GROUND VISIBILITY AND CLOUD COVERAGE ESTIMATION FOR AIR ROUTE MONITORING ON MOUNTAINOUS AREA

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ABSTRACT: Aviation is one of the most important transportation modes in mountainous topography. However, the operation of aircrafts is often interrupted by bad weather such as low cloud, low visibility, and high wind speed. No doubt, these interrupted flight result in issues such as wasted of time loss, more fuel consumption, more CO_2 emission and higher of cost flights. Air Route monitoring is chosen as one application to indicate this issue. Field server which include various sensors is distributed by using sensor network during the flight course. Field Sensor can be used for this application system which can provide the standardization for observing and measuring the characteristics of air route conditions including ground visibility , cloud coverage and wind speed. Air route monitoring application also provides friendly graphical interface for visualizing weather information to flight service controllers or pilots. This research aims to

1) Implement the algorithm for image processing in terms of aviation meteorology applications.
2) Evaluate the effectiveness of the system to flight operation by numerical weather prediction models.

In brief, the system is low cost, since the camera is used to capture the sky condition instead of ceiling and visibility sensors. The weather forecasting analysis which is developed by using image processing techniques from weather sensors and remote sensing data are utilized to provide visual weather information automatically. Moreover, the system can also help to support pre flight decision making, reduce number of divert flights, reduce fule consumption (which can reduce emission of CO_2) and last but not the least can reduce the risk of Air Route accidents.

INTRODUCTION

Aviation weather is one of the most significant factors for air transportation modes because it can affect for safety of flight operation. FAA estimated that 30% of aviation accidents cause due to weather. Moreover, flight cancellation and delays are due to poor weather. Poor weather conditions for aviation include turbulences, low cloud, low visibility and thunderstorms. These conditions can disturb flight operation; for example, due to the terrain topography, The weather fluctuates with topography and elevation.

There are several automated weather information-reporting techniques. Each of them can have a specialized way to report the air route information. Almost weather information report very brief information as textual information. It is difficult pilot and flight service station to interpret the weather information. More over, misunderstanding in weather information can affect to make decision not only prior-flight decision but also in-flight decision.

Moreover, most of the weather information report stems from the weather station which are avialable at the airports. But there are no weather station provide between the flight route. It is necessary for pilot to understand the weather conditions specially during flight route and prior flight. Otherwise, it might affect the flight operation such as accident, divert flight or back to departure airport.

Real-time Air Route monitoring is chosen as one application to indicate this issue. Field server which include various sensors is distributed by using sensor network during the flight couse. Field Sensor Network can be used for this application system which can provide the standardization for observing and measuring the characteristics of air route conditions. Real-time Nepal air route monitoring web application also provides friendly graphical interface for visualizing weather information to flight service controllers or pilots.

METHODS AND EQUATION

This methodology is developed to fulfil the objectives of this research. A methodology is presented in figure 1.

