Traffic Flow Management (TFM) Weather Rerouting Decision Support

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During 1999, record air traffic delays (up 22.2% from 1998) were experienced in the National Airspace System (NAS). Of these delays, 68.8% were weather-related (Jones, 2000). In response, the Federal Aviation Administration (FAA) and the aviation industry have initiated a partnership to improve communications between the FAA and airlines and to expand the use of technology to help alleviate air traffic delays caused by severe weather.

The FAA's Center for Advanced Aviation System Development (CAASD), run by the MITRE Corporation, is developing a Traffic Flow Management (TFM) decision support tool that will help plan the safe and efficient movement of aircraft around convective weather systems while accurately predicting the impact on controller workload and aircraft delays. The goals of this tool are to reduce aircraft delays, make better use of airspace capacity, increase schedule predictability, and maintain safe controller workloads. This tool is implemented as an enhancement to the Collaborative Rerouting Coordination Tool (CRCT) and is called CRCT Weather Problem Resolution (CRCT-WPR).

CRCT

Baseline CRCT (Wanke, 2000) is a set of decision support capabilities being developed by CAASD to evaluate and demonstrate future TFM concepts. Baseline CRCT is currently in daily use and is being operationally evaluated at two sites: the Air Traffic Control System Command Center (ATCSCC) and the Kansas City Air Route Traffic Control Center (ARTCC).

Baseline CRCT includes functionality for rerouting around manually-generated Flow Constrained Areas (FCAs), automatic identification of aircraft predicted to enter FCAs, manual rerouting of aircraft around FCAs, and automatic assessment of the impact of proposed reroutes on sector traffic volume. In baseline CRCT, a Traffic Management Specialist (TMS) manually draws an FCA polygon to represent an area impacted by weather or other factors that limit traffic flow. Manual FCA generation is practical only when few FCAs are needed and the weather is very stable and predictable. This is often not the case with convective weather, which can consist of many storm cells moving at various speeds and directions and involving complex cell growth, decay, splitting and merging.

CRCT-WPR

One improvement CRCT-WPR adds to CRCT is automatic generation of weather FCAs using a weather forecast product. The forecast products currently available include the National Convective Weather Forecast (NCWF) and the Collaborative Convective Forecast Product (CCFP). The NCWF (Mueller, 1999) is a computer model developed by the National Center for Atmospheric Research (NCAR), which provides forecasts extending out one or two hours and is updated every five minutes. CRCT-WPR uses the NCWF; however, the use of CCFP or other forecasts is being investigated.

Figure 1 shows a CRCT Traffic Display with FCAs derived from the NCWF forecast. The FCA polygons represent detections and predictions of severe convective weather extending out in half-hour intervals (0-, 30-, 60-, and 90-minute forecasts). Each weather FCA includes an altitude top and time range. CRCT automatically predicts which flights will intersect these FCAs using the aircraft trajectory and the 4-dimensional location of the FCA.

