Assessment of Meteorological Threats to the Coordinated Search and Rescue of Unmanned/Manned Aircraft

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Abstract The architecture and working principle of coordinated search and rescue system of unmanned/manned aircraft, which is composed of manned/unmanned aircraft and manned aircraft, were first introduced, and they can cooperate with each other to complete a search and rescue task. Secondly, a threat assessment method based on meteorological data was proposed, and potential meteorological threats, such as storms and rainfall, can be predicted by collecting and analyzing meteorological data. Finally, an experiment was carried out to evaluate the performance of the proposed method in different scenarios. The experimental results show that the coordinated search and rescue system of unmanned/manned aircraft can be used to effectively assess meteorological threats and provide accurate search and rescue guidance.
Key words Unmanned/manned aircraft; Coordinated search and rescue; Assessment of meteorological threats; Meteorological data
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In complex search and rescue environments, aircraft face multiple threats, such as radar, fire, terrain and inclement weather. In order to prevent aircraft from being destroyed, these threat elements must be evaluated. At present, there are many studies on the assessment of radar, firepower and terrain, but the combined effects of the coordination between unmanned/manned aircraft and meteorology are rarely considered. Bad weather conditions will not only affect the flight quality of unmanned/manned aircraft, but also may lead to their destruction. Especially in the case of the coordination between unmanned/manned aircraft, the meteorological impact is more complex, and the threat level is higher. Because the power size, speed, type and other performance of the aircraft itself are completely different, different aircraft are greatly affected by meteorological conditions. The impact of meteorological conditions on the coordination between unmanned/manned aircraft is more complicated, and meteorological threats limit the coordination between unmanned/manned aircraft. Therefore, it is an effective way to avoid accidents and reduce losses to assess the threats of severe weather conditions to the coordination between unmanned/manned aircraft before the coordinated search and rescue mission of unmanned/manned aircraft. In this paper, a modeling and evaluation method of meteorological threat degree to the coordinated search and rescue mission of unmanned/manned aircraft based on the Bayesian network was proposed, in which the internal relationship between the coordination of unmanned/manned aircraft and meteorological conditions was comprehensively considered, so as to improve the threats faced by manned/unmanned aerial aircraft during flying, make more effective, comprehensive and reasonable flight path planning and reasonable allocation of collaborative tasks among manned/unmanned aircraft, and improve the survival probability of manned/unmanned aircraft.

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1 Model and assessment of meteorological threats to the coordinated search and rescue of unmanned/manned aircraft based on Bayesian network

1.1 Bayesian network and its reasoning mechanism In the evaluation process, a multi-tree propagation inference algorithm based on Bayesian network will be used. In the network, each node has a processor to calculate its own reliability (posterior probability) using messages passed by neighboring nodes and an internal conditional probability table, and then propagates the results to other neighboring nodes. The processors of adjacent nodes receive the messages, recalculates its own reliability, and propagates the results to the other adjacent nodes until the effect of the evidence has been spread to all nodes.

1.2 Quantitative analysis of weather-related factors affecting the threats to the coordinated search and rescue of unmanned/manned aircraft Meteorological conditions in the search and rescue area will affect the flight safety of manned/unmanned aircraft, including thunderstorms, hail, rain and snow, accumulated ice, clouds, precipitation, wind and sand, as well as air pressure and oxygen content. Air pressure and oxygen content are mainly affected by the altitude of the flight area. According to meteorological factors and the performance of manned/unmanned aircraft, the following six meteorological and altitude related factors can be used as quantitative indicators to assess the level of meteorological threats.

The level of meteorological threats can be quantitatively assessed using the following indicators.

Weather type (WT): the weather is divided into extremely severe weather (such as thunderstorms, and hail), severe weather (such as rain and snow, and accumulated ice), general weather (such as clouds, and wind) and fine weather.

Effect intensity (EI): it indicates the intensity of a meteorological element playing a role, and is divided into five grades: very strong, strong, medium, weak and very weak.

Lasting time (LT): it is the length of time that meteorological elements play a role, and it is divided into three leaves: short (<0.5 h), medium (0.5 – 1.5 h) and long (>1.5 h).

Relative position (RP): it indicates the relative position of manned/unmanned aircraft and the central position of the action area of meteorological elements, and is divided into four categories: inside the action area, on the edge of the action area, outside the action area, and only having a position relationship.

Area altitude (AA): it means the altitude of the flight area, and is divided into five levels: very low (<1 000 m), low (1 000 – 2 000 m), medium (2 000 – 3 000 m), high (3 000 – 4 000 m) and very high (>4 000 m).

Threat property (TP): it refers to the existence form of threat factors affecting the flight of manned/unmanned aircraft, such as existing alone or in combination.

Threat level (TL): it is used to describe the threat degree of meteorological conditions to the safe flight of manned/unmanned aircraft, and the threat degree is divided into three grades: low, medium and high.

The assessment model of threat level adopted in this paper is shown in Fig. 1.

