot 11: responder attributes
Slot 12: resource attributes
Slot 13: action plan

Frame 4 <system state>:

Slot 14: core business attributes
Slot 15: natural environment attributes
Slot 16: social environment attributes

III. CASE STUDY

A. Aircraft accident scenario description

According to the comprehensive judgment of the probability and severity of aircraft unsafety events, the paper selects and construct the typical scenario of the aircraft accident. The case is the 2019 Ethiopian Airlines air crash. The Ethiopian Airlines ET302/B737 MAX-8 aircraft flew from Ethiopia to Kenya. During the takeoff, MCAS was activated due to the wrong reading of the left elevation sensor, which eventually caused the aircraft to crash shortly after takeoff. A total of 157 people were killed on the plane, included 149 passengers and 8 crew members.

B. Case construction based on frame representation

According to the Ethiopian Airlines air crash, it establishes a case model for the causing subject, bearing subject, fighting subject, and system state, as shown in Table I-IV.

The causing subject in this case study is left elevation sensor. Eight slots are proposed to describe the characteristics as shown in Table I. The evaluation slot stores the evaluation results of the causing subject operation, which contributes to the knowledge collection based on the emergency response.

The bearing subjects in this case study are people on board and aircraft. 14 slots are proposed to describe the characteristics as shown in Table II.

The fighting subjects in this case study are responder and resource. 17 slots are proposed to describe the characteristics as shown in Table III.

The system state in this case study are flight transportation business and environment. 12 slots are proposed to describe the characteristics as shown in Table IV.

TAB. I CAUSING SUBJECT CASE MODEL OF ETHIOPIAN AIRLINES AIR CRASH

category	frame	slot		value
causing subject	left elevation sensor	time of occurrence	——	March 10, 2019, 08:38 (L.T.)
		time of occurrence	——	Addis Ababa Airport
		type	natural disaster /accident disaster/public health/society security	Accident disaster
		reason of occurrence	——	system error
		impact scope	——	aircraft and onboard people
		hazard rating	Ⅰ / Ⅱ /Ⅲ/Ⅳ	Ⅰ
		secondary disaster	——	none
		evaluation		

TAB. II BEARING SUBJECT CASE MODEL OF ETHIOPIAN AIRLINES AIR CRASH

category	frame	slot		value
bearing subject	people	type	passenger / flight crew / flight attendant / security guard / maintenance personnel / dispatcher / plus crew	passenger
		name	——	
		gender	male/female	
		date of birth	——	
		country of citizenship	——	
		health status	not injured / minor injury / serious injury / death	death
		location	——	50 km outside the Addis Ababa Airport
		evaluation		
	aircraft	company	——	Ethiopian Airlines
		model	——	B737 MAX-8
		flight number	——	ET302
		damage	no damage/slight damage/serious damage	serious damage
		location	——	50 km outside the Addis Ababa Airport
		evaluation		

TAB. III FIGHTING SUBJECT CASE MODEL OF ETHIOPIAN AIRLINES AIR CRASH

category	frame	slot		value
fighting subject	responder	type	chief commander / coordinator / information officer / firefighter / medical staff	chief commander
		name	——	
		gender	male/female	
		date of birth	——	
		organization	——	
		department	——	
		phone number	——	
		email	——	
		location	——	
		action plan		
		evaluation		
	resource	type	facilities / equipment / materials / information technology	fire vehicle
		basic attribute	——	
		organization	——	airport
		phone number	——	
		location	——	50 km outside the Addis Ababa Airport
		evaluation		

TAB. IV SYSTEM STATE CASE MODEL OF ETHIOPIAN AIRLINES AIR CRASH

category	frame	slot		value
system state	flight transportation business	type	core business/ non-core business	core business
		daily normal flights	——	
		daily delayed flights	——	
		daily canceled flights	——	
		terminal passenger density	——	
		evaluation		
	environment	type	water quality/soil/air/food	soil
		basic attribute	——	
		pollution time	——	March 10, 2019, 08:38 (L.T.)
		pollution area	——	50 km outside the Addis Ababa Airport
		degree of pollution	no pollution / slight pollution / heavy pollution	heavy pollution
		evaluation		

IV. DISCUSSION

Based on the characteristics of civil aviation emergencies, this paper constructs an aircraft accident scenario construction factor model based on four elements: causing subject, bearing subject, fighting subject and system state. It also studies the structural expression and storage of aircraft accident case base based on the frame representation.

The next stage research work is as follows.

(1) Scenario expressions should be able to clearly, accurately and completely express the elements of the scenarios and their interrelationships, facilitating subsequent scenario modeling and scenario evolution analysis[9].

(2) The case base model is constructed to further improve the case inventory model and simplify the case information storage through the framework level network method.

(3) Study the framework of event dynamics, that is, the logical association between events, incorporating behavioral elements. It is the basis for three key technologies for event detection, event extraction, and event fusion

V. CONCLUTION

The paper takes the 2019 Ethiopian Airlines air crash as an example, the case base storage model is established. The analysis results verify the rationality and feasibility of the model in the construction of the aircraft accident case base. This model transforms text-based, unstructured, and coarse event data to structured, automated event data or knowledge representation. It helps to standardize aircraft accident case bases and lays the foundation for improving emergency command and decision-making levels.

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