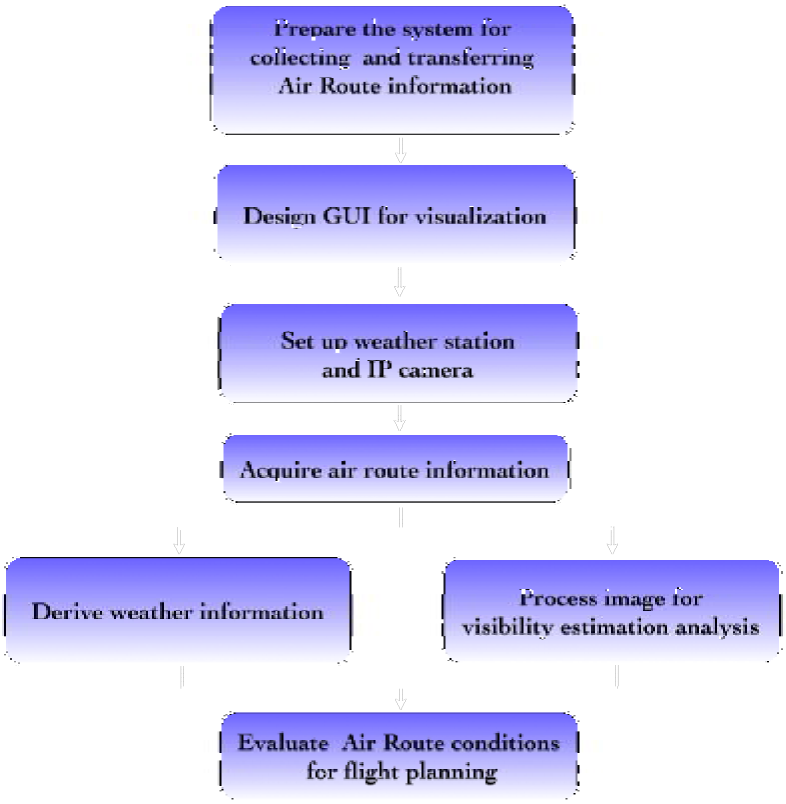


Figure 1: Research Methodology

OBSERVATION SYSTEM

The Observation system (Figure 2) of Nepal Air Route Monitoring which has different sensors called weather station for recording temperature, humidity, barometric pressure, precipitation and wind speed and direction . Moreover, panorama images are taken by IP camera. The weather information from field server has been stored in SOS database and it can be obtained remotely through the Internet to SSG server. The Nepal Air Route Monitoring application provide the information include Cloud and Visibility information, weather information and pre-flight decision support.

VISIBILITY ESTIMATION BY IMPLEMENTING EDGE DETECTION OF IMAGE PROCESSING ALGORITHM

For Nepal Air Route Monitoring application are expected that the IP camera would provide the monitoring of sky conditions along flight route. The sky conditions can be expressed cloud clover and horizontal visibility. As well known that cloud ceiling and visibility play significant roles to make decision for aviation system. However, the digital images from camera can provide remote sky conditions visualization for large areas. Figure 3 depicts the example benchmark image view along the flight route with any sky conditions including clear sky, moderate cloud and fog condition , blending of fog condition or very foggy and snow condition respectively.

The horizontal visibility can be estimated by using known distance of topographical features such as mountains as baselines. Images property can be utilized to estimate visualization visibility, image processing may provide concept to detect the visibility automatically. Therefore, the main of algorithm which is implemented to estimate horizontal the visibility is involved in edge features matching in the images. Thus, image processing technique which based on edge detection technique is chosen. The edge detection algorithms can be described following,

