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## DESIGN OF AIR TRAFFIC CONTROL WEATHER RELATED TRAINING PROGRAM

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Essential components of a new scenario-based air traffic control (ATC) training platform whose effectiveness is being analyzed are outlined with respect to its use in the decision-making skills of trainees when confronted with emergency situations. The custom designed platform allows the trainee to interact with the program such that the 10-minute ramification of a proposed aircraft redirection can be explored visually before a decision is made. Actual previous extreme weather incidences are used. Testing of the platform is ongoing with ATC students from Kent State University. Data from subjective pre- and post-questionnaires as well as objective decision parameters are currently being taken.

The “En-Route Air Traffic Control for Weather-Related Training” program was developed using MATLAB’s Graphical User Interface Development Environment (GUIDE). Fundamentally, the purpose of the program is to provide a platform for experimentation on factors that could potentially enhance the weather-related training for ATC personnel. The training program utilizes past radar data from which a weather-related aircraft incident or accident occurred. The research hypothesis states that this method of scenario-based training for ATC personnel will help reduce similar, avoidable mistakes from happening in the future. Further, if an air traffic controller is trained through these types of scenarios, they should be able to extrapolate that knowledge to apply to different, but similar, emergency situations. The National Transportation Safety Board (NTSB) has reported that the recurrent training of air traffic controllers in emergency situations (such as extreme weather) is often short and not specific (NTSB, 2015). Further, the NTSB noted that it “is critical to provide controllers with specific examples to help them identify unstated emergencies and handle aircraft in the safest manner possible” (NTSB, 2015). Using NEXRAD (Next-Generation Radar) data files from previous occurrences of aircraft incidents/accidents to create radar images for the training program has allowed the research team to explore this type of training and plan for ongoing and future experiments.

### **Design of Training Program**

The “En-Route Air Traffic Control for Weather-Related Training” program consists of two main components: the radar image where data blocks representing aircrafts move along their route towards their destinations and the control section where changes to each aircraft’s altitude, ground speed, and heading can be made. To create the radar images, weather data files were retrieved from NEXRAD data files – Level II provided by Amazon Web Services Platform. The NEXRAD (Next-Generation Radar) network consists of 160 high-resolution Doppler radar sites. These sites detect precipitation and atmospheric movement and disseminates data in approximately five-minute intervals from each site (Ansari S. et al, 2018). The NEXRAD Level II Doppler data was transformed to imitate the radar images available through the En Route Automation Modernization (ERAM) system. This transformation was completed using the

Python ARM Radar Toolkit (Py-ART). The toolkit is an open source Python module that contains weather radar algorithms and utilities (Helmus & Collis, 2016).

First, the NEXRAD station location and event time must retrieve the data files from the Amazon Web Services platform. Then using Py-ART capability, the weather data is transformed to remove any reflectivity data below 5 dBZ and above 75 dBZ. The data is then classified using three reflectivity level ranges. Weather level 1 (light precipitation) consists of reflectivity levels ranging from 5 dBZ to 29 dBZ and is represented on the radar image using midnight blue (RGB of 25, 25, 112). Weather level 2 (moderate precipitation) consists of reflectivity levels ranging from 30 dBZ to 49 dBZ and is represented on the radar image using green (RGB of 0, 100, 0). Weather level 3 (heavy precipitation) consists of reflectivity levels ranging from 50 dBZ to 75 dBZ and is represented on the radar image using cyan (RGB of 0, 200, 200). If no precipitation is present (reflectivity outside of 5-75 dBZ), the radar screen is black. The colors used for weather level 1, weather level 2, and weather level 3 all correspond to the colors used for ERAM (Federal Aviation Administration, 2013). The radar intensity ranges (dBZ levels) were structured to follow closely with the NEXRAD radar intensity ranges for light, moderate, and heavy precipitation (Boyette, 2006).

