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Intelligent Vision Based Decision Making System for Aviation Accidents and Incidents

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Abstract: Safety has become the primary concern for the air transportation system nowadays primarily due to increasing air traffic throughout the world. Various regulatory bodies have been maintaining enormous amount of aviation accidental data repositories. This past data is highly complex because of its many temporal and geographical components along with multiple variables. To be able to analyze this past data, there is always a need of user friendly and GUI based System. This article has proposed an intelligent vision-based decision-making system for the exploration of past aviation accidents and incidents dataset. The proposed visual query-based model is capable to analyse the major factors like flight phases, human factors, weather conditions and faulty components in particular aircraft models which are responsible for those unsafe events and may claim life of many passengers who are traveling and crew personnels. This model enables the users to express "what" visuals should be created instead of "how" to create them. Various case studies conducted through visual queries have proved that the system will be highly able to improve situational awareness regarding flight conditions to the crew members and air traffic controllers along with aviation authorities so that they are able to take timely decisions and deciding on what kind of training staff members need to reduce the consequences of such accidents and incidents.

Keywords: Aviation, Safety , Visual System , Data Visualization , Accidents and Incidents
Categories: H.3.1, H.3.2, H.3.3, H.3.7, H.5.1
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1 Introduction

According to the recommendations of the International Air Transport Association (IATA), the global demand for air travel will double in the next two decades [Zhang and Mahadevan 2019]. This quick growth in demand increases safety concerns along with air traffic congestion and the Air Transportation Management (ATM) system's workload. Many attempts have been made in recent years to improve aviation safety and prevent tragic air accidents. An important footstep in this respect is to grasp knowledge from previous incidents and accidents in order to design appropriate mitigative and corrective measures. Numerous agencies and organizations, such as the Federal Aviation Administration

(FAA), the National Transportation Safety Board (NTSB), the National Aeronautics and Space Administration (NASA), the International Civil Aviation Organization (ICAO), and the US National Airspace System (NAS), IATA, and the Aviation Safety Reporting System (ASRS), etc., manage a variety of accident investigation databases pertaining to any past incident or accident [ASRS Program].

1.1 Factors Responsible for Aviation Accidents

Accidents in the aviation industry are mostly caused by a number of different things. Poor visibility from rain, snow, fog, or thunderstorms can make it more likely that a pilot will make a mistake and cause an aeroplane crash [Mahapatra and Zrnic 1991, Guégan et al. 2011, Klein-Paste et al. 2012]. Geographical and meteorological conditions with a complex climate, low pressure, and mountains are very critical [Guégan et al. 2011]. Natural calamities like earthquakes and floods can destroy any airport facility [Smith 1991, Casadevall 1993]. The aircraft's performance may also be affected due to the variation in air density with altitude. Aside from the previously mentioned factors, human factors such as physical workplace (e.g., hanger) and organizational behavior must be taken into account when designing commercial airplanes. Research shows that 70-80% of past aviation accidents and incidents have occurred due to human errors. In particular, there are twelve human factors identified by Transport Canada and known as the "Dirty Dozen" [Wiegmann and Shappell, 2001]. These factors might result in maintenance errors and eventually mishaps.

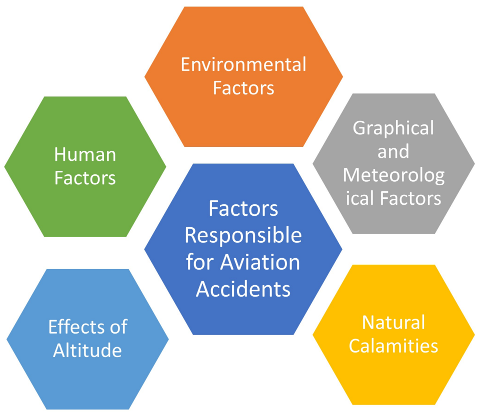

Figure 1: Factors Responsible for Aviation Accidents

1.2 Issues and Research Challenges in Aviation Safety

Although the fatality rate has fallen to such a low level, which makes air transport the safest mode of transportation, the safety performance is not evenly distributed among different countries, regions of the world, and various segments of commercial aviation. There are always ever-growing safety issues and research challenges in aviation [Rohn 2012, Oster et al. 2013, Aviation safety]. Despite the use of new communication and data recording technologies in the aviation industry, there has been a noteworthy improvement in aviation safety. However, there is a need to maintain the safety level and even improve it further. The safety performance of airlines in developing countries, the performance of air axis and non-scheduled operations is another issue. The challenge is to improve safety performance in the case of less effective crew training and inadequate infrastructure. There is a lot of pressure on existing infrastructure at airports like runways and Air Traffic control (ATC). Hence, there is a need to give more attention towards runway infiltration, which may cause serious safety concerns. Human errors need to be rectified to minimize the chances of any mishap. Till date, more focus has been on reactive data analysis. So, another big challenge is to make a more advanced tool for analyzing and showing data so that risk factors can be found before an accident or incident happens in the air.

However, to learn from past crashes and avoid them in the future, efficient tools are required. In order to achieve this goal and lessen the effects of crashes, visual analytics tools have become very popular for exploring data and getting insights from it.

This paper has proposed an intelligent vision-based system for decision making to scale down the likelihood of occurrence of such unfortunate incidents in the field of aviation. The proposed visual query-based model is capable to analyses the major factors like flight phases, human factors, weather conditions and faulty components in particular aircraft models which are responsible for those unsafe events and may claim life of many passengers who are traveling and crew personnels. In overall, the visual system will be highly able to improve situational awareness regarding flight conditions to the crew members and air traffic control members so that they will be able to take timely decisions to reduce the consequences of such accidents and incidents.