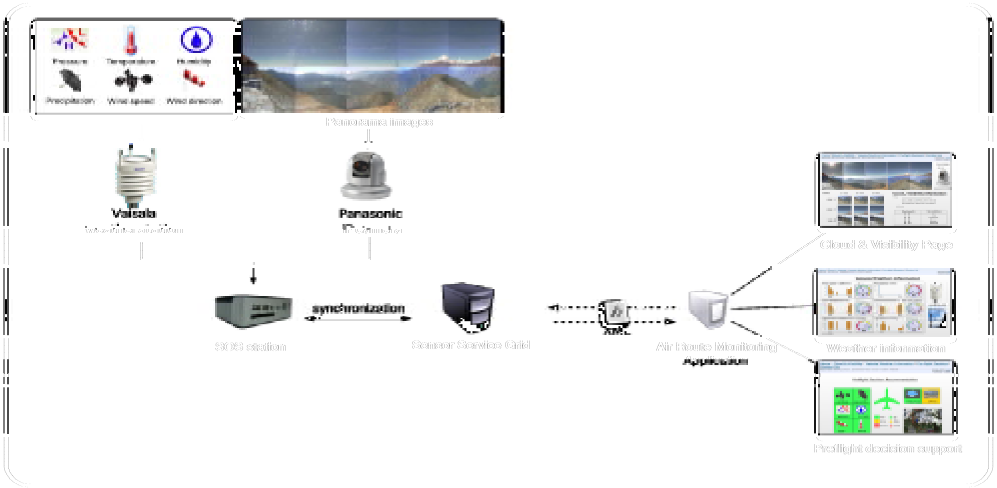


Figure 2: The Observation system of Nepal Air Route Monitoring

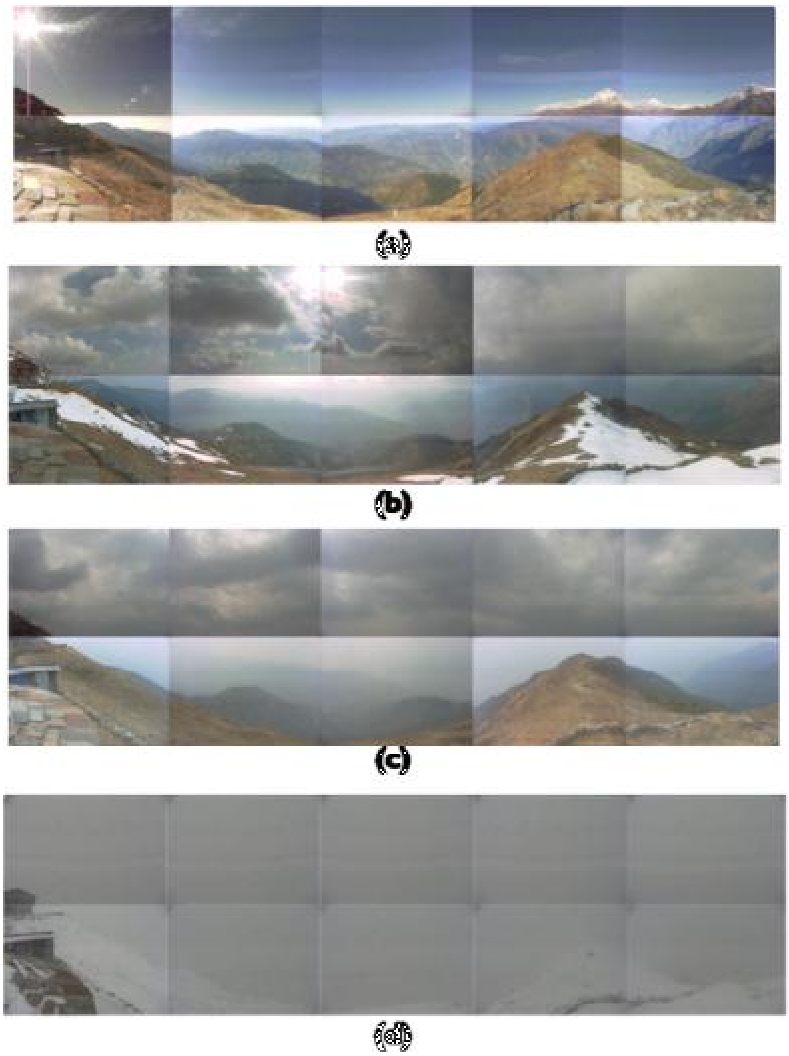


Figure 3: Edge detection and matching algorithm

1. Fixing of reference distance targets

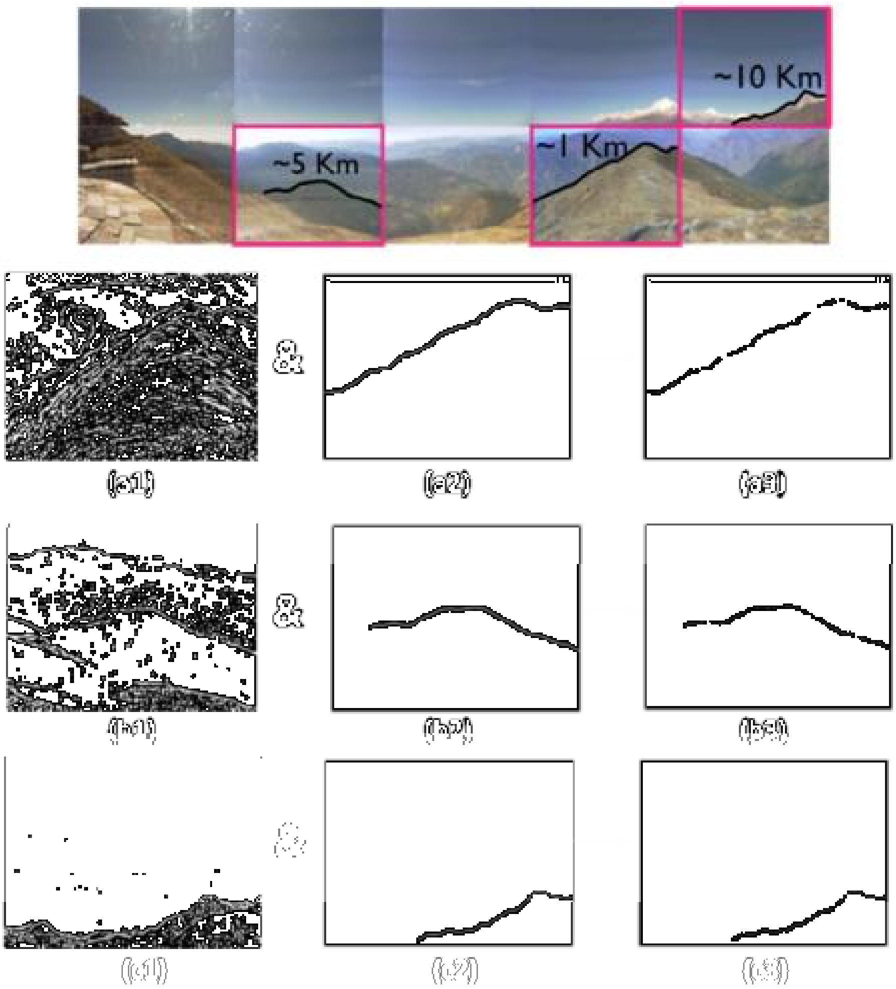
First of all, the set of reference distance targets has to be fixed before the automatically procedure. It is clear that the ridge of mountain or the part of mountain should be defined as the visible targets in terrain areas. To estimate visibility, There are 3 reference distance targets will be concerned including the nearest target has approximately distance 1 Km, 5 Km, 10 Km respectively. The panorama image with reference distance targets which are measured from the camera position to the targets (mountains).

