3D Animation of Recorded Flight Data

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INTRODUCTION
Three-dimensional animation technology has been used for many years for accident investigation purposes. With the advent of faster, lower cost personal computers this technology is now available to multiple individuals at airlines as a cost-effective enhancement for Flight Data Monitoring (FDM) and Flight Operational Quality Assurance (FOQA) programs. Aircraft animations with synchronized cockpit instrumentation are an effective means of presenting results, and drawing cause-effect relationships from recorded flight data.

The animation of an event encompasses the aircraft’s flight profile, cockpit instrumentation, terrain and scenario data. With an increasing number of parameters being recorded on aircraft, a method of relaying the large amounts of available information in a meaningful manner is needed. 3D animations are one such method. Furthermore, 3D animation capabilities are now accessible to multiple end-users from their desktop PC.

TECHNICAL CONSIDERATIONS
The primary consideration in producing an animation of an event is ensuring that the playback is accurate. The animation must account for the sensor type, signal source, valid range, accuracy and resolution of the recorded data. Furthermore, the raw data must be processed to remove any bad data; otherwise the animated sequence will be erroneous. The examples contained herein are taken from the Software Kinetics Ltd ‘Flight Animator’.

FRAMES OF REFERENCE
The data sources pertaining to the aircraft dynamics, motions of aircraft parts, flight path and terrain are relative to specific frames of reference. Several types of transformations including scaling, translation and rotation may be applied to the objects in a known frame of reference.
The principal frames of reference utilized in an animation system are the following orthogonal, right-handed Cartesian frames:

- **Geographic Frame**

  The position and orientation of the aircraft centre of mass is described relative to a set of axes, which are fixed to the Earth. The instantaneous motion relative to the fixed axes can be used to generate the XYZ coordinates and orientation information depicting the aircraft’s flight path.

  The geographic frame of reference is:
  - X (East);
  - Y (North); and
  - Z (Up).

  Figure 1a) depicts the geographic frame of reference.

- **Body Frame**

  The body frame of reference is fixed to an object. Assuming exact symmetry of the aircraft, one convention for defining the aircraft body axes is:

  - X is along the longitudinal reference line of the aircraft, pointing forward. A positive rotation about the X-axis corresponds to right wing down.
  - Y is along the lateral reference line of the aircraft, pointing along the right wing. A positive rotation about the Y-axis corresponds to nose pitch up.
  - Z is orthogonal to X and Y, pointing downward. A positive rotation about the Z-axis corresponds to a positive counter-clockwise rotation in yaw.

  Figure 1b) illustrates the body frame of reference for an aircraft.

![Figure 1: a) Geographic frame of reference [1] b) Body frame of reference [1]](image)

Aircraft models may be defined hierarchically, whereby they consist of multiple child parts attached to parent parts. Body frames of reference are associated with each part, thereby allowing parameter data inputs to drive individual parts, such as the control surfaces. Also, parts may be attached to other parts in such a way that movement of one part will automatically cause movement
of all its attached parts. For example, all the child parts relative to an aircraft’s landing gear may be
driven by the gear position data.

Depending on the availability of data, it is possible to animate multiple objects in a scene such as
multiple aircraft, ground vehicles and markers in the scenery.

FLIGHT PATH RECONSTRUCTION
Flight path reconstruction consists of utilizing recorded flight data to derive the aircraft’s instantaneous
position and orientation relative to an orthogonal, right-handed Cartesian frame of reference that is fixed
to the Earth.

Several algorithms exist for calculating an aircraft’s flight path, which require different sets of input
parameters. The total set of parameters includes airspeed, pressure altitude, radio altitude, ground speed,
drift angle, roll attitude, pitch attitude, heading (true or magnetic), glideslope deviation, localizer
deviation, magnetic variation, wind speed, wind direction, temperature and station pressure.

There are two categories of flight path reconstruction algorithms, those that employ Dead Reckoning
techniques and those that employ absolute-referencing techniques.

Dead Reckoning involves the calculation of incremental distances traveled relative to a previously known
position in the path. Thus, Dead Reckoning algorithms must be initialized before a continuous flight
path can be calculated. For each time interval in the data set the incremental distances traveled along the
three-dimensional frame of reference are computed. The distances traveled relative to the previous
position in the path are then utilized to compute the current position. This is repeated until the complete,
continuous flight path has been generated.

In absolute-referencing, the flight path of an aircraft is determined through conversion of latitude and
longitude to XY absolute grid coordinates. Geodetic latitude and longitude outputs supplied by the on-
board navigation system and recorded in-flight are the input data sources. The two-dimensional
horizontal terrain coordinates can be obtained through conversion of the latitude and longitude
information to the Universal Transverse Mercator (UTM) reference system. The UTM grid reference
system is derived from an ellipsoidal model of the Earth appropriate to the intended application.
Although, each XY path coordinate is calculated independently from the previous position in the path, it
is only an absolute coordinate reference if the data source for the latitude/longitude information is also an
absolute position solution. Global Positioning System (GPS) navigation systems are one such example.