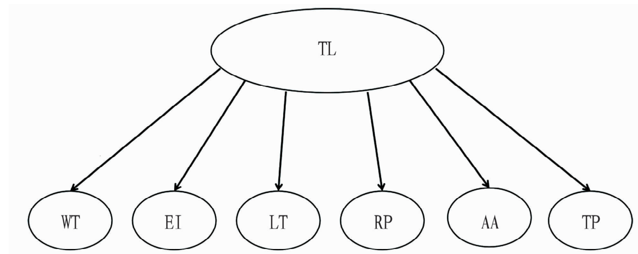

Fig. 1 Model of meteorological threats to the coordinated search and rescue of unmanned/manned aircraft based on Bayesian network

1.3 Determination of conditional probability table Conditional probability table reflects experts' knowledge, so there may be some subjectivity. In order to improve the reliability of the evaluation results, the sample data can be used for repeated debugging, and the data of probability matrix can be appropriately adjusted. In this paper, five meteorological factors affecting the threat degree and threat levels are as the correlation nodes in the threat level assessment model. Threat levels are inferred based on the conditional probability table (CPT) (Table 1).

Table 1 Conditional probability table

Threat	P(WT|TL)	P(EI|TL)
	[extremely severe, severe, general, fine]	[very strong, strong, medium, weak, very weak]
High, medium and low	0.5 0.3 0.1 0.0	0.5 0.3 0.1 0.1 0.0
	0.1 0.2 0.4 0.3	0.1 0.2 0.4 0.2 0.1
	0.0 0.1 0.4 0.5	0.0 0.1 0.2 0.3 0.4
Threat	P(LT|TL)	P(RP|TL)
	[short, medium, long]	[in the area, on the edge of the area, outside the area, only having a position relationship]
High, medium and low	0.1 0.3 0.5	0.5 0.2 0.1 0.0
	0.3 0.5 0.2	0.3 0.4 0.2 0.1
	0.5 0.3 0.1	0.0 0.1 0.5 0.4
Threat	P(AA|TL)	P(TP|TL)
	[very low, low, medium, high, very high]	[single threat, superimposed threat]
High, medium and low	0.0 0.1 0.1 0.3 0.5	0.2 0.8
	0.1 0.2 0.4 0.2 0.1	0.6 0.4
	0.4 0.3 0.2 0.1 0.0	0.8 0.2

2 Application in examples

In this paper, the manned/unmanned aircraft of Anhui aviation rescue system is taken as an example. The manned/unmanned aircraft of this system perform aerial photography, rescue and disaster relief tasks throughout the province. The terrain of Anhui is high in the southwest and low in the northeast, with various landforms, and there are mainly plains, hills and low mountains. The Yangtze River and Huaihe River run through the province, dividing the province into three natural areas: Huaibei Plain, Jianghuai hills and mountainous areas in southern Anhui. The terrain is vast to the north of the Huaihe River. There are mountains between the Yangtze River and Huaihe River in the west and continuous and unbroken hills in the east. There are many steep mountains and strange peaks in the mountainous areas in southern Anhui. Anhui lies in the transition area between warm temperate zone and subtropical zone. With the Huaihe River as the dividing line, the north has a warm temperate semi-humid monsoon climate, and the south has a subtropical humid monsoon climate. It is mainly characterized by mild climate, abundant sunshine, obvious monsoon, and four distinct seasons. Affected by the monsoon climate throughout the year, there are obvious regional differences in precipitation, and the annual variation is very large. There are frequent flood and drought disasters and low pressure. Winter is dry, cold, and windy, and summer is hot and rainy. The general weather in July in southern Anhui is taken as the initial threat condition, and the prior probability of TL node is set. After initialization, when the evaluation system gets the update of the meteorological threat information of the leaf node, the inference of the Bayesian network is triggered, and the probability distribution of each network node is updated. Finally, the probability distribution of the state of the root node is obtained to complete a meteorological threat assessment. Matlab was used to simulate the algorithm, and the algorithm flow was shown in Fig. 2. Table 2 shows the results of meteorological threat degree assessment under different assessment factor state values.

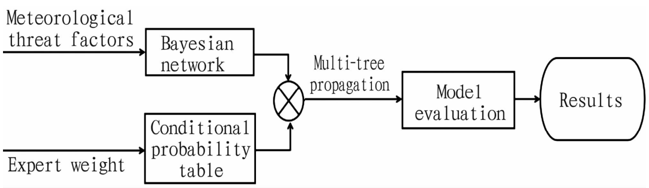

Fig. 2 Algorithm flow

As can be seen from the first group of data in Table 2, under the same meteorological conditions, such as strong thunderstorms or hail accompanied by other bad weather conditions, when the manned/unmanned aircraft flew near the center of the meteorological action area, the probability of high threat degree was much higher than that when the manned or unmanned aircraft carried out the collection task alone. For the probability of medium and low threat degree, the threat degree was determined by the maximum probability method, and it was high. The second group of data shows that in a coordinated search and rescue by the manned or unmanned aircraft, under the same climatic conditions such as rain and snow weather accompanied by other adverse meteorological conditions (such as accumulated ice) and the premise that the meteorological effect was not strong, the threat assessment level was more likely to be medium than that when there was a single manned or unmanned aircraft flying near the meteorological effect area. In the third set of data, the meteorological condition was cloudy weather, and the aircraft was at the outer edge of the meteorological area, the assessed threat level was low whether there was a coordinated search or a separate search.