2. Edge detection

For edge detection, Sobel filter operation method is used for extracting edge of images with 3 x 3 convolution mask, and the selection suitable threshold.

3. Edge matching

The reference image and captured image are totally difference because ideal edge and exact edge differ. This step, the output of the edge detection is matched with reference image based on 3 reference distance targets including



approximately 1 Km, 5 Km and 10 Km respectively by using 'AND' logical operation as same as set intersection. The output of matching has amount of pixels which appear in both reference images and edge images (figure 4).

Figure 4: Matching edge step based on 3 references distance targets including approximately 1 Km (a), 5 Km (b) and 10 Km (c) respectively. Edge detection images (1), Reference distance target images (2), and the output of matching edge image (3)

4. Comparison of matching edge images and the reference images

This step is to compare the output of matching edge images with the reference images. There are 3 pairs of the comparison images based on the reference distance targets including approximately 1 Km, 5 Km and 10 Km respectively. To estimate the visibility is that if observers can see the targets, the visibility can be determined as the farthest target can be seen. A threshold pixel value of 3 targets are examine based on pilot interview. According to adverse sky conditions, it is difficult to identify the visibility target by observation. Different human iris can have different recognize of target. Some conditions the targets are cover by amount of cloud, while others are blended by fog. There are 8 evaluation conditions to estimate the visibility. It is examined that if amount of pixels of matching edge image is more than the threshold pixel values of each reference image, they are inspected that the reference targets (mountains). The farthest distance of target is defined as the estimation visibility as show in figure 5.

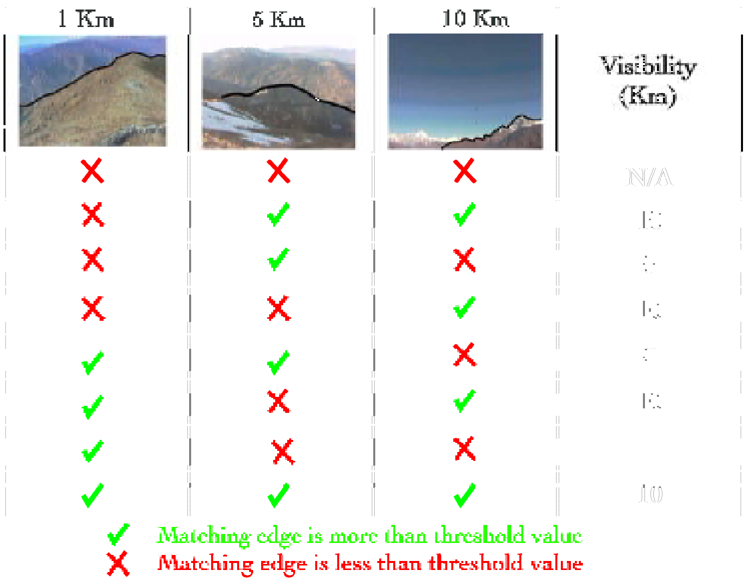


Figure 5: The evaluation conditions to estimate the horizontal visibility.