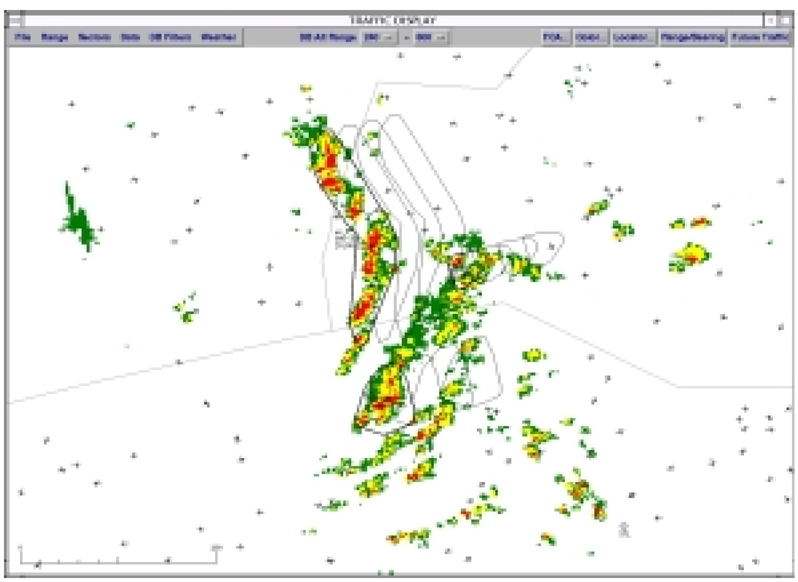

Figure 1. NCWF Convective Weather Forecast Polygons

The TMS can use CRCT-WPR to create a plan to reroute the flights that are in conflict with the FCAs around the weather. The TMS determines how aircraft will flow around the storms and through any holes between storms by generating TFM-Designated Reroutes (TDRs). TDRs are reroute paths created by clicking on locations on the display. Figure 2 shows an example of four TDRs, two north and two south of the storm. Although these TDRs have only two nodes each, TDRs can have any number of nodes, any orientation, and can cross each other.

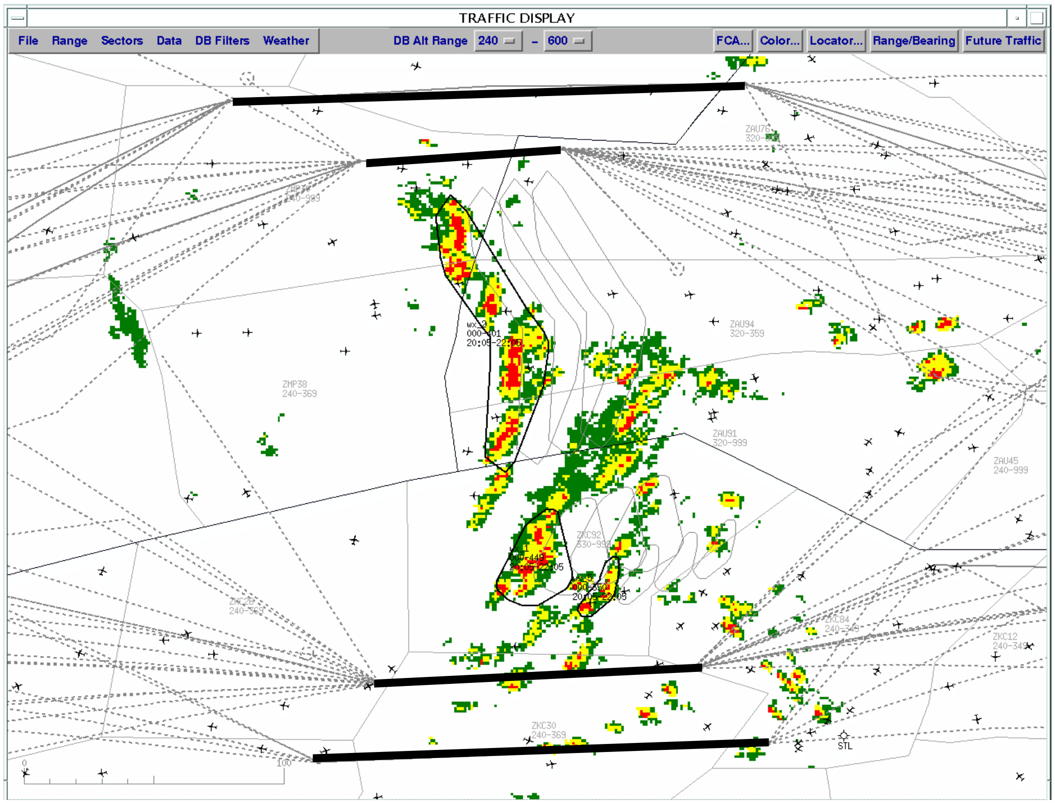

Figure 2. TFM-Designated Routes (TDRs) on the Traffic Display

The TMS can specify parameters for each TDR, such as time period, altitude range, maximum angle aircraft can turn to deviate from their original route, and entry rate. The TDR entry rate specifies the minimum spacing between two aircraft that are joining a TDR. For example, if the TDR entry rate is set to 30 per hour, aircraft must be spaced 2 minutes apart when they join the TDR. The TDR rate allows the TMS to control the flow of aircraft and determines how much traffic will be diverted to each TDR.