Rest of the paper is structures as follows: a brief background of related work done for dashboards development is given in section 2, the proposed intelligent system and its functional modules have been discussed in section 3 and various factor analysis with visualization capability of the model is presented in section 4. Finally, concluding remarks and future scopes are given in section 5.

2 Literature Review

The research community have been paying attention to the analysis of severity of the accidents to find out the key features for accurate and precise prediction of accidents. During this process, the major focus remains on the behavior and accuracy of the used prediction model. At this stage, the interpretation of the causes behind those fatal aviation mishaps is ignored. This issue can be solved by performing the data visualization through dashboards which provide the capability to analyze various features of any dataset to find out the major factors that may affect the harshness of such mishaps. It also helps in visualizing the variation in trend of those features. Numerous studies have already been conducted to examine the characteristics that are primarily responsible for any accident or incident.

[Chen 2004] described information visualization as “computer generated interactive graphical representations of information”. [Li et al. 2022] have proposed a hybrid algorithm, named Light Gradient Boosting Machine-Tree-structured Parzen Estimator (Light GBM-TPE) with data visualization capability to investigate the importance of features during the investigations of accident severity. The proposed algorithm calculates the SHAP values of every parameter of the dataset to identify their impact on the model's prediction accuracy when compared with mean prediction value. The authors have found that "Latitude", "Longitude", "Day of the week" and "Hour" provides more impact on any accident severity. Depending on the observed SHAP values, the vision based technique is employed to decide how much the accident severity is influenced by the decisive factor. This proposed solution performs better in comparison to other algorithms named LightGBM, Gradient boosting Decision Tree ,Logistic Regression, and XGBoost in terms of accuracy, F1, recall and precision.

With the increasing demand of air transportation, safety has become the primary concern for aviation sector. [Zhang and Mahadevan 2019] have proposed a "proactive safety" paradigm with an aim to find out the risk levels of aviation accidents to predict the severity of peculiar events. The authors have proposed a hybrid model consisting of ensemble of deep neural networks and support vector machine (SVM). Initially all the events have been categorized based on risk level and their consequences. Then, relationships between the event synopsis and event consequences have been developed using SVM model. Along with this, an ensemble of deep neural network is trained to find the associations between event outcomes and event features. To blend the results of two machine learning models, an innovative fusion rule is developed. The prediction on risk level category is extended to event level outcomes by using probabilistic decision tree.

Another framework for road accident data visualization and analysis, in temporal and spatial dimensions, has been proposed by [Sunkpho and Wipulanusat 2020]. This interactive dashboard was developed using Tableau which is highly capable in improving the data management. In addition, it provides capability to render the queries using maps and charts. This research helps in implementing the road safety policies in Thailand to reduce the fatal road accidents in future. Following Table 1 provides a brief about the related work done specifically for developing the data analysis and visualization tool in aviation sector:

Author	Purpose	Description	Relative Findings
[Feldman et al. 2022]	To develop GUI for pre-flight planning and proactive situational awareness of flight plan with decision making capability.	This dashboard is named as Supplemental Data Services Provider-Consolidated Dashboard (SDSP-CD). It improves the operator's situational awareness about the flight plan and risk assessment before the flight.	The experiments revealed how users approach risk assessment and interpret interface information. It has been found there is need to improve the interface's information display and help the users to easily understand and interpret it.
[Zhang et al. 2020]	To improve the pilot's dashboard feature extraction capability	This article presents a mask R-CNN method for improving the real-time tracking by extracting the feature information of gaze area in simulated pilot's dashboard.	The proposed method provides improved target feature extraction accuracy.

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Table 1 – *Continued from previous page*

Author	Purpose	Description	Relative Findings
[Wilkins et al. 2020]	Developing a common dashboard for efficient and effective collaboration among NAS stakeholders and TFM	This article presents a web-based platform to support decision making and record actions to facilitate the real time monitoring and alerting tool. To support the collaborative pathfinder process, agile development methodologies were used for proposed dashboard design, engaging with in-house operations specialists to build user stories and acceptance criteria.	This tool facilitates collaborative problem-solving among stakeholders located in different locations in real time.
[Arjun et al. 2022]	Presented an Eye-tracking technology for pilot's cognitive load estimation with development of Virtual Reality based dashboard.	Considering the lack of system to constantly monitor the workload of pilot, this Eye tracking technology provides the solution with automatic monitoring capability. This technology estimates pilot's cognitive load using the properties of 3D graphs and created a Virtual Reality dashboard that visualizes cognitive and ocular data.	The proposed dashboard is able to figure out what is the best information that should be shown to the participants/pilots.
[Patriarca et al. 2019]	Designed a comprehensive safety dashboard to enhance the Safety Intelligence of decision-makers	The authors have presented a structured strategy for learning from previous events which is named as Toolkit for ATM Occurrence Investigation (TOKAI). This can be used as a reporting for Air Navigation Service Providers (ANSPs) about the adverse events. This empowers the capability of the decision makers. It facilitates both exploratory multivariate analysis of system performance and meta-analysis of the inquiry process.	The user-friendly dashboards track comprehensive safety performance analyses and prioritize proactive incremental risk assessment. beginning with the reporting of bad events and progressing to the identification of tasks and factors that should be investigated.