IMPLEMENT OF NEPAL AIR ROUTE MONITORING APPLICATION

One proposed of this thesis is to implement Air Route information interface with field server information including the analyzed of weather information and data from image processing part. The weather graphical user interface provide client such as pilot or flight service controller to interact with the GUI real-time. The concept to implement the visualisation of Real-time Nepal Air Route Monitoring is that the way to synchronize with SSG which is provide weather information from SOS station. Moreover, various information sources can be integrated based on 3rd party applications as show in figure 6. There are 3 main concepts to fulfil Real-time Nepal Air Route Monitoring.

1. Data services

Data service is a service to serve real-time sensor information computation, SSG provides compatible SOS OGC standard web services and Java APIs to simplify how developers utilizes sensor data in standardized format.

2. Visualization service

For sensor information visualization, SSG provide publishable graphical widgets such as gauges, charts and graphs of sensor information measurement that is possible to share for 3rd party application on the Internet easily.

3. Interoperability application

For Real-time Nepal Air Route Monitoring applications, the sensor information from SSG can be used gather with various data sources for creating the visualization based on specific application via web services.

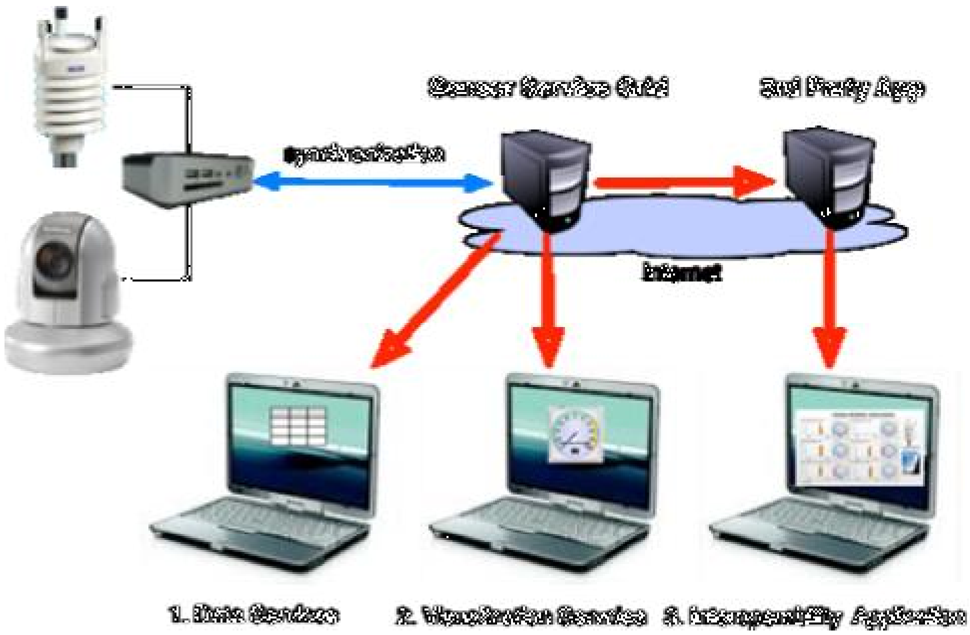


Figure 6: Overview of the system

NEPAL AIR ROUTE MONITORING VISUALIZATION

1. Weather Information page (figure 7)

This page displays the gathered sensor network information. The virtual gauges have been used to show the sensor data such as, wind speed, wind direction, barometric pressure, precipitation, temperature and humidity. Moreover, the bar chart shows the historic data being obtained from the sensors. This web page not only shows the current values of above mention weather parameters but also shows the historical weather information that provide the clients for tracking the weather information in detail.

