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Using both Graphical Software and Statistical Metrics for the Evaluation of a Decision Support Tool

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Abstract
In the Federal Aviation Administration (FAA), evaluating the trajectory prediction accuracy of air traffic management decision support tools is traditionally performed using quantitative techniques. For example during accuracy tasks performed by the FAA's Simulation and Analysis Group (ACB-330), a decision support tool can generate thousands of trajectory predictions when processing several hours of air traffic data. Programs are run that process this data and generate a relational database of results. Statistical techniques are then applied that aggregate the results and provide some inference to the data. This paper presents these techniques supplemented with recently developed graphical interface tools. By combining the quantitative and graphical results, the analyst can not only express the quantitative impact of trajectory accuracy results but also illustrate some of the reasons for the inaccuracy. The quantitative and graphical analysis automation also shows how aircraft trajectory accuracy can be performed.

Background
The Federal Aviation Administration (FAA) has sponsored the development of several ground based air traffic management decision support tools (DSTs) to support the en route and terminal air traffic controllers. A fundamental component of a DST's design is the trajectory modeler, upon which its functionality is based. The trajectory modeler provides a prediction of the aircraft's anticipated flight path, determined from the flight plan and radar track data received from the National Airspace System (NAS) Host Computer System (HCS). Therefore, the trajectory accuracy, or the deviation between the predicted trajectory and the actual path of the aircraft, has a direct effect on the overall accuracy of these automation tools.

The Conflict Probe Assessment Team (CPAT), which is a part of the Simulation and Analysis Group (ACB-330) at the FAA's William J. Hughes Technical Center, developed a generic method of sampling a set of aircraft trajectories for accuracy measurements. This methodology is called interval-based sampling and is defined in [1]; an example of its application is presented in [2]. The accuracy measurement data provided by this methodology is stored in an Oracle database.

Typically the CPAT analysts use established inferential statistical techniques to assess the DST. This paper presents an application called *TrajectoryGUI* that provides the analyst with graphical representations of the trajectory and track data, which facilitates the analyst's understanding of the trajectory errors.

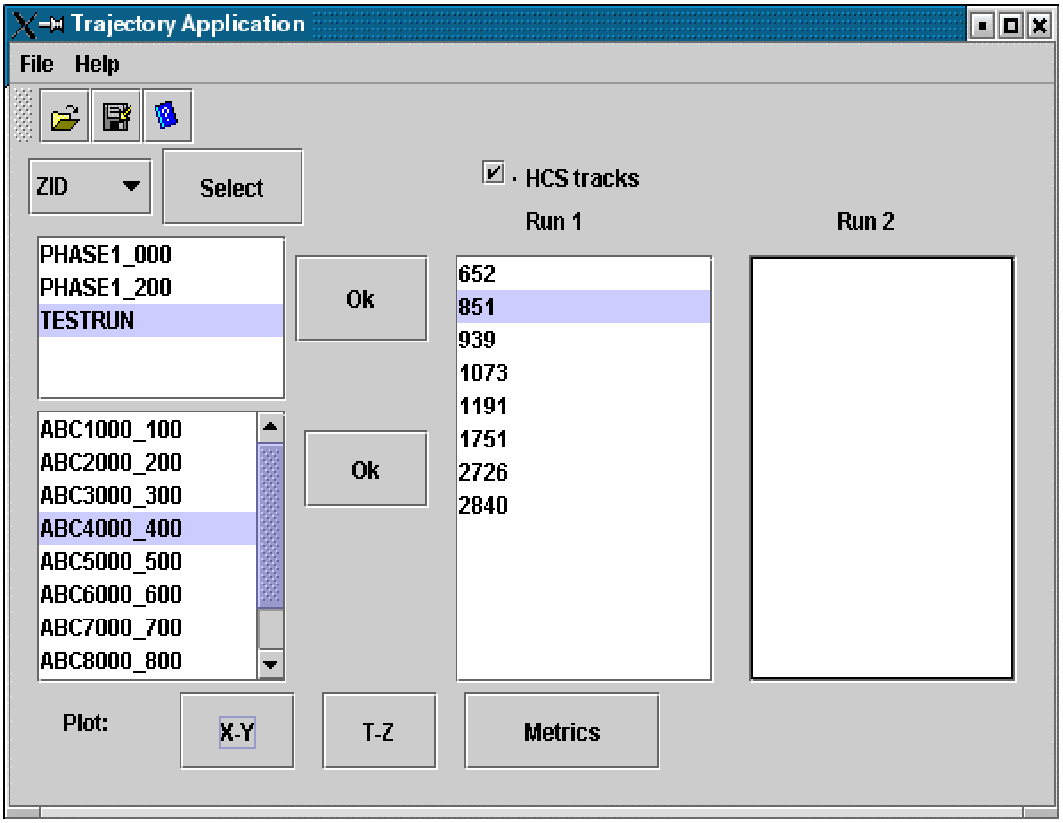

Figure 1: Main Window

TrajectoryGUI

TrajectoryGUI was designed and developed by CPAT on a Sun with the Solaris Operating System. This software takes advantage of Java's portability and can also be executed as a remote X application on a PC with the Red Hat Linux operating system. *TrajectoryGUI* interacts with an Oracle 8.1.6 relational database to execute queries for collecting flight data and flight trajectories. After launching the program, the analyst sees a window for selecting the parameters for the trajectory comparison. Figure 1 presents an example of this window.