Data blocks which represent the position and movement of each aircraft are then added to the radar screen. They consist of an aircraft marker (square symbol) and alphanumeric data that includes the flight identification, altitude, and ground speed. They are designed to provide enough information about the aircraft to make realistic decisions with respect to separation and weather. In addition to the aircraft marker and alphanumeric data, a gray line projects from the top left corner of the aircraft marker as a visual indicator of both the aircraft heading and ground speed. Figure 1 shows the radar image with eight aircrafts present.

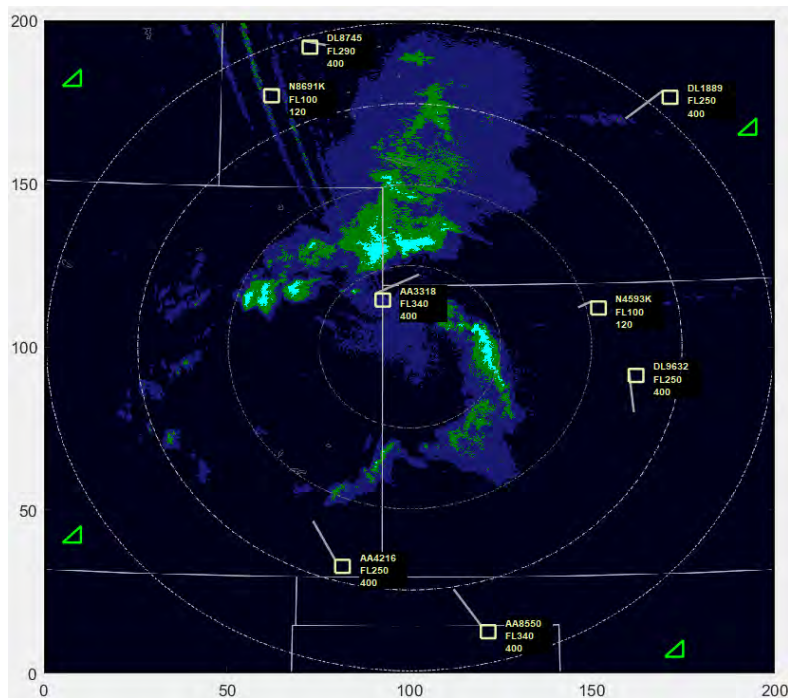


Figure 1. Radar image with eight data blocks representing aircrafts.

The program code uses the aircraft heading and ground speed to calculate the horizontal, Equation 1, and vertical, Equation 2, on screen movement of the aircraft marker and alphanumeric data at one second intervals.

$$x_i = x_{i-1} + \Delta x \quad (1)$$

$$y_i = y_{i-1} + \Delta y \quad (2)$$

Where  $x_i$  is the new current x-position of the aircraft,  $x_{i-1}$  is the x-position of the aircraft one second interval prior, and  $\Delta x = GS \sin(H)$ , is the change in the x-position of the aircraft during the one second time interval. For the  $\Delta x$  calculation,  $H$  is the aircraft heading at that interval and  $GS$  is the aircraft ground speed at that interval. All variables for  $y_i$ , the new current y-position of the aircraft, are similarly defined with  $\Delta y = GS \cos(H)$ . In addition, the end-point of the gray line projecting from the top left corner of the aircraft marker shows where the aircraft will be two minutes later if it continues at its current heading and ground speed. The needed position end-point to plot this line is calculated using Equation 3 and Equation 4:

$$x_{ind\_end} = (x_i) + GS \sin(H) \cdot t_{2\ min} \quad (3)$$

$$y_{ind\_end} = (y_i) + GS \cos(H) \cdot t_{2\ min} \quad (4)$$

Where  $x_{ind\_end}$  and  $y_{ind\_end}$  are the x- and y-position of the end-point of the plotted direction indicator, respectively, and  $t_{2\ min} = 120s$  is the time needed to find the coordinates of this point 2 minutes later. The background code of the computer program then plots the line from  $(x_i, y_i)$  to  $(x_{ind\_end}, y_{ind\_end})$ .

