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Web Based Dashboard of Airplane Turbulence Mitigation

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Mitigation; weather research and forecasting model; richardson number index;Turbulence.

ABSTRACT

Airplane accidents still occur frequently, one of which is caused by turbulence. To minimize the risk, an effective forecasting system is needed. This research focuses on developing a web-based dashboard for aircraft turbulence mitigation by considering factors such as convective cloud growth, Richardson number index, and wind shear. The dashboard was developed through four steps: requirement analysis, design, implementation, and verification. The Richardson number index (Ri) is calculated using a formula involving temperature and wind speed at different geopotential heights. Alert status is determined based on Ri values and other parameters, with three alert levels: 'Alert 1', 'Alert 2' and 'Alert 3'. The system provides alerts based on user input. If the cloud cover is less than 50%, the "Alert 1" status is displayed; if Ri < 0.25, the "Alert 2" status appears; and if the wind shear exceeds the threshold, the "Alert 3" status indicates that flights are prohibited. Pilot tests show that the system works well and the Ri calculation results are comparable to existing Richardson calculators. The dashboard allows users to access critical information related to turbulence and flight status in real-time, thereby improving flight safety. Timely alerts help in flight-related decision making. This research successfully developed a web-based dashboard for aircraft turbulence mitigation that works well. By monitoring convective cloud growth, Richardson number index, and wind shear, the system is able to provide relevant alerts to improve flight safety.

INTRODUCTION

Aircraft accidents are one of the most serious threats in the aviation industry, which can be caused by various factors, one of which is turbulence (Cao et al., 2018; Kharoufah et al., 2018; Storer et al., 2019). According to data from the International Civil Aviation Organization (ICAO), turbulence accounts for about 65% of total reported aviation incidents. This shows that turbulence is a global issue that affects flight safety and requires greater attention from all relevant parties (Al-Shraideh, 2024; Kılıç, 2020; Sönmezgil, 2016).

In Indonesia, which has many airports and flight routes, turbulence often occurs due to erratic weather conditions and diverse geography (Gössling et al., 2023; Sardjono et al., 2021). For example, in mountainous areas and valleys, rapid weather changes can cause dangerous turbulence. The 2016 crash of Hongkong Airways flight number HX-6704 at

Soekarno-Hatta Airport shows how serious the impact of turbulence can be, where bad weather caused several passengers to be injured.

Several previous studies have tried to address the problem of turbulence using various methods, such as weather modeling and historical data analysis (Muñoz-Esparza et al., 2014; Rodi, 2017; Spalart, 2015). However, many of these studies have not integrated information technology-based approaches to provide real-time information to pilots and flight crews. Past research has shown that mathematical modeling can help in understanding turbulence patterns, but it is not enough to provide fast and efficient warnings.

With the number of flights increasing every year, the need to improve flight safety is becoming increasingly urgent (Sciences et al., 2018). An early warning system capable of providing accurate information on the likelihood of turbulence before an aircraft takes off is essential to prevent accidents and protect passengers (Veermann et al., 2014). Therefore, this research is highly relevant in the context of aviation safety in Indonesia and worldwide.

This research offers a novel approach by developing a web-based dashboard that integrates three key factors-convective cloud growth, Richardson number index, and wind shear-to predict and mitigate the impact of turbulence. This method differs from previous studies that generally focus on one or two factors only. With this system, it is expected to provide more precise and quick warnings to users.

The main objective of this research is to develop a web-based dashboard system that can accurately predict the risk of aircraft turbulence. The system will be designed to provide the necessary information to pilots, crew, and other relevant parties before the flight, thus allowing them to make better decisions in the face of extreme conditions.

The benefits of this research are not only limited to improving flight safety, but can also improve the operational efficiency of airlines. With accurate and real-time information, airlines can reschedule flights or reroute if necessary, reducing the risk of financial losses due to flight cancellations. In addition, this research also has the potential to be applied to various airports and airlines around the world, thus making a significant contribution to the global aviation industry.

RESEARCH METHODS

In this paper, there are three factors that influence the airplane flight namely the cloud cover, Richardson number index, and wind shear. If the cloud cover less than fifty percent then the status is ‘Siaga 1’ indicating there is possibility to turbulence. If the Richardson number index is less than 0.25 then the status is ‘Siaga 2’ which means there is high turbulence. If the wind shear is more than twenty then the status is ‘Siaga 3’ meaning the flight is prohibited.

