Advanced Accident Flight Path Simulation And Innovative Visual Animation

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Aims of this paper

To present a process of
- reconstruction,
- simulation, and
- advanced innovative visual animation of time dependent flight paths and aircraft evolutions

The approach is intended to be used in flight accident analysis

“Forensic engineering”: the application of scientific and engineering knowledge to legal matters, such as accident reconstruction

Authors have created an integrated simulation environment in order to make almost fully automatic the process of accident analysis
Available Data in Flight Path Reconstruction

Data sources considered here are:

- ground-based Air Traffic Control (ATC) radar tracking system,
- on-board flight data recorder (FDR),
- Voice Data Recorder (VDR)

- Radar tracking systems provide time histories of aircraft position \((x,y)\), including altitude \(z\) when the vehicle is equipped with an altitude transponder.

- Radar data are recorded by an ATC station in the vicinity of the accident site.

- On-board FDRs provide at least time histories of Indicated Airspeed \((V)\), Magnetic Heading \((\psi)\), Barometric Altitude \((z)\), and Normal Body Acceleration \((a_Z)\).

- FDR are carried by a wide variety of aircrafts and are designed to withstand the rigors of severe accidents.
Reference Frames

... having their origins at the Vehicle Mass Center and moving with it:

- "vehicle-carried vertical frame" $F_v$: axes are parallel to a conventional stationary earth-surface frame $F_e$

- "wind-axis frame" $F_w$: has axis $Ox_w$ along the velocity vector and axis $Oz_w$ in aircraft plane of symmetry

- "body frame" $F_b$: a conventional frame attached to the aircraft
Motions Derived From Accident Data

A key steps: the estimation of the angle of attack (AOA) by the evaluation of forces, airspeed and specific information about the airplane (lift characteristics).

- Wind-axis Euler angles \((\psi_w, \theta_w, \phi_w)\) with respect to frame \(F_e\) and acceleration vector components \((a_{xw}, a_{yw}, a_{zw})\), are determined from vehicle position derivatives and from the wind information.

- The angle of attack \(\alpha\) allows the determination of the wind-axes, and of the body-axis Euler angle time-histories.

- The attitude of the “body frame” \(F_b\) relative to \(F_V\) is determined by Euler angles \((\psi_b, \theta_b, \phi_b)\), which are of primary interest in the analysis of vehicle motion.

It is assumed a negligible sideslip along the flight path, and, consistently, a zero side force.
Reconstruction Procedure

RADAR-DERIVED
POSITION DATA
\(x, y, z\)

ON-BOARD
RECORDED DATA
\(V, \psi_b, z, a_{zb}\)

Data Smoothing,
1st & 2nd Derivatives
Computation

\(\dot{x}, \Delta x, \dot{y}, \Delta y, \dot{z}, \Delta z\)
\(\dot{V}, \dot{\psi}_b, \dot{z}, \ddot{z}, a_{zb}\)

LOCAL WIND
ESTIMATES

Wind axes,
Forces & Angles
Computation
\((a_{yW} = 0)\)

\(a_{xW}, a_{zW}\)
\(\phi_W, \theta_W, \psi_W\)

AIRCRAFT
PERFORMANCE
DATA

Angle-of-Attack,
Body-Axis Angles
Computation
\((\beta = 0)\)

\(\phi_b, \theta_b, \psi_b\)
Available Data in Flight Path Reconstruction (2)

Row data (left)
Vs.
Smoothed data (right)
Uncertainties

- In motion reconstruction, we assume that certain types of data anomalies, such as dropouts, wild points, etc., have been removed and that corrections for temperature, pressure, etc., have been made to air data.

- Uncertainties are also admitted for meteorological data:
  - Wind measurements, if available, may have been recorded many miles away from the crash site and at a different time.
  - Usually, wind velocity components are obtained only as a function of altitude, and it must be often assumed a negligible vertical component.

Despite these limitations, one can compute satisfactory estimates of angle-of-attack, and body-axis-Euler-angles time histories.
An example ...

A possible Accident Scenario

Estimated Time-Histories
Flight Visual Representations & Animations

- Corrected/smoothed data + estimated/crosschecked remaining flight parameters enable detailed accident scenarios inspections and analyses

- Optimised video sequences, and clearer animations are created by using the well-known 3ds-max software and scripting capabilities

- Advanced rendering techniques give then to the accident animation a realistic outcome with their sophisticated shading, shadows, transparency and texture effects

- Visual flight simulations are achieved with the aid of the open-source flight simulator FlightGear (FG), used as a visualization server

- a client c++ program (compiled against some FG base-libraries) passes to FG all necessary data in real-time via an UDP net protocol

- Reconstructions are enhanced by synchronizing visual animations with dialogues between pilots and ATC
Flight Visual Representations & Animations (2)
Conclusions

- The proposed approach is particularly helpful when data sets provided by FDR are made of a small number of flight parameters (example: small commercial/general-aviation aircrafts with no thrust data)

- Lack of information, coupled with a poor collection of data on local wind conditions, could be significant in the analysis of complex manoeuvres when the physical sense time-histories is not straightforward.

- In accident analyses, visualizations are addressed to different kind of interlocutors such as technicians, pilots, lawyers and judges.

- Arises the necessity of having available different tools to represent in more ways the aircraft motion arises from the type of The high level of generality and modularity of the developed software, allows the representation and the analysis of any accident data in short time.