The above conclusions were drawn in the given case of prior probability. If the prior probability is changed and the state values of meteorological threats in the table above remain unchanged, the data of threat level distribution probability in the table will change significantly, and the assessment results will be changed. This shows that in the Bayesian method, the prior information has a memory effect, and its evaluation results are related to not only the current information but also historical information, so the algorithm has an accumulation effect.

Table 2 Results of meteorological threat assessment

No.	Meteorological threat assessment factor	Assessment factor status value (λ)	Threat level distribution probability (*Bel*)
1	WT	[0.5 0.3 0.1 0.0]	[0.781 6 0.211 1 0.007 3]
1	EI	[0.2 0.5 0.1 0.1 0.0]	[0.781 6 0.211 1 0.007 3]
1	LT	[0.3 0.5 0.2]	[0.781 6 0.211 1 0.007 3]
1	RP	[0.5 0.3 0.1 0.0]	[0.781 6 0.211 1 0.007 3]
1	AA	[0.0 0.1 0.2 0.5 0.2]	[0.781 6 0.211 1 0.007 3]
1	TP	[0.3 0.5]	[0.781 6 0.211 1 0.007 3]
2	WT	[0.1 0.5 0.2 0.2]	[0.036 1 0.897 2 0.066 7]
2	EI	[0.0 0.2 0.5 0.2 0.1]	[0.036 1 0.897 2 0.066 7]
2	LT	[0.4 0.5 0.1]	[0.036 1 0.897 2 0.066 7]
2	RP	[0.5 0.3 0.1 0.1]	[0.036 1 0.897 2 0.066 7]
2	AA	[0.1 0.3 0.4 0.2 0.1]	[0.036 1 0.897 2 0.066 7]
2	TP	[0.4 0.5]	[0.036 1 0.897 2 0.066 7]
3	WT	[0.1 0.1 0.5 0.3]	[0.001 6 0.387 4 0.705 0]
3	EI	[0.0 0.1 0.2 0.5 0.2]	[0.001 6 0.387 4 0.705 0]
3	LT	[0.6 0.3 0.1]	[0.001 6 0.387 4 0.705 0]
3	RP	[0.0 0.1 0.2 0.5]	[0.001 6 0.387 4 0.705 0]
3	AA	[0.6 0.2 0.1 0.1 0.0]	[0.001 6 0.387 4 0.705 0]
3	TP	[0.6 0.3]	[0.001 6 0.387 4 0.705 0]

3 Conclusions

In a coordinated search and rescue by manned or unmanned aircraft, under complex meteorological conditions such as low pressure and thin oxygen, meteorological threats will have a great impact on the safe flight of manned or unmanned aircraft. In this study, weather-related factors and coordination factors affecting the safe flight of manned/unmanned aircraft were analyzed, and then a Bayesian network model was established. Bayesian network reasoning method was used to model and evaluate the meteorological

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ecology and are suitable for the sustainable development of urban parks through public bidding, establish fair comprehensive assessment criteria for project profits, implement the indicator elimination system, and improve the professional and efficient level of park management save government management costs and improve management efficiency. To promote the integration of culture, business and tourism, it is necessary to plan diversified sports events, cultural and recreational activities, commercial consumption, *etc.*, without affecting the ecological environment of parks, and encourage the appropriate integration of culture, sports, tourism and business, so as to ensure the orderly management of parks and efficiently transform the ecological value.

3.4 Improving the system of laws and regulations and relevant laws, norms and standards The local system of laws and regulations should be improved, and the laws and regulations of urban parks should also be improved based on the experience of advanced cities, so as to formulate a system of laws and regulations for park management that is systematic, detailed, strict, fair and just. The standards of park management should be drawn up, and for important parks, and the boundaries of responsibilities and rights of park management administrative subjects, law enforcement subjects and responsibility subjects, as well as provisions on the specific content of park management, facility management, operation mode, management personnel training and other aspects should be clear. A scientific legal basis should be created to protect the park ecological background and sustainable development. According to the relevant requirements for the construction of demonstration areas of park city, standards for park operation and management that meet the development needs of Chengdu should be formulated to provide technical support for the realization of the ecological value of parks. Meanwhile, the basis for law enforcement should be strengthened, and patrol commissioners, law enforcement teams, inspection teams and other departments should be configured under the special park administration bureau to restrain illegal and unethical phenomena during park management.

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threat degree. Simulation results show that the algorithm can reasonably evaluate the complex and varied meteorological threats to the coordinated search and rescue of manned or unmanned aircraft, and improve the safe flight rate of manned/unmanned aircraft in the process of coordinated search and rescue.

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