The analyst first chooses an Air Route Traffic Control Center (ARTCC) from one of the 20 centers in the United States from a combo box. In the example shown in Figure 1 the analyst has selected the Indianapolis ARTCC (**ZID**). This information is used to query the database to fill a list area that identifies the scenario cases present in the database. In the example the analyst has selected the scenario case identified as **TESTRUN** by highlighting it and clicking the OK button. This selection causes another list area to be filled that identifies the available flights. In the example the analyst has selected flight **ABC4000_400** by highlighting it and clicking the OK button. This represents a flight with the aircraft identification (ACID) of ABC4000 and a computer identification (CID) of 400. This selection causes another text area that identifies the trajectories that were generated by the DST for this flight and available for the *TrajectoryGUI*'s plotting functions. In the example the analyst has selected trajectory number **851** highlighting it and clicking the OK button. At this point the analyst has a number of optional plots available: an **X-Y** plot, a **T-Z** plot, and a **Metrics** data listing.

The window displayed if the **X-Y** button in the main window is selected will contain a plot of the flight's trajectory data and, if the analyst has checked the check box in the main window labeled **HCS tracks**, it will also contain the flight's track data. In either case the plot will contain the projection of the trajectory and/or track x-y coordinates onto the horizontal plane. This plot uses a rectangular Cartesian coordinate system based on stereographic projection. X-Y define the horizontal plane with positive X being east and positive Y being north. Figure 2 shows an example for which the analyst checked the **HCS tracks** check box so that the resulting plot contains both the trajectory and the track data. In this example it can be seen that the trajectory exhibits a significant lateral error.

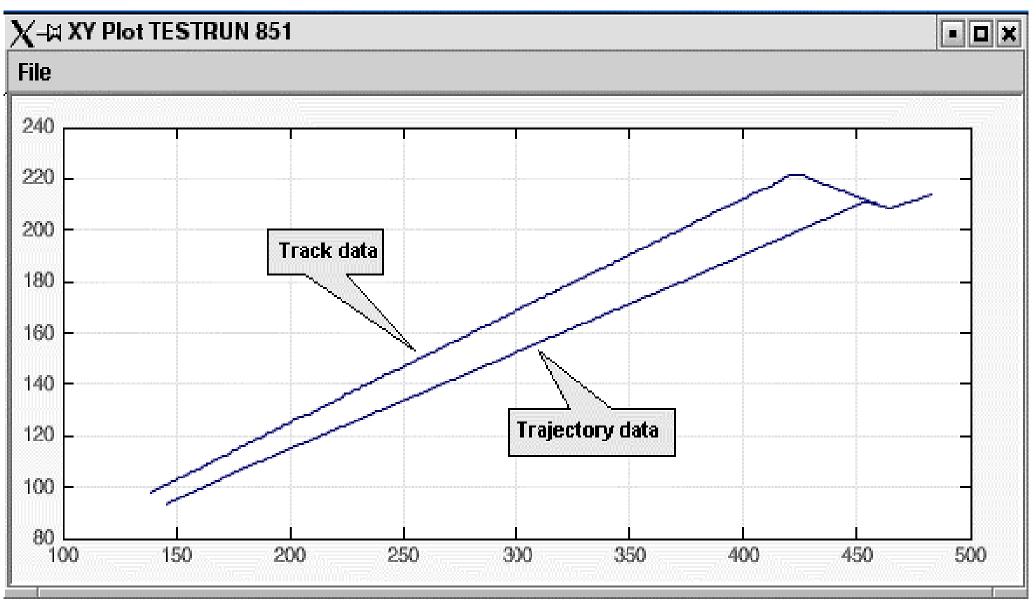

Figure 2: X-Y Plot

The window displayed if the **T-Z** button in the main window is selected will contain a plot of the flight's trajectory data and, if the analyst has checked the check box in the main window labeled **HCS tracks**, it will also contain the flight's track data. In either case the plot will present this data as altitude versus time. An example of this plot is not provided.

