A COMPUTER AIDED VIDEO TRACKING SYSTEM FOR DETERMINING THE POSITION AND SPEED OF AIRCRAFT NOISE SOURCES

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ABSTRACT

This paper describes a relatively simple and inexpensive technique for determining the position and speed of aircraft noise sources whilst undertaking noise trials. The system developed is totally portable and operates by digitizing and combining video pictures taken at various angles of the aircraft's flight track. With the aid of a computer, the aircraft's speed and time varying propagation distance data can be quickly calculated. Results obtained from the system when conducting a low flying aircraft noise trial were in agreement with distance and speed data acquired from a specialised kinetheodolite tracking system.

INTRODUCTION

In noise measurements there is a requirement to know accurately the position of the noise source and its distance from the receiver. This is often more difficult to establish than the actual measurement of the sound level.

In the past the Royal Air Force Institute of Health and Medical Training's Environmental Noise Department (END) has carried out numerous noise trials on both rotary and fixed wing military aircraft. Many of these trials were conducted in conjunction with the Acoustic Division of the National Physical Laboratory. Data from these trials [1][2], in the form of propagation distance with respect to L_{Amax} and L_{Ae}, have been used in the construction of a large data base [3] for use in the joint END/NPL *AIRNOISE* computer prediction model of military aircraft noise.

A typical noise trial consists of the aircraft flying a pre-determined flight track at various altitudes, engine power settings and various ground speeds. However, due to many influencing factors, mainly lack of sufficient navigational accuracy and meteorological conditions, the required flight conditions are not always met. The use of an airfield or ranges radar or optical kinetheodolite tracking facility to produce the actual height, off-line distances and ground speeds would be required. When trials were conducted with the NPL, their video tracking system would also be used. Where there was no tracking facility available, the aircraft's position had to be visually estimated.

It was decided to develop an aircraft tracking system to enable the END to determine the necessary distance and speed data of aircraft noise sources for inclusion into the *AIRNOISE* model. Aircraft can be tracked by radar or optical systems. Most radar systems available to the END are unsuitable, having operational and accuracy limitations when tracking aircraft noise sources at low altitude. In mobile form they are far too expensive. It was therefore decided to develop a computer aided tracking system which would operate using video cameras.

SYSTEM REQUIREMENTS

The computer aided video tracking system would have to fulfil the following requirements:

a. Inexpensive.

b. Simple to operate and install.

c. To determine the position of the aircraft in x,y and z coordinates.

d. To produce the aircraft's average ground speed.

e. To calculate the time varying propagation distances for later comparison with the measured noise levels. The combined data would then be implemented into the *AIRNOISE* prediction model.

OVERALL APPROACH

It was decided that the tracking system would operate by utilising the images from three static video cameras each with a fixed field of vision. In theory, the aircraft's position can be determined using only two video cameras. However, by incorporating a third camera into the system, the precision in determining the aircraft's location would be greatly increased. The aircraft's height and displacement would be determined using three calibration poles of known heights, sited at set distances from each camera. The angles of the aircraft from the horizon and camera centre line could then be determined, as displayed in figure 1. By using trigonometry the altitude and displacement of the aircraft is therefore easy to calculate.

By combining the horizontal and vertical angles from all three video pictures at the same instance in time and by using triangulation calculations the position of the aircraft can then be easily determined using a computer, as shown in figure 2. As a result of calculating the aircraft's position, the average ground speed of the aircraft can be calculated using the distance flown and the number of video frames taken to traverse the distance.

