Detection and Analysis of Hard Landing and Near Miss based on Cessna 172G Flight Data and Utilization of Flight Data Monitoring

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Abstract

Hard landing and Near miss are two important factors of flight safety in aviation management as miscalculation in any of them could lead to passengers discomfort or in some cases, a catastrophic disaster. This paper aims at detecting the hard landing and near miss and other important factors in one of the most used flights at our college Aviation Department, Cessna 172 with G1000 and hence providing safety measures to avoid them in flight training for students. Flight Data Monitoring is a program which is organized in the school of aviation that intends to educate students and grade their performances with more sophisticated web based tool. This tool is developed to process, analyze, and visualize the flight data. The instructor uses this tool to fetch data from the flight and analyze performances of students. The tool uses some of the statistical methods and data analytics concepts for data visualization and thus helps improve the safety and quality of the FDM Program.

Keywords: Hard landing, Near miss, Data Analytics, Flight Data Monitoring, Aviation

1. INTRODUCTION

Hard landing is an unfavorable incident that occurs when the flight lands on the ground with a greater force than normal while landing. Hard landings are caused sometimes due to bad weather, mechanical problems or pilot error. There are several proposed methods that can be used to detect hard landing in flights. Hard landing can be measured by measuring the depression of the shock absorber of main landing gears. Hard landings can even be detected by measuring the pressure of hydraulic liquid of the shock absorber which is in direct relation with the vertical force that the plane experiences while landing. These devices are not integrated with all the flights so detection process can be tedious sometimes. There are other devices such as a piezoelectric meter that detects the change in the pressure of the fluid and converts it into electric signals. Unfortunately most of the flights will not have those devices integrated to it. So detecting hard landing using the data collected during flying becomes important. Normal Acceleration is a parameter that can quantify the hard landing incident more accurately. Normal acceleration varies less as the flight descends and spikes up as soon as landing gears touches the ground. However this spike will not last for an entire second. It is because of this reason, sometimes it might miss to track this spike in our data, since the data is being recorded at a rate of 1Hz, i.e., data is captured at every 1 second interval. It is hence concluded that this method is not quite reliable. Even though normal acceleration is the only factor that shows a clear dependency on hard landing, there are other factors that contribute significantly towards hard landing if observed carefully. Researches have shown that the factors like aircraft's pitch, descent rate and indicated air speeds also contribute to hard landing. In fact a steep decrement in the altitude followed by a pitch decrement spike at a sufficiently greater speed can be considered as hard landing. The aim of the paper is to quantify these parameter changes and hence be able to classify landings as hard or soft based on the landing data.

Near miss detection and analysis is yet another crucial part of the Flight Data Monitoring program. Near misses are identified by calculating the closeness of two flights on air. The geo co-ordinates of the flights are fetched when they are closer than the threshold specified. These co-ordinates are later used to plot the flight paths on a map. These plots help the flight instructor to see the whereabouts of the incident and help take appropriate action.

2. TOOLS AND FRAMEWORKS

AmCharts
Amcharts is a JavaScript/HTML5 charts and maps data-visualization library for websites and applications. Amcharts has been extensively used to visualize results obtained for various flight parameters. Amcharts column chart is used to displaying parameters with positive peak results such as indicated air speed, cylinder temperatures, low fuel and skid frequencies. Stacked bar charts with negative values are used to represent positive and negative peak values such as overbanking, overpitching and hardground. These charts provide features like disabling and enabling individual attribute representing chart columns, zooming into the charts to view a subset of values and more.

OpenLayers
OpenLayers is an open-source JavaScript library for displaying map data in web browsers as slippy maps. It provides an API for building rich web-based geographic applications similar to Google Maps. This tool is used for the implementation of near miss analysis. The user provides input date ranges and flights between which near miss incidents need to be found. The map gets an array of co-ordinate values along with the timestamps which is used to plot as a vector layer with labelled timestamps.

3. METHOD

Data Mining
Every flight is equipped with a built-in microchip that records all the flight parameters at a rate of one record per second. Each flight record consists of 64 columns of data which has flights geographical and positional information such as date, time, latitude and longitude, GPS altitude, roll, pitch and yaw and operational parameters such as air speed, normal and lateral acceleration, engine temperatures, pressure readings, voltage and amperage readings and some other values which help to calculate important parameters. The recording starts when the flight engine is turned on and the flight is all set to takeoff. It lasts for several flight trips and this is helpful in statistical analysis of each flight trip. The data gets accumulated over several hundreds of thousands of rows for over a period of months. The chip is removed occasionally to collect the raw data and is stored in a computer.