The window displayed if the **Metrics** button in the main window is selected will contain a tabular listing of the accuracy measurement data selected from the database. Figure 3 shows an example of this window. The first column represents the sample time for the data. The second column is the build time for the trajectory. Note for this example the sample time and trajectory build time do not change. The third column is the look-ahead time for the trajectory error measurement. The fourth column is the time. The fifth column is the horizontal error with its lateral and longitudinal components in the sixth and seventh columns respectively. The eighth column is the vertical error. The remaining columns contain flags that are indicative of the state of the flight at that particular time. This information is useful so the analyst has immediate access to the measurement data while plots are being displayed.

Metrics Data TESTRUN 69285 ABC4000_400

File

Metrics data

TmDiff	TrajBuildTm	LkAhdTm	Tm	HorzErr	LatErr	LongErr	VertErr	TmErr	ClearFlag
69290.0	69285	0	69290	0.2493	0.2492	0.0042	0	0	0
69290.0	69285	60	69350	1.8475	1.6884	-0.7502	0	0	0
69290.0	69285	120	69410	5.9518	5.6568	-1.8506	0	0	0
69290.0	69285	180	69470	10.2078	9.7118	-3.1432	0	0	0
69290.0	69285	240	69530	14.3994	13.7434	-4.2969	0	0	0
69290.0	69285	300	69590	18.7536	17.8729	-5.6795	0	0	0
69290.0	69285	360	69650	22.0654	21.1056	-6.437	0	0	1
69290.0	69285	420	69710	21.922	20.9871	-6.3335	0	0	1
69290.0	69285	480	69770	21.6342	20.6315	-6.5102	0	0	1
69290.0	69285	540	69830	21.6809	20.6874	-6.488	0	0	1
69290.0	69285	600	69890	21.3557	20.3644	-6.4307	0	0	1
69290.0	69285	660	69950	21.0296	20.0461	-6.3559	0	0	1
69290.0	69285	720	70010	20.9683	20.0271	-6.2115	0	0	1
69290.0	69285	780	70070	20.5153	19.6072	-6.0363	0	0	1
69290.0	69285	840	70130	20.2185	19.3658	-5.81	0	0	1
69290.0	69285	900	70190	19.7897	19.021	-5.462	0	0	1
69290.0	69285	960	70250	19.3896	18.757	-4.9124	0	0	1
69290.0	69285	1020	70310	19.0303	18.4609	-4.6201	0	0	1
69290.0	69285	1080	70370	18.6992	18.1388	-4.5437	0	0	1
69290.0	69285	1140	70430	18.2727	17.7544	-4.3212	0	0	1
69290.0	69285	1200	70490	18.0261	17.518	-4.2496	0	0	1

Figure 3: Metrics Data Listing

For the ABC4000_400 flight example, the lateral deviation illustrated in the X-Y plot was also listed in the Metrics data listing and depicts their relationship. The horizontal and lateral errors are rather large. The column labeled ClearFlag explains the main reason for the inaccuracy. When the ClearFlag changes to 1, it indicates an air traffic clearance was submitted altering the flights route. Therefore, the errors following the measurement at 69650 and beyond exhibit this change in the flight's route. The errors before this time indicate an unknown intent (not entered in the trajectory modeler) or lag in the entry of the change in route into the NAS. The longitudinal error is not necessarily explained by the route change but indicative of other errors, such as speed intent or wind forecast errors. The vertical errors in the Metrics plot were all zero. The aircraft was cruising at 31,000 feet and had no vertical transitions in this sample. As a result, the trajectory prediction was completely correct in the vertical dimension.

Additional capabilities of *TrajectoryGUI* include:

- a printed output of the X-Y, T-Z plots, or Metrics listing
- an image file output of the X-Y and T-Z plots
- an ASCII file output of the Metrics listing.

Future Work

TrajectoryGUI was just recently developed and to date has had limited use. As seen in Figure 1 it is planned that data for two flights can be simultaneous displayed on a single X-Y or T-Z plot. These flights may be from the same or from different scenario cases. It is anticipated as the CPAT analysts use this application additional modifications will be made to enhance its use. The example flight presented shows how the analyst can utilize both *TrajectoryGUI*'s graphical plotting functions as well as its extraction of trajectory accuracy metrics (via the Metrics data listing). Automating both these functions allows the analyst to focus on the errors and not the mechanics of plotting and extracting trajectory data.

References

[1] Cale, M., Liu, S., Oaks, B., Paglione, M., Ryan, Dr. H., Summerill, S. (December 3-7, 2001), "A Generic Sampling Technique for Measuring Aircraft Trajectory Prediction Accuracy," *Presented at the 4th USA/Europe Air Traffic Management R&D Seminar*, Santa Fe, NM.

[2] Paglione et al. (May 1999), "Trajectory Prediction Accuracy Report: URET/CTAS," (DOT/FAA/CT-TN99/10), WJHTC/ACT-250.