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Table 1 – *Continued from previous page*

Author	Purpose	Description	Relative Findings
[Anderson et al. 2020]	Created a decision-supporting interactive interface to help in the construction and maintenance of an air traffic control tower(ATCT).	Three key criteria, such as economy, safety, and efficiency, were subjected to PCA and hierarchical clustering analysis. This resulted in the creation of an interface that supports the choice of whether an airport should build a tower.	This updated decision aid is essential in giving airports considering the construction of an ATCT more information because the FAA's resources and budget are limited and the price to construct a physical tower is rising.
[Meister et al. 2022]	To design and develop 3D- AR based weather visualization for improving weather communication in General Aviation (GA)	It is a 3D AR thunderstorm cell lifecycle visualization tool. This application helped in terms of more accurate knowledge about the thunderstorm's dynamics. The animation and interactivity of the representation helped to explain thunderstorm theory and could be crucial to improve general aviation weather training.	This 3D AR based visualization could be decisive to reduce the aviation accidents and incidents in future. The machine learning models can inherit this knowledge for improved forecasting.
[Mangortey et al. 2020]	To propose an intelligent and repeatable technique for selection of reduced set of parameters for flight safety and risk analysis.	To remove highly correlated and redundant parameters, correlation analysis is performed. Then metadata and empty parameters are removed during pre-processing, keeping in view the requirements of regulatory bodies. After this, clustering algorithm is used to identify abnormal events and anomalies while grouping the similar flights. Visualization dashboards have been created after performing variance method to identify and analyze parameter significance in cluster formation.	A systematic process for removal of anomalies from the flight operations data can be highly crucial for accident, incident investigation and safety analysis. The proposed techniques can be further used for other flights and air frames.

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Table 1 – *Continued from previous page*

Author	Purpose	Description	Relative Findings
[Pisano and Ciminello 2020]	To develop a Visual Analytical dashboard for examining the structural health conditions of aircraft panel	This article proposed a structural health monitoring system to detect any change in material properties due to any impact. This visualization tool is capable to provide more accurate and timely information for exploration and navigation to the domain experts about any structural change. This information can be further analyzed using Principal Component Analysis-based algorithm.	Various infrastructures in the field of civil, mechanical, and aerospace engineering can be highly benefited by employing these kind of damage detection and identification techniques. This in turn will enhance safety, lower the maintenance costs and extend operational life.

Table 1: Review Summary of Dashboard Designing

Most of the studies have been done to figure out how to design the interface for applications like flight planning, flight simulators, weather issues, feature extraction, etc. There are few research on aircraft accidents and incidents that employ information visualization approaches to seek trends and uncover connections and relationships in the accident records. For this reason, data visualization utilizing a graphical user interface (GUI) is crucial because it reveals previously hidden facts when applied to accident data from the past. These investigations motivate the need for the development of visual analytics tools, which could be crucial to study this ever increasing pool of heterogeneous accidental data for safety analysis. There is need for an intelligent visualization based analyses system that can choose a reduced set of significant parameters which are highly responsible for accidents. The proposed visualization based model could also be useful for quickly reviewing historical crash data and examining the underlying causes.

3 Proposed System Model

Identification of hazards, evaluation of risks, collection and analysis of data are all essential component of a functional safety system model. We create a framework for analyzing spatio-temporal data. Expressiveness and ease of use are the key component of any visualization based query model. With this aim, the proposed system supports multiple visual queries with user friendly interface. Figure 2 depicts the system's functional modules. Users can perform visual searches by interacting with various graphical components of the interface like map and widgets.

When user interact with the interface by forming visual queries, each command with specified constraints causes a query to be generated at the back-end, which is then interpreted as VizQL [Hanrahan 2006]. Now further it makes a connection to dataset via SQL connector and interpret the results in the form of visuals on the interface. Once the query results have been retrieved, the system presents them on the map, allowing users to visually improve their queries repeatedly. This model enables the users to express "what" visuals should be created instead of "how" to create them. Any user on the aviation team, regardless of their familiarity with query languages, can now unlock the full potential of their data through a user-friendly visualization interface.

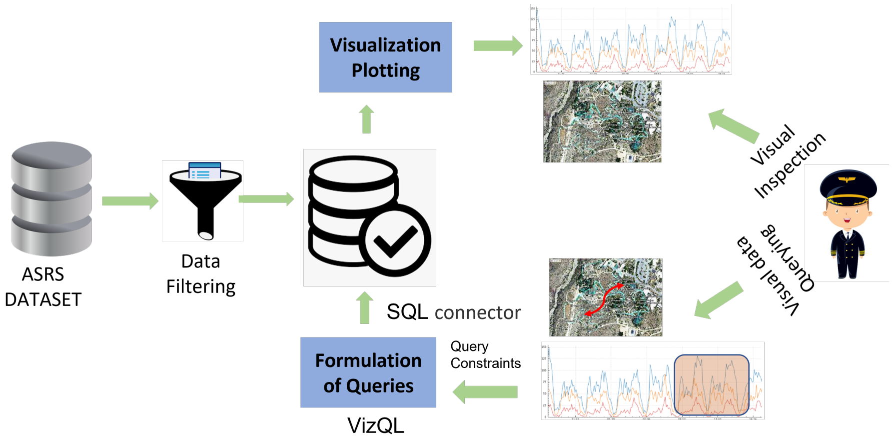


Figure 2: Proposed System Functional Modules

3.1 Data Gathering

In this implementation, the ASRS dataset is used as it covers every practical aspect of aircraft accident. As part of the NASA and FAA agreement for reporting aviation incidents and accidents, this dataset has accident information since April, 1976. The ASRS database is the world's largest archive of voluntary, confidential safety information contributed by front line professionals in aviation, such as pilots, controllers, mechanics, flight attendants, and dispatchers [ASRS Database]. The confidentiality and independence of the ASRS dataset are decisive factors for its long-term success in identifying various latent system threats in the National Airspace System (NAS). This database serves as the foundation for further study on a wide range of aviation safety issues. The database also contains expert analyst's coded information from the original report which is used for data retrieval and analysis.

