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Application of Data-Driven Bayesian Belief Network for the Analysis of Factors Contributing to Risk of Civil Aircraft Shooting Down Over Conflict Zones

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Aviation security incidents such as shooting down civilian aircraft over the conflict zones stay one of the most significant challenges of civil aviation industry. While industrial regulations do not provide standardized objective risk assessment methodology, a significant array of publicly accessible data is available for an analysis with the help of machine learning algorithms. This study demonstrates a possibility to utilize data-driven Bayesian Belief Networks in order to develop probabilistic model and identify factors influencing on aviation security event.

Keywords: Bayesian Belief Networks, data-driven, probabilistic model, risk, security, aviation.

1. Introduction

International regulations require air carriers to implement a process of risk assessment (ICAO, 2018), however the tool recommended by the regulations to facilitate this process – risk matrices – have several disadvantages. Risk matrices are susceptible to ambiguity and uncertainty (Anthony Cox Jr, 2008; Duijm, 2015).

Large arrays of publicly available data can contribute to the process of risk assessment of civil aircraft overflying conflict zones. Our previous research identified a number of economic and geo-political factors that influence aviation security and can be used to calculate the probability of civil aircraft shooting incidents. Amongst these variables are the GDP per capita, the type of war conflict and its intensity (Bukhman, Brito, & Sung, 2022). In this study the authors adopted a Generalized Linear Model to predict the probability. However, regression models do not support prognostic or diagnostic inference. This type of inference is supported by causal probability models, such as Bayesian belief networks (Qazi & Khan, 2021).

In this paper we propose a data driven Bayesian belief network to predict civil aircraft shooting probability. We use a dataset of nearly 1600 data points containing recent incidents affecting civil aviation flights in the Middle East, the Gulf and North Africa in 2009-2020 (Solutions, 2022). This dataset was supplemented by the data related to geo-political and economic factors.

2. Proposed Methodology

A Bayesian Belief Network is a graphical probabilistic model composed of vertices and edges. Vertices, also called nodes, are random variables and edges capture the causal link between variables. The algorithm to solve a BBN inference was developed by J. Pearl (Pearl, 1985).

3. Risk Assessment Model

To build the model we will use structural learning capabilities of BBN and EM (Estimation-Maximization) algorithm (Hugin, 2022). The datasets used for the model consist of:

1. A dataset of security related incidents and weapons used in conflicts (Solutions, 2022).

2. A dataset of conflict type (*1 – extra-systemic, 2 – interstate, 3 – internal, 4 – internationalized internal conflict, 5 – absence of a conflict*) and intensity (*1 – minor conflict, 2 – war, 3 – no conflict*) (Harbom, 2010) .
3. The data of income categories of countries that replaces GDP per capita for this model as Bayesian Belief model requires categorical data (*1 – Low-, 2 – Lower-middle-, 3 – Upper-middle-, 4 - High-income economies*) (Bank, 2022).
4. A dataset consisting of the types of weapon (*1 – anti-aircraft artillery; 2 – anti-tank guided missile; 3 – anti-tank weapon; 4 – conventional surface-to-air missile; 5 – improvised explosive device; 6 – Rocket / Mortar / Artillery; 7 – rocket-propelled grenade; 8 – small arms; 9 – surface-to-surface missile*).
5. A dataset consisting of the type of incident/event (*1 – missile launch, 2 – Air & Air Defence Activity, 3 – UAV Event, 4 – Weapon test, 5 – Projectile event*).

4. Simulation results

For the simulation we run the Bayesian Belief model using Hugin software, the result is provided on Fig 1. This example demonstrates probability distribution given minor (*intensity_level = 1*) internationalized internal conflict, meaning a conflict between the government and internal opposition, with intervention from other states (Harbom, 2010) (*type_of_conflict = 4*) in a country with low-income level (*income_cat_q = 1*) and using rocket/mortar/artillery (*weapon_type = 6*) that can cause projectile event with probability of 93.71%.

The accuracy of the model calculated with built in tools of Hugin software is 69%, according to the research literature this is a good fit (Marcot, 2020)

5. Conclusions

Identification of factors causing aviation security event is extremely important in current geo-political circumstances. It can support decision making process of planning civilian flights to or over conflict zones. Data-driven approach utilizing Bayesian Belief Networks can bring benefit to current risk assessment and decision-making process in the industry.

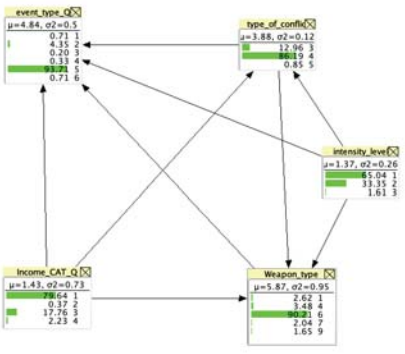

Fig. 1. A Bayesian Belief model representing probability distribution of factors influencing on aviation security event

References

Anthony Cox Jr, Louis. "What's Wrong with Risk Matrices?". Risk Analysis 28, no. 2 (2008): 497-512.

The World Bank. World Bank Country and Lending Groups. 2022.

Bukhman, S., M. P. Brito, and M. Sung. "Predicting Surface-to-Air Shooting of Civil Aircraft in a Geo-Political and Conflict Environment (Unpublished)." 2022.

Duijm, Nijs Jan. "Recommendations on the Use and Design of Risk Matrices." Safety Science 76 (2015/07/01/ 2015): 21-31.

Harbom, Lotta, and Peter Wallensteen. 2010. "Armed Conflicts, 1946-2009." Journal of Peace Research 47 (4): 501–9.

The Hugin Graphical User Interface.

ICAO. "Risk Assessment Manual for Civil Aircraft Operations over or near Conflict Zones, Doc 10084." 2018.

The Aircraft Accident Investigation Board of the Islamic Republic of Iran. "Flight Ps752 Accident Investigation. Final Report.", 2021.

Marcot, Bruce G., and Anca M. Hanea. "What Is an Optimal Value of K in K-Fold Cross-Validation in Discrete Bayesian Network Analysis?". Computational Statistics 36, no.3(2020): 2009-31.

Aviation Safety Network. "Aviation Safety Database - Contributary Cause Security." 2022.

Pearl, J. Bayesian Networks: A Model of Self-Activated Memory for Evidential Reasoning. UCLA Computer Science Department, 1985.

Qazi, Abroon, and M. Sajid Khan. "Exploring Probabilistic Network-Based Modeling of Multidimensional Factors Associated with Country Risk." Risk Analysis 41, no. 6 (2021): 911-28.

Osprey Flight Solutions. 2022.