Data Cleaning
The raw file from the flights are huge and all the values are comma separated. However, proprietary software such as Microsoft Excel cannot handle such big files. First the raw data files are formatted to csv using statistical package and social sciences tool (SPSS). A module is developed that allows the user to upload csv files and moves the contents to database. The data has to go through various stages of processing, formatting and filtering before it is pushed to the database on cloud. Processing of data includes specifying the datatypes (string, integer). Formatting involves stripping out trailing and leading spaces, converting date and timestamps from raw data into appropriate date formats and so on. Filtering data involves removal of unused columns. Appropriate code scripts are written to avoid duplicate records in the database.

Data Visualization
The code basically consists of 3 layers viz. Front end, Back end, Database. The user requests data for a specific parameter whose data needs to be fetched. An Ajax call is made from the front end layer. The API in the back end processes this request and runs the appropriate query to fetch data from the cloud database. Further processing is done and an array of data that has all the information needed for visualization in the front end is prepared. This data is sent and parsed with charts and maps.

Data Analysis

Hard Landing: The current process for deciding that an aircraft has had a "hard landing", and thus may have compromised the safety and integrity of the landing gear, is based on a subjective assessment by the pilot and flight crew. The pilot determines whether a hard landing has occurred based on the pilot's experience and perception of the landing events (R. Kyle Schmidt, 2013). However this information is not reliable as pilots can make errors and there are other factors which might tend for pilot to miscalculate hard landings. Aviation school at Carbondale conducted experiments on flight landings to develop a mathematical model that could classify landings to be "hard" or "normal". It is found that the prime factors that affects landings are faster descending rates, landing at high speeds and

slapping the nose of the flight after touchdown (Lei, Wang & Wu, Changxu & Sun, Ruishan & Cui, Zhenxin, 2014). Most of the flight landings were "hard" as recognized by the pilot whenever the pitch changes abruptly went low. The main reason for this was found to be the descent rate and the air speed of the flight. It is expected that material damage can occur in any landing with a descent rate beyond 10 ft/s. (R. Kyle Schmidt, 2013).

Figure 1. Landing phase

Comparing the results the thresholds for each factors were calculated. It was found to be approximately -3 meters per second descent (-10 ft./sec) at any time around 15 seconds or less to time "t", any speed above the taxi speed limit, for the purpose of the model it was considered to be 16 meters per second (50 ft./sec), a pitch change of -6 degrees per second at time "t" which contributed to the slap and a steady GPS altitude with minimal changes for the next 10 to 15 seconds just to ensure that the incident happened during landing phase and not while the flight was in air. It was then concluded to be hard landing if all these constraints are met simultaneously.

Figure 2. Hard landing visualization
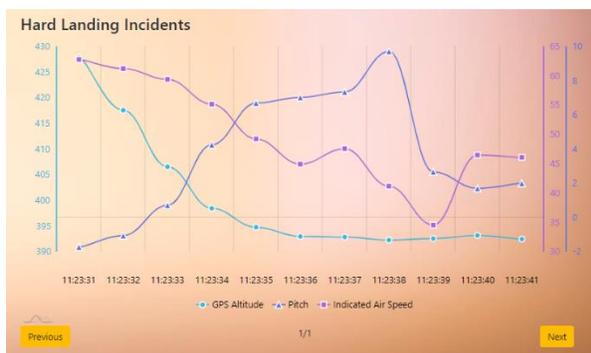
Near Miss: The closeness of 2 flights are decided if their latitude and longitude differences are as close as 0.005 or less and their altitudes are as close as 500 feet. The back end provides an array of data that has latitude, longitude, GPS altitude, and time-date information of both the flights that satisfies the above constraints on their close encounter. The array of latitudes and longitudes are then carefully plotted on the map and are joined by lines with different colors. Timestamps are posted on the lines to give user a clear picture of where the flights were at any a given point of time.

Figure 3. Near Miss Visualization

To give user more insight on proximity between flights, a chart representing the distance of separation of flights during close encounter is plotted over time. This proximity is calculated based on calculating distance between 2 3-D co-ordinate points.

Figure 4. Calculating distance between 2 points in a 3D plane.
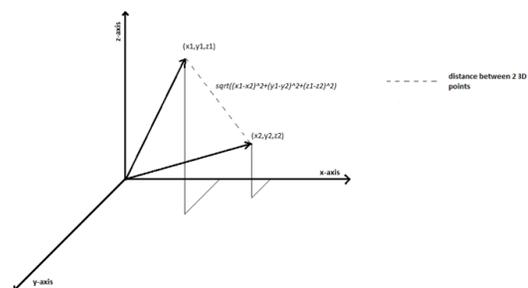
The latitude, longitude and GPS altitude parameters from the flight data can fully define the spatial information of a flight. The co-ordinate differences for x and y axes are calculated by taking the absolute difference between latitudes and longitudes of flights at a time instant. It has to be then converted into feet from degrees.