The aircraft marker and alphanumeric data are colored yellow (RGB of 238, 243, 174) to signify that the user is responsible for the safety of that aircraft. This follows the coloring used by the ERAM system to show that a data block is under the responsibility of an air traffic controller (Federal Aviation Administration, 2013). For the purpose of weather-related training experimentation, the data block was designed to be a simplified version of what is available to controllers in the field.

## Control Section

During the test scenario the program allows the participant to have control over each aircraft's altitude, ground speed, and heading. Also available to the user of the program is a predictive tool that visualizes the next ten minutes of an aircraft's route. Each aircraft that is included in the test scenario is shown in the control section of the program. To make changes to an aircraft, the participant must select the radio button next to the flight identification of that aircraft. To reduce the number of mistakes made during a test scenario, when an aircraft is selected in the control section the aircraft marker and the alphanumeric data of the corresponding data block changes from yellow to red. This color change allows the participant to confirm the changes are being made to the correct aircraft on the radar image. Once an aircraft is selected, the edit boxes below the radio buttons fill with the information of that aircraft. The user can then make changes to any parameter that will continue to ensure the safety of the aircraft. These

changes are applied to the equation that controls the movement of the data block on the radar image. The control section of the program is located to the right of the radar image. Figures 2(a) and 2(b) show the components of the control section display that allow for the decision-making of the participant and the corresponding changes to the data block on the radar image, respectively.

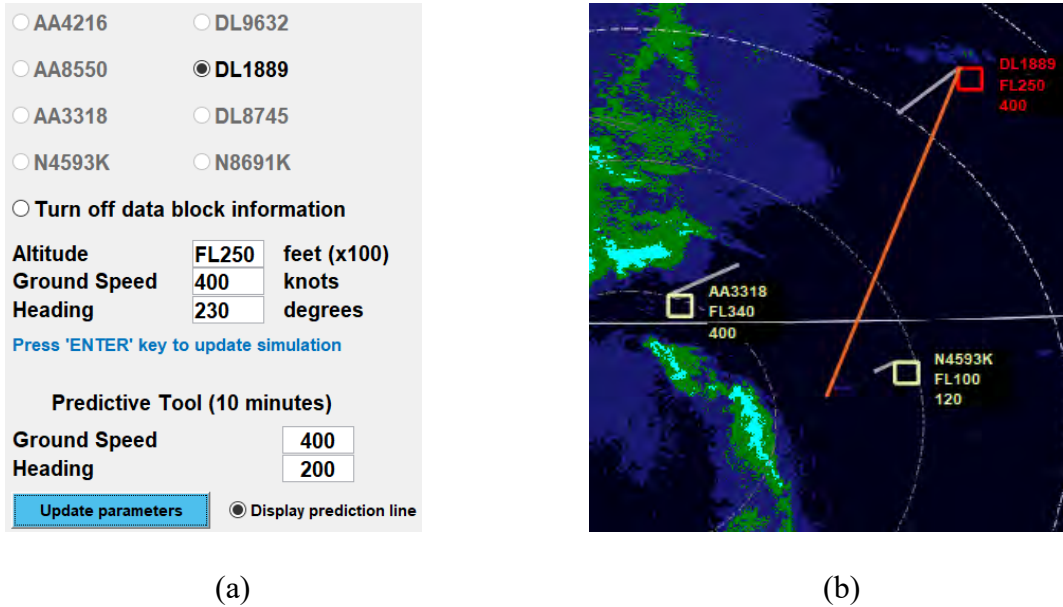


Figure 2. Aircraft control and predictive capabilities: (a) Control Block and (b) Radar Image