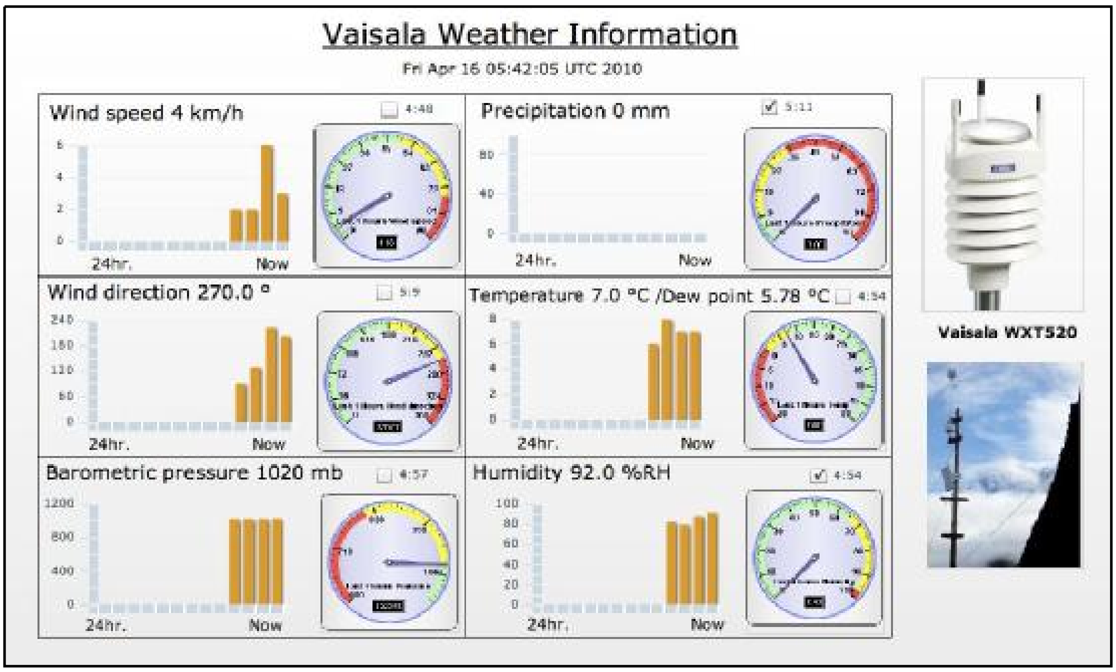


Figure 7: Weather Information

2. The cloud and visibility page (figure 8).

The contents of this page provide the mosaic images along the flight route view, taken from IP camera (installed at Khopra stations, Nepal). This camera is configured to take 10 images channel with in 300 seconds interval, with 51 horizontal degree each image. Further, the web page provides the facility to view the previous images taken by the camera. User can view previous 6 hours history of images from the web site. This can be done by using a slider bar (scrollable) which can change the image display. Moving from right to left shows the previous images. Moreover, the change of weather can be seen under the "visibility" panel. This area shows the historic image information such as 5 min, 10 min and 15 min of 3 references target images. Pilot and flight service controllers can plan to decide flight decision that the flight should be taken off or not. Moreover, even if the flight is decided to go, pilot can also plan flight route and flight level of aircrafts for all phase of flight.

Figure 8: Cloud & Visibility Information page.

3. Pre-flight Decision page (figure 9)

This web page shows the final results to support the decision to make flight as shows in figure 9. This section of system matches the observed sensor results with the suitable weather condition parameters and alerts the user in case of risky weather conditions for the flight. This section makes use of colour codification system to show the severity of weather for flight. Green colour shows the acceptance of weather for flight, yellow shows the warning, last but not the least red shows the restricted flight weather conditions. For flight decision support, even if one of weather requirement values fall in restriction values, the flight will be assumed as a cancellation flight.