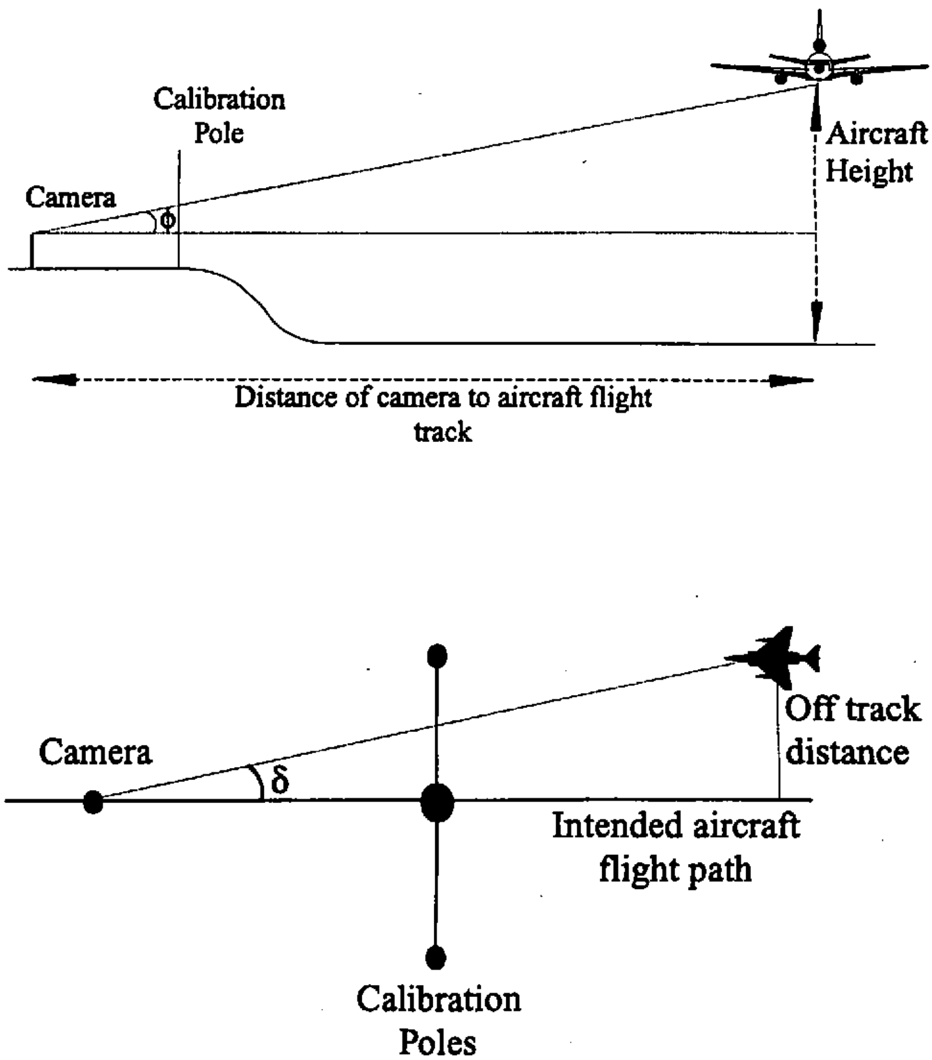

Figure 1 - Methods of determining aircraft angles and displacements

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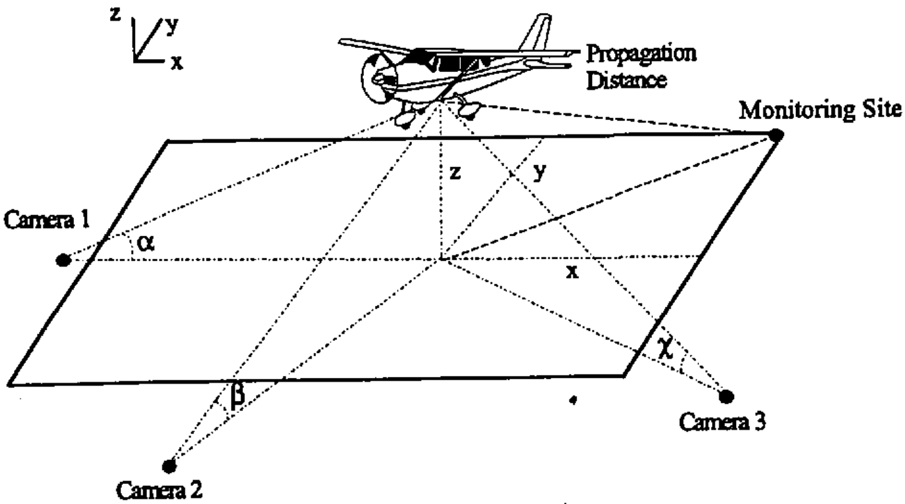

Figure 2 - Typical tracking system arrangement

To ensure that the system requirements *c*, *d* and *e* would be fulfilled to the highest order of accuracy possible. The tracking system must be capable of:

i. Recording and playing back high quality video images to ensure accurate location of the noise sources when later analyzed.

ii. Accurate synchronization of all three cameras for when the aircraft's position is combined.

iii. Accurate measurement of all camera to camera distances when calculating the aircraft's position.

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DEVELOPMENT

HARDWARE

To ensure high picture definition of the recorded images, three high quality standard format video cameras were used. These were fitted with wide angle lenses giving a field of view of approximately 70 degrees. This results in a much wider area through which the aircraft can be tracked when compared with the standard lenses. To also ensure high picture quality when the video images are being played back, a industrial specification video player was acquired. The video player has variable speed forward and reverse motion and utilises a 4-head playback system to provide stationary, flicker free freeze frames. To ensure accurate synchronization of all three video cameras, the output of an external radio-code clock is recorded onto the audio channel of each camera. The recorded signals are later decoded for inclusion into the video display on a computer.