After the TMS creates an initial plan, CRCT-WPR evaluates the plan and attempts to find reroutes onto the TDRs for flights that are in conflict with weather. First, the TDRs that each flight could potentially use are determined based on the maximum turn angle, time range, and altitude limits of the TDRs. Then, CRCT-WPR performs an optimization to determine which flights will be assigned to each TDR based on minimizing arrival delays while staying within the rate limits of each TDR. Flights scheduled to take off after the plan start time can be delayed on the ground in order to fit into an available slot on a TDR.

The dotted lines on Figure 2 show the proposed reroutes generated by CRCT-WPR for this plan. Rerouting to one of the two TDRs closest to the storm would cause the least delay for most flights, but the rate limits on these TDRs have caused some of those flights to use the TDRs further north and south.

The plan in Figure 2 required less than 10 seconds for CRCT-WPR to evaluate. However, execution time increases as the number of conflict aircraft or TDRs increases. Since CRCT-WPR is designed for rapid processing, plans can be created, evaluated, modified, and reevaluated quickly.

When the plan evaluation is complete, CRCT-WPR displays the plan results including statistics on flight delays and the number of aircraft rerouted. Information is also displayed about the flights that were not able to be incorporated into the plan, including the number of flights that could not find a slot on any TDR, and the number of flights that would have to turn too sharply to reach a TDR. CRCT also generates predicted sector loading based on the plan reroutes, so that the TMS can determine whether the reroutes might cause unacceptable workloads for sector controllers.

Elevated sector counts may not always mean that a plan should be rejected. The plan shown in Figure 2 will route all flights going south of the storm through one sector (Kansas City sector number 30) causing higher-than-normal sector counts. But the flights that are rerouted into sector 30 are all being merged and lined up in four neighboring sectors. Within sector 30, these flights will be flying in-trail on the two parallel TDRs. Slightly elevated sector counts may be acceptable for this sector as long as the crossing traffic is light. The ability to spread the work of handling merging and diverging traffic across several sectors is an important capability of CRCT-WPR.

CRCT also has a Future Traffic Display where the TMS can view the predicted locations of aircraft or weather. Using this display, the TMS can look at future periods of high congestion and assess whether the situation might be too complex for sector controllers.

If the TMS is unsatisfied with the results of the planned reroutes, the plan can be modified. The entry rates on TDRs can be lowered to reduce traffic through congested sectors, the rates can be raised for under-utilized TDRs, and new TDRs can be added to avoid congested areas or to increase the number of flights using the plan. The new plan is then evaluated, a new set of reroutes is produced, and the results of the new plan are assessed. This cycle can be repeated until the TMS is satisfied that the plan moves flights past the weather as efficiently and safely as possible.

While CRCT-WPR is built specifically to handle weather, the tool can also work for other flow restriction problems. For example, an equipment failure disrupting ATC in a particular region can be handled using CRCT-WPR by manually generating an FCA around the region and building TDRs to route flights around the FCA.

Next Steps

CRCT-WPR is ongoing research. CAASD is assessing NCWF accuracy to determine guidelines for how close TDRs can be safely placed near weather forecast polygons in different situations. CAASD is also assessing CRCT-WPR in a laboratory environment to determine whether CRCT-WPR can perform better than the current TFM procedures in certain weather situations. Field evaluations of CRCT-WPR are planned for 2001.

In order to be an effective TFM decision support tool, CRCT-WPR still needs to be expanded and improved in some areas. These areas of research include the following:

- Improved weather forecasts and understanding of forecast accuracy
- Expanded collaboration (including ATCSCC, ARTCCs, Airlines, and Pilots)
- Improved load balancing and resource rationing
- Improved controller workload predictions
- Improved management of forecasting inaccuracies

In conclusion, CRCT-WPR can be an effective tool for dealing with large convective weather systems and other traffic flow problems. Continued research by CAASD and weather research organizations will improve the ability of CRCT-WPR to safely reduce flight delays caused by convective weather.

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