3.2 Data Preprocessing

In order to convert the raw data into a clean dataset with more usefulness and efficiency, data pre-processing is performed. Since ASRS contains a range of heterogeneous data (e.g., text data, category data, and numerical data), developing a visualization model from the complete dataset is difficult. When combining and analyzing data, cleaning up dirty data makes it simpler. It is challenging to create an information visualization tool that can study the complete dataset at once. So, the visualization model has been developed on 50229 records of data which spans across 10 years of data starting from 2011 to 2020. Here, in this article, ϕ_k correlation coefficient which is refined version of Pearson's Contingency test [Baak et al. 2020], is used for calculating correlation between the variables whose results shown in Figure 3 . It operates reliably across categorical, ordinal, continuous (interval) variables and capture non-linear dependencies. ϕ_k is accessible via a public Python library. Since the used dataset have 68 categorical and 13 numerical variables phi_k is the best choice for this dataset. Features with less than 95% missing values are selected. Threshold of correlation for feature selection is marked as 0.7. It is thus capable of not only identifying the most significant traits, but also deciding how many features should be maintained for optimal applicability.

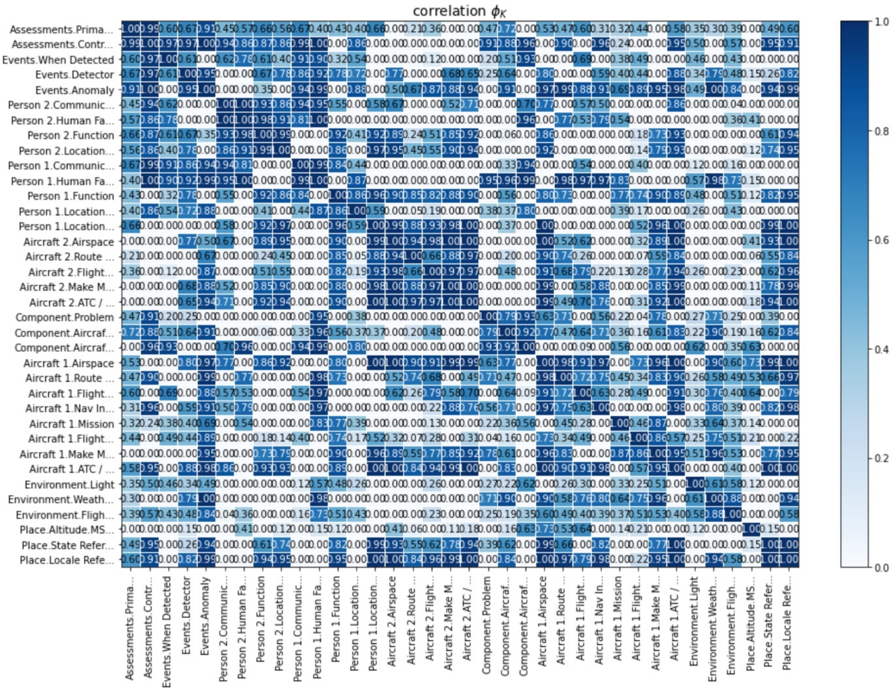


Figure 3: The ϕ_k correlation matrix between variables

3.3 Visualization Interface Creation

A broad variety of visualization methods are available in Tableau [Tableau 2022], including bar graphs, line charts, pie charts, and geographic charts with longitudes and latitudes. Users can choose from a wide range of choices in Tableau. An interactive dashboard is created with the help of Tableau that will answer research questions and help in taking informed decisions. Tableau offers the option of copying and pasting tables into its interface or directly connecting to a data source. In this study, a PostgreSQL database was linked directly so that all the fields may be used in subsequent visualizations for deeper investigation. It has shelves that let the user drag an attribute into a certain area to make it part of the visualization. It enables us to select and filter data to find out hidden information that is challenging to observe manually from large datasets.

4 Intelligent Vision based Decision Making System

The proposed intelligent visualization based system has been designed to facilitate an interactive analysis of ASRS data which would help in taking informed decisions and initiating actions to handle an unusual situation. This system combines the visual query model with different visual actions and representations that users can change to meet their needs. Users can run queries on the data by visually altering the conditions like map, time constraints, human factors, aircraft model, etc. In the following subsections, the process of selection of slices for query formulation by the proposed visual system has been presented. Query composition and result exploration with different classes of queries are also discussed here.

4.1 Elements of User Interface

The purpose of designing any dashboard is to provide user interaction with back-end of any visual system. This makes data visualization easier for the user to access datasets and makes decision as per analysis. A visual user interface system incorporate information like stats, schedules, analytics and much more. Proper planning and research is must to design any user friendly interface. The proposed intelligent visualization system consists of many components like map, time selection widget, human factors analysis widget aircraft model analysis widget as shown in figure 4. The major components of the system along with their roles are described as follows:-