Latitude/Longitude information from Dead Reckoning systems, such as inertial navigation systems, may
also be used to reconstruct an aircraft’s flight path. However, the user should be aware of the different
error characteristics for the different types of navigation systems. Dead Reckoning solutions are subject
to increasing errors as a result of the integration of bias offsets and scaling errors over time [2].

The Z-coordinate is derived from radio and pressure altitude information.

The process of choosing an algorithm for reconstructing an aircraft’s flight path must take into
consideration the accuracy, sampling rate and resolution of the recorded parameter data, as well as, the
input data source [3].
External data sources such as a known touchdown point on the runway may be used to make fine adjustments to the aircraft’s calculated flight path. Thus, the optimum flight path is obtained through correlation of data from:

- Multiple flight path reconstruction techniques;
- Radar systems;
- Cockpit voice recorder and air traffic control transcripts;
- Ground observations; and
- Pilot reports.

Refer to Figure 2 for an illustration of an aircraft’s flight path.

Figure 2: Aircraft flight path [1]

**TIME-BASED SUBTITLING**
Cockpit voice recorder transcript, air traffic control transcript or other time-based text transcripts may be overlayed with the animation.

**INSTRUMENTATION**
The graphical display of data-driven instrumentation is a means of relaying the recorded flight data in a manner similar to what the pilot may have observed in the cockpit. Some examples of cockpit instrumentation include: control stick, control wheel, tachometer, altimeter, horizontal situation indicator
(HSI), airspeed indicator, Electronic Flight Instrument System (EFIS) Primary Flight Display (PFD) and Electronic Centralized Aircraft Monitor (ECAM). Figure 3 is a snapshot of an aircraft animation with an instrument panel.

Figure 3: Aircraft animation snapshot with instrument panel and terrain elevation data [1]

DATA INTERPOLATION AND SMOOTHING
Bspline smoothing, cubic spline and linear interpolation are examples of numerical methods, which may be applied to individual parameters to derive intermediate values between recorded samples.

SCENERY AND ENVIRONMENTAL FACTORS
To further augment understanding of a particular event, environmental factors such as visibility, cloud layers and daylight illumination may be depicted. Terrain elevation data, runways, towers, navigation aids, ground vehicles and buildings are other examples of cultural features, which may be rendered. External references such as digital maps, weather reports and detailed approach plates are required to ensure the information is represented correctly.

Figures 3 and 4 are illustrations of terrain elevation data and a final approach relative to the glideslope.
REAL-TIME PLAYBACK
Despite the computation-intensive algorithms for the graphics and spatial reference frames, the software design must ensure time accuracy during real-time playback of an animation.

INTERACTIVE CONTROL
Some key system characteristics include camera view control (chase, chase ground, cockpit and fixed ground), time control (playback speed and direction) and camera position control (radial, horizontal and vertical distances). These assist the analyst with the interpretation of a flight segment. Unlike videotape, which was more commonly used in the past, direct access to desktop animation systems allows the end-user to interact with the system. Figure 6 illustrated four different view perspectives.
BENEFITS
There are numerous, wide-ranging benefits of 3D animations. These include:

- Crew self-assessment;
- Flight training;
- Airline safety improvement;
- Human factors study; and
- Operational procedures review.

One example scenario would be a pilot self-debriefing session following a particular flight.

CAUTIONS
Misuse of animation systems may result in misleading results and events being falsely interpreted. For example:

- incorrect use of numerical methods may skew the data;
- representation of subjective information such as weather phenomena should be clearly indicated;
• instrument displays reflect the status of recorded data, which may not necessarily represent the actual instrument accuracy and functionality; and
• conclusions regarding what the pilot actually saw should not be drawn from the recorded data.

CONCLUSIONS
3D Animation is a compelling, useful method for visualizing recorded flight data. It is an effective means of conveying the results of analyses to various end-users in a manner that is easily understood. The tremendous benefits of 3D animation are contingent on the fidelity and accuracy of the animation.

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BIOGRAPHIES
Ms. Carole Bolduc is a Professional Engineer at Software Kinetics Ltd. She is currently the Project Engineer on the Flight Data Monitoring project. She has participated in projects relating to Flight Data Monitoring, flight data recorders, aircraft certification and navigation systems. She obtained her Bachelor of Aerospace Engineering Degree from Carleton University in June 1993 and her Master’s Degree in Aerospace Engineering from Carleton University in June 1995.

Mr. Wayne Jackson has managed research projects at TDC since February 1993 in Flight Data Monitoring, crash survivability, flight recorders, air traffic control, cockpit voice recorder (CVR) explosion analysis and wake vortex prediction. He has 29 years of experience in air navigation software development, research and project management. He is a Professional Engineer with degrees in Mechanical Engineering from the University of Western Ontario and Computer Science from the University of Waterloo.