The predictive tool makes it possible for the participant to see what a proposed new route of a selected aircraft would be. The predictive tool uses the edit box inputs for ground speed and heading to calculate what the x-position and y-position of the aircraft will be in ten minutes. Equation 5 and Equation 6 show the how the predicted x- and y-positions of the aircraft marker in ten minutes,  $x_{10}$  and  $y_{10}$  respectively, are calculated:

$$x_{10} = (x_i) + GS_{10} \sin(H_{10}) \cdot t_{10 \text{ min}} \quad (5)$$

$$y_{10} = (y_i) + GS_{10} \cos(H_{10}) \cdot t_{10 \text{ min}} \quad (6)$$

Where  $x_i$  and  $y_i$  are the current x- and y-positions, respectively, of the aircraft marker,  $H_{10}$  is the edit box input heading,  $GS_{10}$  is the edit box input ground speed, and  $t_{10 \text{ min}} = 600\text{s}$  is the time needed to find the predicted position of the aircraft marker ten minutes later. The background program code then plots the predictive line from  $(x_i, y_i)$  to  $(x_{10}, y_{10})$ . The user can either use the tool with the aircraft's current ground speed and heading or the participant can view how a different ground speed and/or heading will change the aircraft's route.

In the example shown in Figure 2(a), flight DL1889 was selected. The current ground speed of the aircraft was 400 knots with a heading of  $230^\circ$ . The user wanted to see a projected ten-minute route of the aircraft corresponding to the ground speed remaining at 400 knots but changing the heading to  $200^\circ$ . Notice that in Figure 2(b), the data block for the selected flight

changed to red, the 2 minute current route indicator remained grey and the 10 minute new route indicator was added using an orange line.

### Weather Scenario Selection

The weather scenario chosen for the design verification was based on an aircraft incident that occurred on August 8, 2015. According to the National Transportation Safety Board (NTSB) report, Delta Airlines flight DL1889 was heading to Salt Lake City, Utah from Boston, Massachusetts when around 02:00 coordinated universal time (UTC), while traveling near the Nebraska/Colorado border, the aircraft encountered hail which resulted in an emergency landing of the aircraft. As a result of the hail the aircraft had damage to the windshield, airframe, the leading edges of the wings, the aircraft skin, and the nose cone (NTSB, 2015).

### Discussion/Future Work

Currently the research team is conducting experiments with air traffic control students at Kent State University. The experimental procedure is registered and approved through the University of Akron Institutional Review Board (IRB) since it involves participation from human subjects. The experiments are designed to record subjective results from each participant based on their ratings of workload, confidence, and benefit. Objective results such as final aircraft routes and time of decision-making are also recorded. Figure 3 shows an example of how these results can be viewed with the full routes of the eight aircraft on the radar image. In this case, the route remained uninterrupted during the occurrence of severe weather to show how vectoring is needed to avoid the occurrence of severe weather. The color of each route corresponds to the color of the destination marker. The analysis and conclusions made based on these results will be released at a later date.

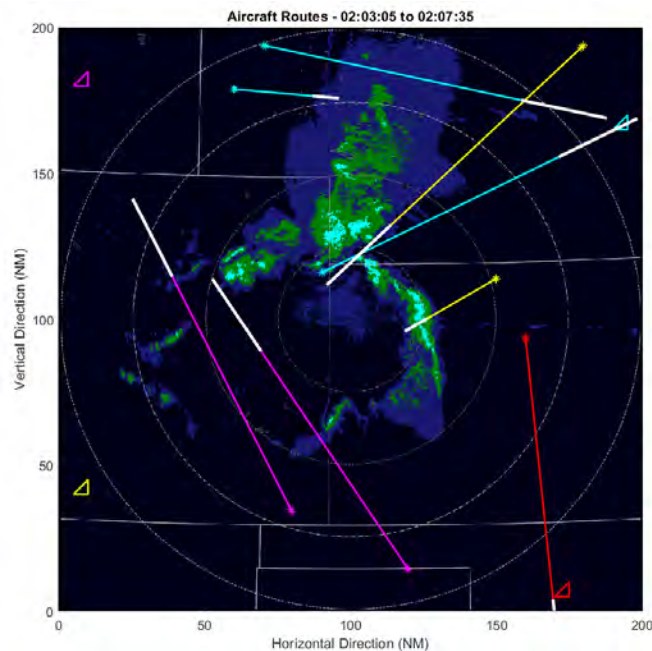


Figure 3. Aircraft routes displayed on the radar image.

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