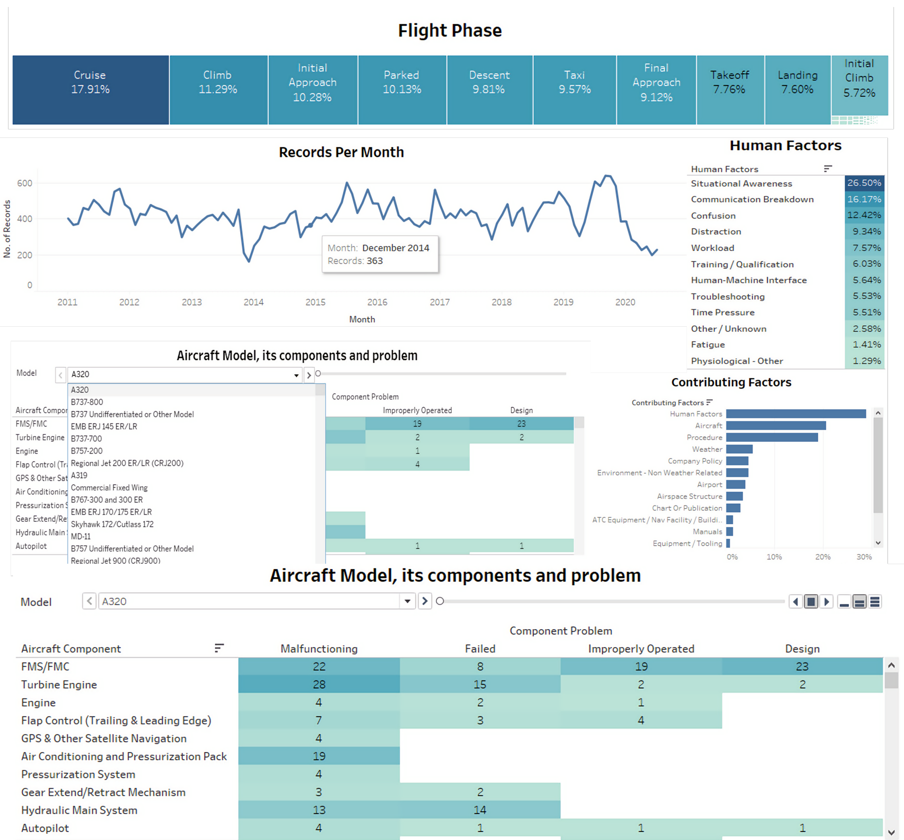


Figure 4: Visualization Interface Components

- **Map:** Maps serve numerous purposes in this framework. They provide a canvas for presenting the query results, allow users to establish spatial constraints, as well as construct and improve queries. The visual representation for this type of data is a point cloud. Spatial constraints can be created by clicking on the bubble on the map; that creates a single region spatial constraint. The user can keep only the selected region by clicking on the 'keep only' button on the tool-tip. The selected region can be excluded by clicking on the 'exclude button' on the tool-tip. Atomic spatial constraints can be clubbed to form complex queries. Multiple regions can be selected by using the rectangle, lasso, and radial buttons appearing on the top left corner of the map interface.
- **Time Selection Widget** Users can establish time constraints using this widget. A user can select a year by clicking on the drop-down. This drop-down allows the user to select all, a single, or multiple years. A user can select and deselected all the years by selecting and deselecting the "All" check box. Single selection can be done by only selecting the required year check box, and multiple selection can be done by selecting the required year check box from the drop-down.
- **Human Factors Widget** This widget allows users to select and specify major contributing human factors. It is defined through the drop-down list, which allows the user to select the required attribute.
- **Aircraft Model Widget** This panel enables users to select an aircraft model with its components.
- **Chart Filters** This allows us to select attributes on the chart and filter other graphs based on the attribute selected.
- **Distributions** Few charts on the dashboard allows us to see distribution of various attributes.

4.2 Building and Designing Query Model

The selection (and refinement) of data slices through query restrictions is a key parameter in query formulation. Queries in our model adhere to the following structure:

```
SELECT * FROM  Flights
WHERE <conditions>
```

Instead of need to type the conditions in the WHERE section, they can do so visually. There are three types of constraints in the proposed model: geographical, temporal, and attribute constraints. These restrictions apply to parameters in the ASRS data-set. Furthermore, each inquiry is linked to the set of dangerous occurrences and hazardous procedures that appear in its results. A query is made up of a set of restrictions on space and time.

Temporal constraints define time frames that restrict the values of the selected year. An ASRS record satisfies the constraint if time = selected year. If multiple years are selected then ASRS record satisfies the constraint if $time = Year_1$ OR $time = Year_2$ OR $time = Year_{\mathrm{n}}$.

Equalities conditions can be used to specify **Attribute constraints**. If $ASRS.A = a$ for the specified value a, the ASRS record meets the attribute equality requirement associated with the category attribute A.

Spatial constraints uses region conditions to express query result. If for the given value a, $ASRS.State = a$, then the ASRS record meets the spatial constraints associated with the categorical attribute State.

Existing atomic queries can be combined to build new atomic queries. Given two atomic queries Q1, Q2, it is possible to design a new query Q3 such that $result(Q3) = result(Q1) \cap result(Q2)$. This is possible because query constraints are closed under intersection, a fundamental property.

4.3 Query Articulation

The suggested query visualization approach can provide numerous responses to inquiries over the aviation accident dataset . User are capable of performing atomic and complex queries. This model is capable of responding to following types of questions by choosing data slices over the user interface:-

- Spatio-temporal distribution and relation between flight conditions, light and involvement of passengers.
- Finding most occurring anomaly, contributing factors, human factors and relation between them that leads to unsafe occurrences and hazardous operations.
- Figuring out faults in aircraft.

4.4 Query Result Visualization

This involves rendering the ASRS records on a map and then applying the filters to get various visual representations. During visualization and interaction with ASRS Data, when query results are shown on a map, they can be filtered in different ways to make different visual representations. The approach proposed in this article provides support for visual representations that are appropriate for the attribute types associated with the ASRS record.

4.4.1 Case Studies

This section offers a few case studies that proves the usefulness and ease of use of the proposed intelligent decision making visual system . Finding and investigating the major causes of unsafe occurrences and hazardous operations will help the user to make an informed decision the possibility of such events in the future.