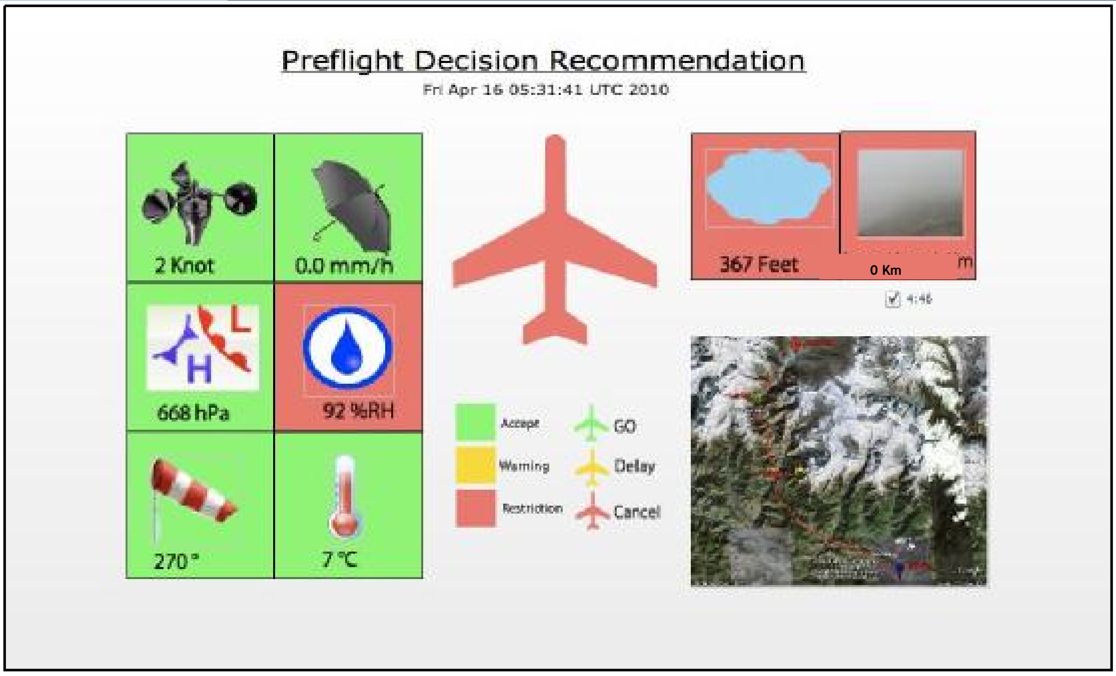


Figure 9: Pre-flight Decision Recommendation

CONCLUSIONS & RECOMMENDATIONS

Aviation weather conditions play important role for aviation management system. It can be interrupted by adverse weather. Nepal also faces this issue; especially the flight route between Phokara and Jomsom airport where there is no weather station between them. The current project uses Sensor Network and integrates with Air Route monitoring system to address this issue.

The underlying work does the analysis of Air Route information at Khopra station between Phokara and Jomsom airport, Nepal. Further, Air Route information system is also implemented using Field Sensor Network. User having minimum computer skill can handle the system simply. A weather station consist of temperature, humidity, wind speed and direction , barometric pressure and precipitation sensors along with a field server including IP camera to capture images along the flight route has been establish to the system. The system gathers weather information and transfers it to the server automatically. The client such as pilots or flight service controllers can access the data via web service interface through internet on real time.

The edge detection algorithm has been successfully implemented for visibility estimation. The concept of matching edge between edge image and reference image is used for identify that the reference targets of images are visible or not. This technique is developed based on visual flight rule (VFR) which is significant for pilots to decide to take off aircraft.

The system is low cost, since the camera is used to capture the sky condition instead of ceiling and visibility sensors. The real-time visibility estimation analysis which is developed by using image processing techniques is utilized to provide visual visibility automatically on real-time. In addition, a friendly user interface of Nepal Air Route Monitoring application can help users (such as flight service controller or pilot) to interpret the Air Route information. Moreover, the system can also help to support pre flight decision making, reduce number of divert flights, reduce fule consumption (which can reduce emmission of CO_2) and last but not the least can reduce the risk of Air Route accidents.

However, the adverse weather condition has directly impact on the field server specially heavy snowfall. Most recently, the IP camera has shift the capture position due to strong weather condition. As the system has many layers and problem in one layer can disturbe other operations if they are tighty depended. It is hard to know where the actual problem lies. Is that because of the network or lack of power supply on mountain to operate camera or some weather conditions has destroyed the sensor equipemtns. There is need to develop a system which can detect the cause of problem automatly and can respond to the server.

To fulfil the aviation management system,the weather station are needed in different elevation. The adverse weather such as low cloud ceiling and low visibility are unexpected occur. The pilot need to adjust ceiling in different level. Thus, provinding of several weather station is useful for supporting flight decision.

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