Simulating the interaction of cabin crew with passengers during aircraft emergency evacuation conditions

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ABSTRACT:
In this paper we briefly describe new modelling capabilities within the airEXODUS evacuation model. These new capabilities involve the explicit ability to simulate the interaction of crew with passengers in managing evacuation situations.

OVERVIEW OF CREW MODELLING CAPABILITY:

Aircraft cabin crew have a pivotal role in managing and bringing about a successful aircraft evacuation. However, traditionally mathematical models of aircraft evacuation have used an implicit representation of crew procedures. This technique requires users of models to determine and impose the outcome of crew procedures as opposed to simulating the process and the model predicting an outcome. The airEXODUS aircraft evacuation model [1-8] has been extended to enable the explicit simulation of the action of cabin crew during aircraft evacuation. The model is based on a detailed investigation of crew behaviour during both controlled experiments and real aircraft evacuation situations.

As part of this development, human behaviour in aircraft 90-second certification trials and real emergency evacuations were studied in detail. For certification trials, this was based on an analysis of video footage from past trials and transcripts from interviews with crew. Accident analysis was undertaken using crew and passenger transcripts from accident investigations found within the AASK database [9-11]. A finding from this work is that cabin management procedures are nearly always employed by cabin crew during certification trials and quite often during real emergency evacuation scenarios. The investigation indicates that these procedures may involve crew instigated exit by-pass/re-direction or in more severe emergency scenarios passengers' forming their own exit choice. A finding of this work is the possibility of conflicting goals between passengers and crew - crew are generally concerned with maximising exit utilisation and thereby reducing the overall evacuation time for the aircraft whereas passengers are generally concerned with attempting to reduce their personal (including persons with whom they are attached) evacuation times. The investigation, indicates that during certification evacuations, passengers are generally very compliant to crew instruction and are thus more likely to follow a crew command and to redirect to another exit than in severe emergency scenarios especially those involving fire which has breached the cabin. In these more severe scenarios passengers are more likely to be concerned with their own self interest.

Based on this original study, new behaviour sub-models for crew-passenger interactions have been suggested and new algorithms developed to represent this behaviour within the airEXODUS evacuation model. Algorithms capable of simulating crew redirection procedures in 90-second certification trials have been developed. These are then extended to simulate behaviour in real emergency evacuations involving fire and smoke. This involves developing additional algorithms for passenger exit choice. The original investigation of accidents indicates that both passenger and crew decisions are based on the information that is obtained from the environment during the evacuation (referred to as dynamic information) and known aspects of their environment (referred to as static information).

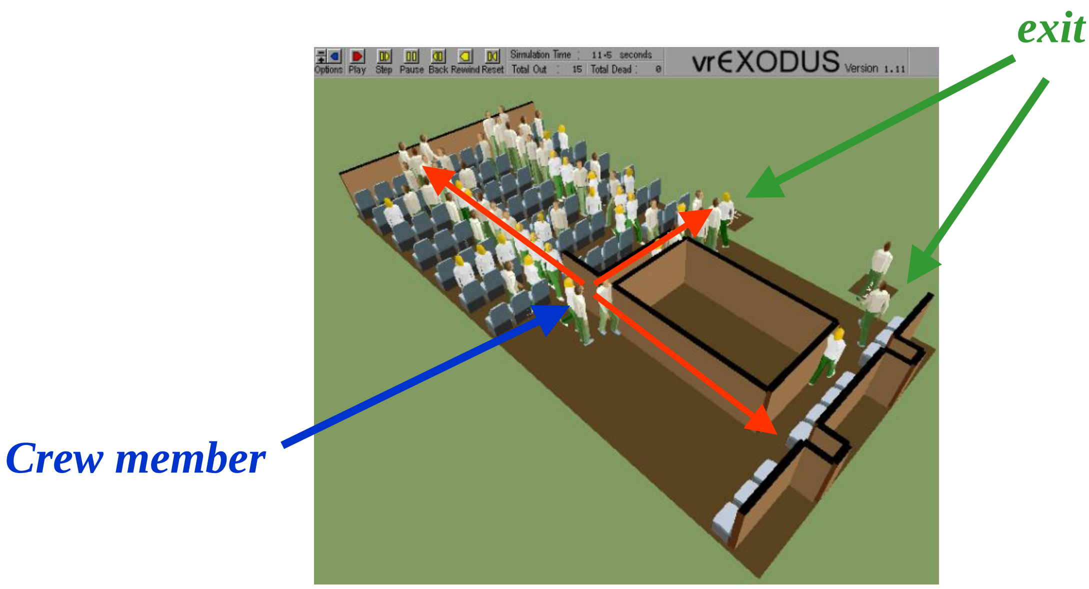


Figure 1: The crew can make decisions based on information gathered through line of sight. Crews line of sight is indicated by red lines along the aisles, note crewmember cannot see what is happening at distant exit located behind the monument.