Richardson number index (Ri)

To describe the turbulence, in this paper the Richardson number index (Ri) is used. Follows [6], the formulation of the Richardson number index is given by the following equation

$$Ri = \frac{g(\Delta T_v + \Gamma_d \Delta z)\Delta z}{T_v[(\Delta \mathrm{U})^2 + (\Delta \mathrm{V})^2]}.$$

Where $g = 9.8\, m/s$ is the gravity acceleration force and $\Gamma_d = 9.8\, K/km$ denotes the dry adiabatic laps rate. Here, eight input such as temperature at the highest geopotential height (T1), temperature at the lower geopotential height (T2), wind speed toward East at the highest geopotential height (U1), wind speed toward East at the lower geopotential height (U2), wind speed toward North at the highest geopotential height (V1), wind speed toward North at the lower geopotential height (V2), geopotential height at the highest geopotential height (z1) and geopotential height at the lower geopotential height (z2) are needed.

The Ri indicates that the wind shear can cause turbulence in statically stable air. The stability of the air commonly is described by using the geopotential height change. The small change means flow is dynamically unstable and turbulent [6]. According to [3, 6, 7], the threshold of the Richardson number index is 0.25. If $Ri < 0.25$, means that dynamically unstable and turbulent or high turbulence.

Web based dashboard development

The web based dashboard is developed using four steps namely requirement analysis, design, implementation, and verification (Engel et al., 2021; Zeggaf, 2023). In requirement analysis step, we identified any requirements to develop the software including the software specification. In the step of design, we create the software design such as use case, class, and activity diagram. In implementation step, we create the code based on codeigniter framework. In step verification, we test the software using black box testing. We also compare the Richardson number index calculation with the Richardson calculator in [6] to check our result is comparable with the reference. Generally, there are four actor in this software. The first one is administrator that has privilege to create, read, update, and delete other users account, flight schedule, flight history, weather and airport information. The next one is airplane crew that has privilege to check turbulence, read the information of flight schedule, read of the weather data and flight history. The third actor is pilot that has same privilege with the airplane crew. The last actor is general user that has privilege to read flight schedule, airport information, and weather data.

RESULTS AND DISCUSSION

In this section, some results will be presented and discussed. General user can access the dashboard. They will get some general information such as flight schedule and status and airport information. The pilot and airplane crew can access the dashboard by log in with their account. They will be directed to the dashboard as given in Fig. 1. Some information such as flight schedule, threshold value, whether data, and turbulence checking.

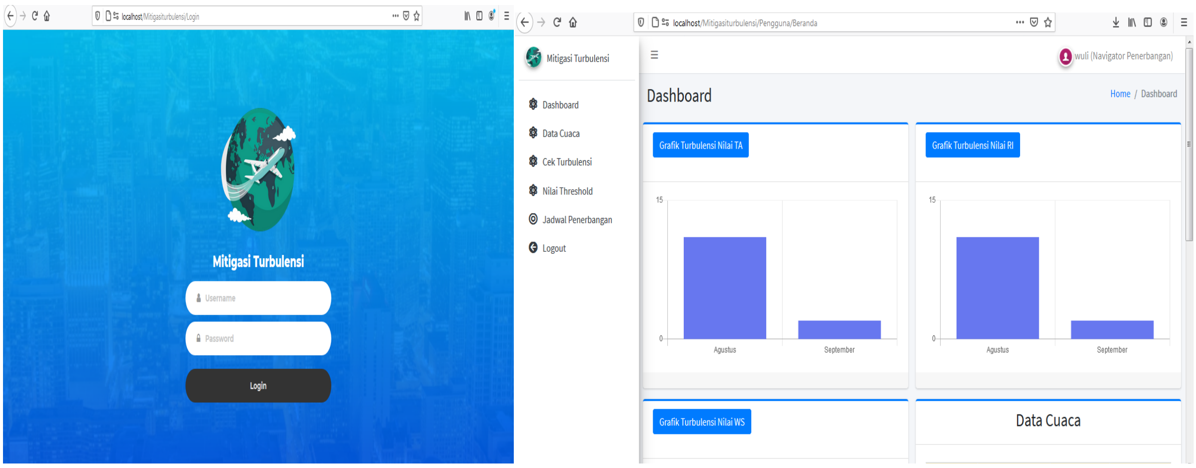

Figure 1. Log in page (left) and user dashboard (right)

To check the turbulence, the user is needed to input some values. The first is value of the clouds. Here, the value (in percent) is start from 0 to 100 percent as shown in Fig. 2. If the inputted value is more than 50 percent, the alert and status ‘Siaga 1’ will show in the screen. The user will be directed to the turbulence calculation page as shown in Fig. 3.