4.4.1.1 Rendering Hazardous and Unsafe Occurrences on a Map

A hazard is a circumstance that has the potential to cause or contribute to an incident or accident involving an aircraft. Although risks are an inescapable aspect of aviation activities, they can be controlled through mitigation techniques that reduce the likelihood of the risk occurrence which leads to a harmful situation. The first phase in the safety management process is hazard identification. Important and common aviation-related dangers include flight visibility conditions represented in terms of visibility, cloud distance, and ceiling. The map in Figure 5, shows the year-wise distribution of unsafe and hazardous occurrences with the number of records in that specific region,along with three more charts that shows the distribution of flight conditions, light, and involvement

Figure 5: Year-Wise Distribution of Hazardous and Unsafe Occurrences Across the World

of passengers in those hazards occurrences. The flight conditions includes Visual Meteorological Conditions (VMC),Instrument Meteorological Conditions (IMC), Mixed Flight Conditions (MFC) and Marginal conditions which describe the weather conditions that are suitable for the pilot to fly the aircraft safely. In VMC, pilots have sufficient visibility to control aircraft while in IMC pilots don't have sufficient visibility. MFC is the condition in which there are no predefined and fixed flight conditions. After the visual analysis of data via UI, it is found that most of the unsafe and hazardous occurrences are recorded in VMC and MFC flight conditions. Also, we are able to identify those areas which are more prone to VMC and MFC flight conditions. The provided information helps in updating situational awareness and flight strategy as per flight condition. At the same time, it can also be integrated with flight planning applications that can raise alerts to avoid such risky regions during flight.

The amount of light also plays a vital role in flight conditions. Light chart on the right hand side in Figure 5 shows that most of the unsafe and hazardous occurrences are recorded in daylight, followed by night, dusk, and dawn, respectively. However, night crashes cause pilot fatality compared to day times. This confirms that night incidents are slightly more likely to be fatal. During the night, it is harder to observe the things like hills, mountains, power stations etc. Basically, the pilot can't see the obstacles he wants to avoid. Also, It has been noted that the majority of unsafe and dangerous incidents that occurred after 2015 involved passenger planes. These finding can helps in air traffic planning and flight clearance timings.

4.4.1.2 Anomalies Identification

There is an increasing emphasis on proactive safety management systems to enhance the safety of present air carrier operations. A series of instances with similar features might potentially highlight safety concerns. The objective of flight anomaly detection is to identify significant types of unsafe situations. Figure 6 represents the distribution of anomalies identified in the ASRS dataset. More than one-third of all anomalies involved a non-adherence violation such as failing to follow: established procedure, a traffic controller clearance, or a Federal Air Regulation (FAR). These events illustrate how

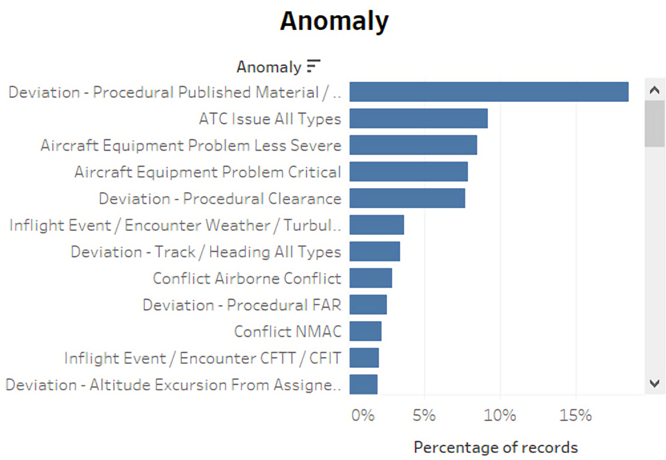


Figure 6: Distribution of Anomalies Identified

even professional, well-trained pilots, controllers, and others might find themselves in a situation where a regulation or procedure is not followed . It also indicates about how a FAR or published method matches up with a person's ability to follow it in a certain situation. This visualization will help to formulate measures and plans for the future that may support flight condition based monitoring and maintenance which would reduce the unsafe occurrence caused due to major types of anomalies.

4.4.1.3 Factors Contributing Towards Unsafe Occurrences

The major goal of risk management is to concentrate on factors that pose the highest threats. Every system is inherently risky when it comes to safety but there are other factors also which can cause catastrophic aircraft accidents. Figure 7 shows the distribution of contributing factors to any unsafe occurrences. It is observed that the three most common contributing elements are human factors, followed by aircraft model and procedures. These factors are responsible for 68.34% of all hazardous and unsafe events. Human error has emerged as a major issue in both maintenance procedures and air traffic handling. Medical, psychological, economic, working environment and educational components are the major human factors that have an impact on aviation safety. Hence, there is a need to develop innovative techniques for enhancing the capacity to make decisions in emergency situations with proper training. Figure 8 provides insights about various human factors that contribute to hazardous and unsafe occurrences.

As we can observe that three most common human factors that lead to such incidents are situational awareness, communication breakdown, and confusion. As a whole, these three contribute 55.09% of the total factors. To avoid the future disasters, it is immensely essential to target these factors. Also this Information helps aviation authorities for conducting trainings that allows workers to hone their observational skills with maintaining calm and alert conditions. This would also help in taking informed and advanced decisions by the pilot or other related personnel like engineers, ground staff, etc.