For every 0.01 degree change in latitude, it corresponds to nearly 2888 feet change and for every 0.01 degree change in longitude, it corresponds to nearly 3630 feet change.

This is used as a source for conversion of degrees into feet. After having all the co-ordinate differences under a common unit, feet. The distance between 2 flights at that instant is calculated using below formula.

Formula 1.

Proximity=sqrt(lat_diff**2 + long_diff**2 + alt_diff**2)

Where

lat_diff   = latitude difference
long_diff   = longitude difference
alt_diff   = altitude difference

all measured in feet.

Figure 5. Flight proximity visualization

It is expected that the proximity graph will usually be a curvature which indicates the flights are nearing till a point and then moving apart.

However it may vary at times depending on the direction of flights nearing and departing.

Engine CHT, Airspeed, Bank, Pitch, Fuel Quantity: Each parameter is visualized based on what information is more important in them. In this scenario, the peak values of these parameters are more crucial. Ex: Lowest fuel quantity attained over a period of month would alert the instructor to take appropriate action and Highest Cylinder heat temperatures measured over a period can be used to see if the behavior is consistent so that Flight analyst can alert for a repair check on that cylinder. Column and Stacked Horizontal Charts are used to display positive peaks and positive/negative peaks respectively.

Frequency Plots

Hard Ground and Skid Frequency: These are the type of parameters where measuring their number of occurences over a period of time becomes more vital than measuring peak values. When an aircraft is flying with zero sideslip, the occupants perceive no lateral acceleration of the aircraft and their weight to be acting straight downward into their seats. An appropriate formula is derived and it is considered that a skid or an uncoordinated turn is said to have happened if the flight roll and lateral acceleration exceeds certain thresholds.

Formula 2.

Skid=(norm_ac>2.8 | norm_ac<-1.5)

Where

norm_ac   = normal acceleration
| indicates pipe or Logical OR

However the data samples are present for every second and counting the number of occurences might not be a straight forward task. Hence all the data samples fulfilling the constaints are gathered and sorted with respect to date/time. Once we have the data sorted with date/time, it is then grouped using date and hour minute part of time and aggregation function is applied.

Table 1. Table before grouping

Local Date	Local Time	Roll	NormAc
03-04-2017	17:28:43	-11.45	0.3
03-04-2017	17:28:44	-12.23	0.27
03-04-2017	17:28:45	-12.1	0.25
03-04-2017	18:05:09	-15.29	0.22
03-04-2017	18:05:10	-15.76	0.23
03-04-2017	18:05:11	-16.2	0.23
03-04-2017	18:05:12	-16.51	0.25
04-13-2017	15:47:23	6.44	0.48
04-13-2017	15:47:25	5.53	0.46
04-13-2017	15:47:26	5.07	0.4
04-13-2017	15:47:28	4.78	0.5
04-13-2017	15:47:29	4.56	0.58
04-13-2017	15:47:30	4.34	0.53
04-13-2017	15:47:31	4.4	0.41
04-13-2017	15:47:32	4.19	0.47

Table 2. Table after grouping

Local Date	Local Time
03-04-2017	2
04-13-2017	1

Trend Analysis

The ultimate goal of FDM program is to prevent unwanted incidents and also analyze the trend of certain incidents over a long period and check if the incidents have been decreased over years after the implementation of the program. Hence we calculate the two important parameters there ever is, hardlanding and nearmiss over all the flights for a large range of time period. We calculate every hard landing/near miss incident that happened on every flight and categorize it based on which year the incident happened.

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6. CONCLUSIONS

After observing the trend it is found that the hard landing and near miss incidents are regulated over years after implementing FDM program. The program was successful in aiding instructors to grade students based on their pilot records. The program also helped students to learn in an efficient way with better visualization of their performances.

7. ACKNOWLEDGEMENTS

8. REFERENCES

R. Kyle Schmidt, (2013). System and method for determining aircraft hard landing events from inertial and aircraft reference frame data.

Lei, Wang & Wu, Changxu & Sun, Ruishan & Cui, Zhenxin. (2014). An Analysis of Hard Landing Incidents Based on Flight QAR Data. 398-406. 10.1007/978-3-319-07515-0_40.

Kakuichi Shiomi & Masanori Saito, (2004). Method for displaying position of an aircraft in a display for air traffic control