Mechanisms are provided within the models for passengers and crew to gather both types of information. Primarily this is achieved through a rudimentary implementation of line of sight (see Figure 1) and the restrictions that the geometry of the structure and the smoke conditions within the cabin impose upon passengers and crew (see Figures 2 and 3). The resulting algorithms are more adaptive and allow passengers to look beyond their immediate surrounds and to appreciate the implications of the evolving evacuation dynamics within the cabin. This enables more realistic decisions to be made based on their available information.

(a) total view of region surrounding crewmember located at exit R2	(b) white cross indicates line-of-sight region afforded to crewmember located at exit R2	(c) visibility stencil imposed on line-of-sight region based on smoke concentration in vicinity of crewmember located at exit R2	(d) resulting visibility capability for crew member located at exit R2, only 3 paxs are visible through the smoke

Figure 2: Reduced visibility due to smoke. Reduced visual access is imposed on the line-of-sight calculation due to the presence of smoke, this reduction is determined through calculation of smoke extinction coefficients.

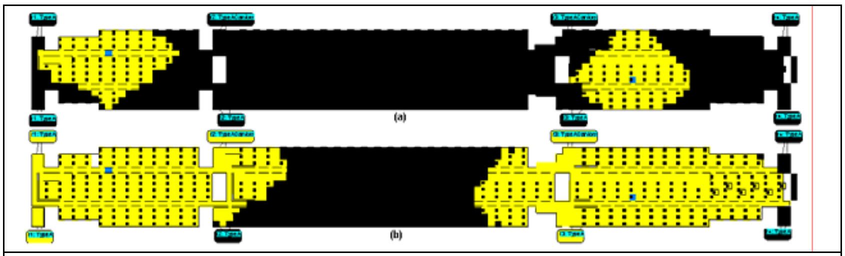


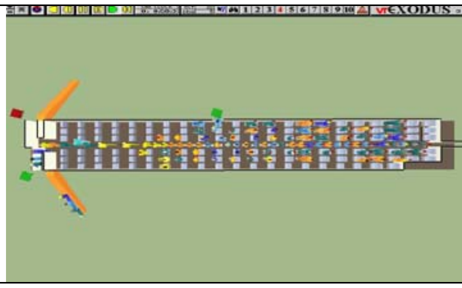
Figure 3: The visibility algorithm takes into account the difference between illuminated and non-illuminated objects in smoke. The figure displays standing level visibility in smoke for two paxs during an evacuation (a) when viewing other paxs (i.e. non-illuminated) and (b) when viewing illuminated exit signs.

In summary, the model consists of several key components, namely:

- Visual Access for crew and passengers
- Communication between crew and passengers
- Crew decision making process
  - Is redirection needed?
  - Selecting a pax to redirect
  - Primary exit preference
  - Crew fallibility
- Pax decisions making and response.

(a) congestion as evacuation begins, only forward exits are available at this time. 'H' above heads of some paxs indicate that they are already being exposed to dangerous levels of heat.

(b) paxs begin to climb over seats to avoid congestion in the rear of the aircraft, overwing exits still not available.



(c) congestion at rear of cabin still serious as overwing exit becomes available.

(d) paxs crawl under smoke layer as they approach Type-III exit.

(e) location of fatalities indicated by body icon in the aisle, note bodies found in seats, aisle and within exits, also multiple fatalities found at a single location.

Figure 4: airEXODUS prediction of the Manchester B737 fire of 1985.

The new behavioural capability has been demonstrated through a number of examples including the influence crew may have in redirecting passengers away from a Type-III exit and several examples involving fire.

The new model has also been used to reproduce a fire situation similar to the B737 Manchester airport disaster of 1985. In this example the exits are opened in the same sequence as in the actual incident and the passengers, crew and cabin interior is exposed to a representative fire. The fire is based on data derived from a full-scale test fire conducted by the US FAA at Atlantic City.

In the simulation the available crew attempt to manage the evacuation within a cabin environment which is rapidly deteriorating due to the presence of hot fire products. The simulations demonstrate a range of behaviour including seat jumping, exit recommitment, passengers crawling under the smoke layer, loss of visibility due to smoke, as well as physiological response to heat and toxic fire products (through the use of Fractional Effective Dose models for toxicity [7,8]). The simulation results in 57-66 fatalities with an average of 61 fatalities. At Manchester, 55 people died.

Concluding Comments:

Using the airEXODUS evacuation model, in conjunction with realistic fire data (which can be produced by full-scale experimentation or CFD based fire modelling [12,13]) the outcome of events such as Manchester are predictable. This provides further justification for the incorporation of some form of evacuation modelling into the evacuation certification process.

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