The outcomes derived from the visual inspection of data can improve decision-making and prevent pilot error-related incidents. Keeping in view these observations, the

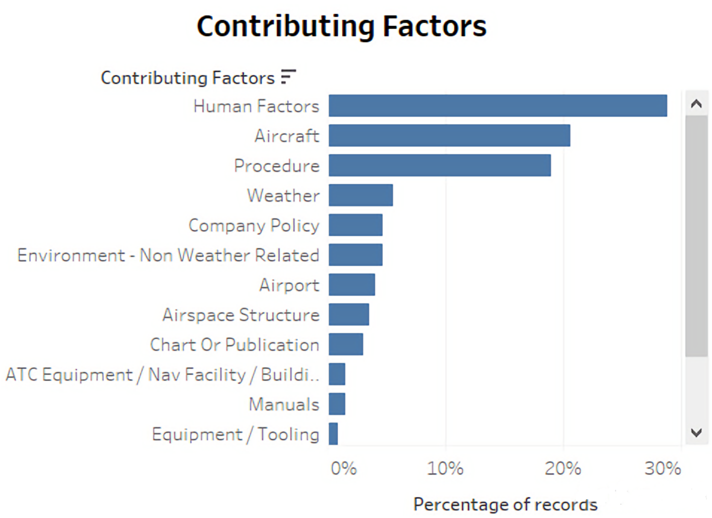


Figure 7: Distribution of Contributing Factors

aviation industry can also improve other related infrastructure implementations, aircraft maintenance, and more importantly, the pilot training process can be improved.

Human Factors

Human Factors	
Situational Awareness	26.50%
Communication Breakdown	16.17%
Confusion	12.42%
Distraction	9.34%
Workload	7.57%
Training / Qualification	6.03%
Human-Machine Interface	5.64%
Troubleshooting	5.53%
Time Pressure	5.51%
Other / Unknown	2.58%
Fatigue	1.41%
Physiological - Other	1.29%

Figure 8: Filter to Select Human Factors

This visualization tool is also able to identify the distribution of anomalies for each human factor that leads to hazardous and unsafe occurrences as shown in figure 9. We can filter the Human factor by selecting from drop-down list which will give us the percentage of occurrence of each anomaly. This relation between each human factor and anomaly will help us to understand the reason why human is facing such situation. Ultimately,

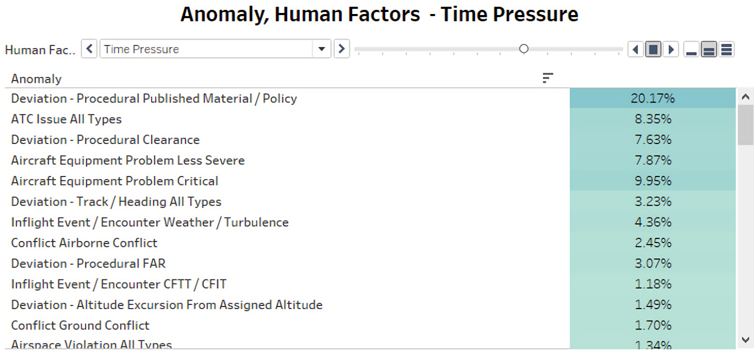


Figure 9: Distribution of Anomaly for Each Human Factor

this would aid in making decisions to prevent the occurrence of any catastrophe or at least to mitigate its impact. Divergence in procedural published material/policy, which accounts for 20.17 percent of total variables, is also established as a key cause of the occurrence of the most common human factors.

4.4.1.4 Identifying Faulty Aircraft Components

Faulty equipment is one of the most frequent causes of aviation accidents. Defects in aeroplanes can be caused by a design flaw, a manufacturing flaw, or normal wear and tear. Despite the fact that the plane is inspected before and after each flight, mechanical errors are the second prominent cause behind aviation accidents. Keeping this in mind, there is a need to study and identify those aircraft models which have history of mechanical faults. This visualization tool can filter such aeroplane models by selecting them from a drop-down menu as illustrated in in the upper portion of figure 10. In the UI, the aircraft models are organized in declining order based on the number of problems encountered. About 20.65% of aviation accidents have occurred due to some mechanical fault in aircraft.

In addition, we can also determine the problematic component of each aircraft model as well as the type of difficulty that component is experiencing. Early detection of problems can avert malfunctions or failure. Though not all mechanical failures result in crashes, passengers and crew members may be gravely harmed if one or more aircraft components fail. It is also observed that the A320 aircraft model has the highest records in the ASRS dataset and common problems included in it are manufacturing of turbines and FMS/FMC design issues. Figure 11 displays the list of manufacturers of faulty components in descending order of the number of records. The Boeing model has the record for most faulty components in the ASRS dataset. This visual system also creates a list of faulty components developed by a particular manufacturer. Here is a list of Boeing-manufactured faulty components, as seen in Figure 12. The oxygen system, crew door, and main gear are the components with the highest defects.However, based on these records, we conclude that diagnostic systems are required for the detection of fault in aircraft system at an early stage of their emergence. The results of this analysis may help supervisory authorities make choices between manufacturer and components on the basis of safety. Additionally, they can assist aeroplane operators in identifying malfunctioning units that require special care. To get rid of the safety risks caused by the most faulty