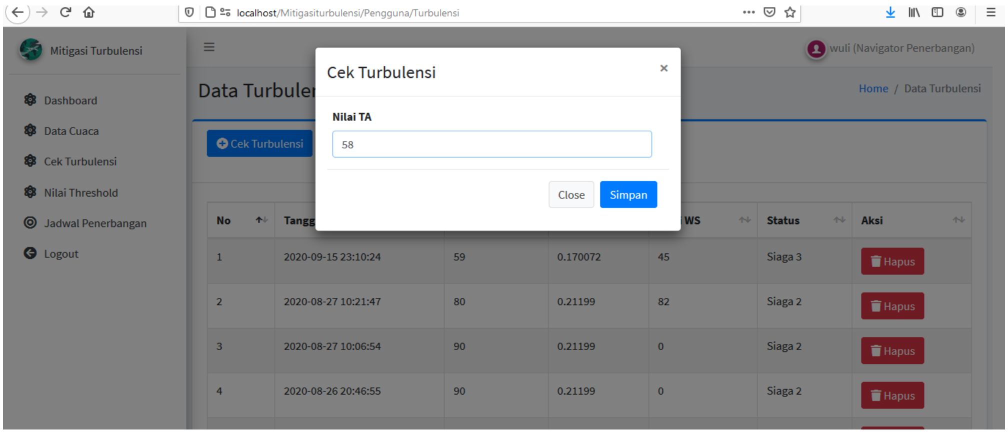

Figure 2. Turbulence checking page. Input cloud cover value

As shown in Fig. 3. The user is needed to input several values to calculate Richardson number index such as temperature at the highest geopotential height (T1), temperature at the lower geopotential height (T2), wind speed toward East at the highest geopotential height (U1), wind speed toward East at the lower geopotential height (U2), wind speed toward North at the highest geopotential height (V1), wind speed toward North at the lower geopotential height (V2), geopotential height at the highest geopotential height (z1) and geopotential height at the lower geopotential height (z2). The result will be the Ri (Richardson number index). If the Ri less than the threshold ($Ri < 0.25$), the user will be directed to the wind shear page, alert and status ‘Siaga 2’ will show in the screen as shown in Fig. 4. Note that, result of the Ri is comparable with the Richardson calculator in [6].

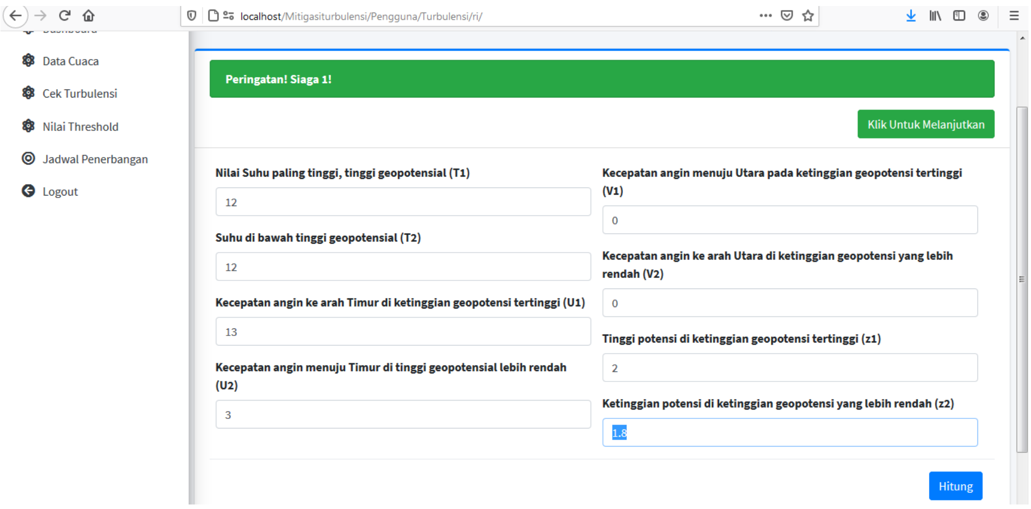

Figure 3. Richardson number index input and calucation and status ‘Siaga 1’