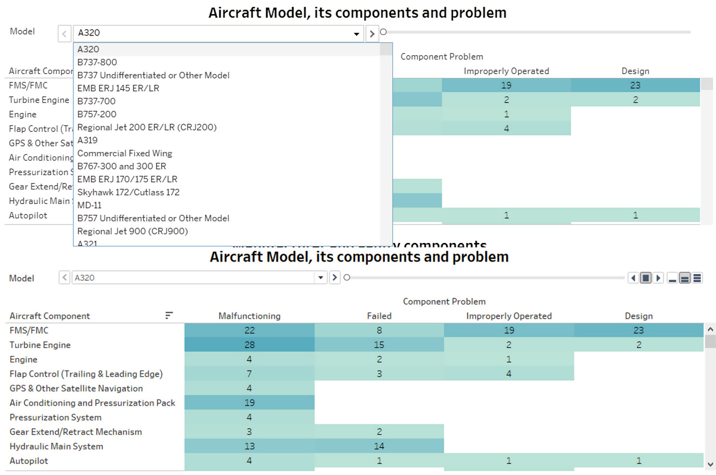


Figure 10: Filter to Select Aircraft Model

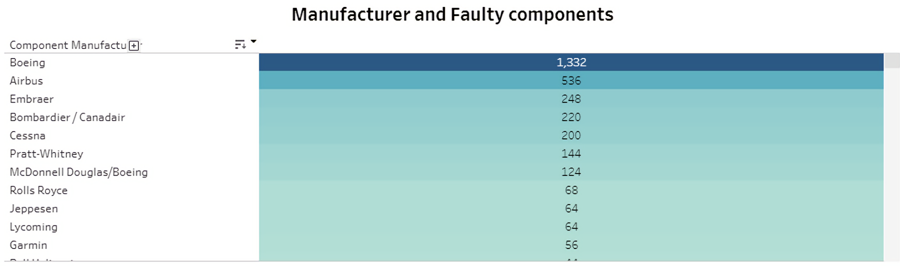


Figure 11: Manufacturers of Faulty Components

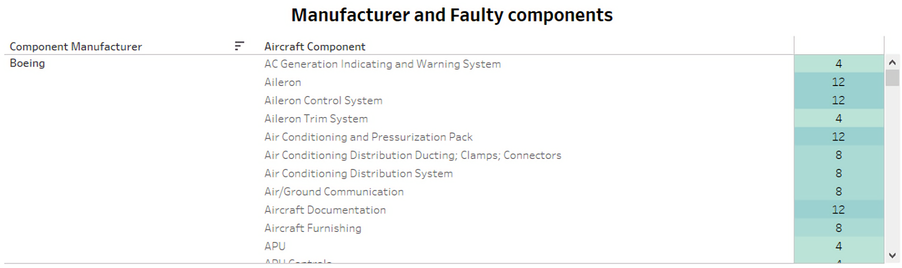
parts of an aeroplane, the aviation authorities should work closely with the manufacturers to create effective modification programmes for these models or components.

4.4.1.5 Studying Behavior Over Time

Understanding safety dynamics can be aided by observing the pattern of aviation accidents w.r.t time. This information can be useful to aviation authorities when making decisions regarding safety. Multiple temporal slices can be selected for the analysis in the visual interface, simplifying the comparison procedure. The following are a few observations discovered in the data after visual inspection.

- **Contributing Factors:**Studying common contributing factors associated with time will help users make informed decisions. On studying contributing factors, it is observed that there is a slight improvement in cases related to aircraft after 2015. Aircraft contributed 22.01% of all records until 2015, then dropped to 19.12%.

- **Human Factors:** Studying common human factors associated with time will help users detect improvements and new problems that leads to unsafe and hazardous occurrences. When studying human factors, it's clear that human factors confusion


Manufacturer and Faulty components

Component Manufacturer	Aircraft Component	
Boeing	AC Generation Indicating and Warning System	4
	Aileron	12
	Aileron Control System	12
	Aileron Trim System	4
	Air Conditioning and Pressurization Pack	12
	Air Conditioning Distribution Ducting; Clamps; Connectors	8
	Air Conditioning Distribution System	8
	Air/Ground Communication	8
	Aircraft Documentation	12
	Aircraft Furnishing	8
	APU	4

Figure 12: List of Faulty Components that Manufacturer Creates

is getting better, but after 2015, there are more problems with situational awareness and the flight deck.

– **Involvement of passengers:** We can't generalize the data on the involvement of passengers as it is fluctuating a lot year-wise, but if we take an overall look at the trend, then we can conclude that more flights with passengers involved are recorded with unsafe and hazardous occurrences after 2015.

It is also possible to download the reports as Image,.csv, .xlsx , and pdf in order to undertake an exploratory study to uncover significant trends in the data and compile and publish that information in order to improve the decision-making process. In the Table 2, we can see how quickly the most important events occur when user interact with the dashboard.

Events	Average Time Taken(in Sec)
Connecting to Data Source	0.42
Computing Layout	0.30
Executing Query	0.28
Geocoding	0.46

Table 2: Execution Timings of Various Events

5 Conclusion and Future Work

This manuscript proposed an intelligent visualization based decision-making system, particularly for the exploration of past aviation accidents and incident dataset. In particular, the dashboard support users to apply visual queries by rendering over maps and other system components which provides the capability to reveal the underlying causes that could be precursors to safety-related incidents. At the same time, visual query system will contribute towards understanding the variation in trend of those features. Our proposed query system is highly expressive and user-friendly. To show its ability and effectiveness, several case studies have been carried out. The hidden information from the last ten year's ASRS dataset can be selected and filtered out easily using the proposed visual system. The model can identify flight phases, human factors, and aeroplane model along with faulty hardware component that are majorly responsible for aviation accidents and incidents. The outcomes derived from the visual inspection helps in improving situational awareness regarding flight strategy as per flight condition. At the same time, it can also be integrated with flight planning applications that can raise alerts to avoid the likelihood of unsafe situation. Overall, we can say that the proposed vision-based system can prove to be a major turnaround for the aviation sector due to its decision-making capability based on which timely and informed decisions can be taken to reduce the possibilities of accidents and incidents. It also aids in deciding the type of training staff members need to reduce the consequences of unsafe events. In the future, more capabilities and prediction models can be added to the dashboard to be able to get accurate forecasting capabilities. In addition to this the visual system can also be integrated with flight simulators to improve the the training process of the staff personnels.

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