The last input is wind shear value as shown in Fig. 4. If user input wind shear value more than the threshold then the alert and status ‘Siaga 3’ will show in the screen as shown in Fig. 5. In this case, it means that the airplane is prohibited to fly. If this happen, the schedule will be postponed. This information can be seen by general user in the flight schedule menu.

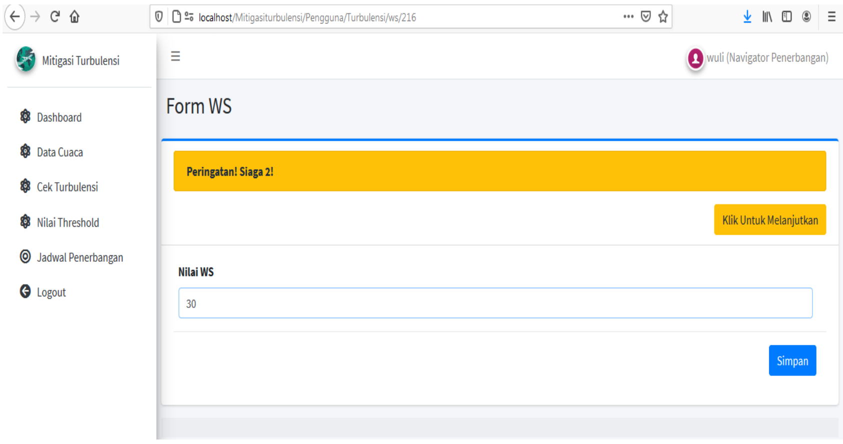

Figure 4. Wind shear input and status 'Siaga 2'

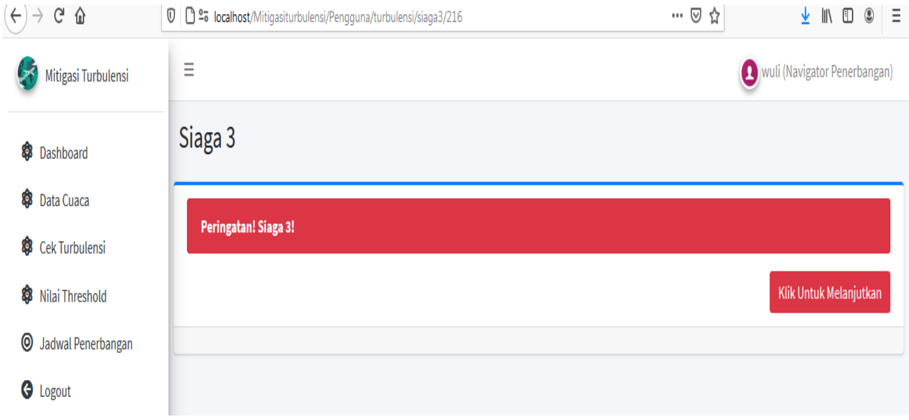

Figure 5. Satus 'Siaga 3'

CONCLUSION

This research successfully developed a web-based dashboard for aircraft turbulence mitigation that works well. By utilizing three key factors-convective cloud growth, Richardson number index, and wind shear-the system can provide timely warnings of turbulence risk before an aircraft takes off. Warning statuses of "Alert 1", "Alert 2" and "Alert 3" provide a clear indication of the level of turbulence that may be encountered, thereby improving pilot and crew preparedness. However, to improve the effectiveness of this system, there are several suggestions for further research. First, the development of a system that can consider additional variables, such as broader regional meteorological conditions and historical flight data, could provide higher warning accuracy.

In addition, integration with other aviation technology tools, such as navigation and flight control systems, can create a more comprehensive ecosystem in turbulence monitoring and mitigation. By involving real-time weather monitoring technology and improved communication systems, future research can also explore the application of machine learning to predict turbulence based on more complex data patterns. These measures are expected to not only improve flight safety, but also provide more efficient and responsive solutions to future turbulence challenges.

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