The major obstacle with the initial development of the system was the process of converting the aircraft's position from the video images into a set of coordinates. The conversion process can be carried out by two methods. One method acquires the video image one frame at a time on to a computer screen, whereas the other method overlays a computer generated grid system onto the video picture. The aircraft's position is then determined using an x,y screen cursor operated by the computer mouse.

Both methods of digitizing have their advantages and disadvantages, as listed.

Frame Grabber :-

Advantages: There are a wide choice of low cost systems available.

Disadvantages : The digitized picture quality is inferior to the original video image. Hence the location of the aircraft is far more difficult and consequently uncertainties are introduced. The process of 'grabbing' the video image onto the computer is not real time.

Video overlay method :-

Advantages : There is no degradation of the quality of the video picture and the process runs in real time.

Disadvantages : There are very few systems available and are more expensive than frame grabber systems.

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One of the system requirements was to maintain the quality of the picture definition. A commercially available computer screen/video overlay card was therefore obtained. The card combines the VGA output of any PC computer which has a features output on the VGA card, with the video output of a PAL format video player. The combined video and computer image is then output to a standard video monitor. By the use of a cursor generated by the computer, the aircraft is tracked manually along its flight path for each frame of the video recording.

SOFTWARE

The developed software is fully menu driven and consists of five separate routines:

1-3: Digitizing of the three separate video camera locations using a common routine.

4: Combining the three digitized tracking files from which the aircraft's position in x,y and z coordinates is calculated. The origin is usually the main microphone site, which is sited directly under the flight path.

5: The calculation of the aircraft's average ground speed and the propagation distances with respect to time from the various microphone sites. The aircraft's trajectory is also displayed in graphical form.

Before the aircraft images are digitized the position and height of the calibration poles in front of each camera must be digitized, which will then enable the aircraft angles to be later determined in routine 4. The aircraft's position on each video camera must then be manually digitized for every video frame, to eventually create a computer file of time referenced screen coordinate data.

Once all the images have been digitized the three data files are combined with their respective digitized pole screen coordinates. To enable the software to then calculate the aircraft's position in x,y and z coordinates, the exact location of all the cameras must be known in order to determine their exact distances between each other. Consequently, the use of map grid coordinates are used for both the entry of camera and microphone site locations. The aircraft angles from the horizon and camera centre lines are derived from these combined files. By utilising the distances obtained from the grid coordinates and combining all three data files the aircraft's position in x,y and z distance coordinates, for each video frame, is then calculated.

The final requirement is to calculate the aircraft's average ground speed and its time varying propagation distance from each microphone site. To achieve this simply and quickly, the aircraft's position is converted into the grid coordinate system. This also provides a far easier method of graphically plotting the aircraft's flight path.

VERIFICATION OF THE TRACKING SYSTEM

The verification of the tracking system was carried out at a low flying aircraft noise trial at a calibrated military range. The range has the facility to track aircraft using both radar and kinetheodolite systems. American F15-E, British Harrier GR5 and Tucano turbo prop aircraft took part in the trial. Each aircraft flew along a single flight track at various altitudes and engine power settings. As a consequence of the single flight track and limitations in positioning the cameras, the typical arrangement depicted in figure 2 was altered. A single tracking camera was positioned 1km from the flight path with the remaining two cameras located under the flight track near to the main measurement site, monitoring the approach and departure flight paths.

The inaccuracy in radar in determining the altitude of aircraft when operating at low level was very apparent. The radar data occasionally showed the aircraft to be at a negative altitude. The distances and speeds which were obtained from the ENDs tracking system were therefore only verified against the kinetheodolite tracking data.

During the GR5 runs, poor meteorological conditions prevented the use of the kinetheodolite system. Accurate tracking of the GR5 was therefore only possible using the ENDs tracking system.

ACCURACY

Tracking data obtained from both systems during the F15-E and Tucano runs, showed that the video tracking system has a maximum variation in the height, off line and ground speed data of +/- 5%. These differences are due to a combination of factors mainly:

a. Manually maintaining accurate tracking of the aircraft.

b. Ensuring accurate measurement of all distances and positions.

c. Maintaining the visibility of the aircraft during the runs.

The greatest uncertainties arise from condition *a*. The system software requires that the aircraft must be tracked accurately for every single video frame. Any deviation of the tracking cursor from the aircraft will cause inaccurate results. Also the positioning of the tracking cursor on the aircraft is also important. A difference of up to 10 metres can be immediately introduced, depending upon where the tracking cursor is positioned on the aircraft.

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CONCLUSIONS

Often in environmental noise measurement more time and effort is spent in resolving the non-acoustic elements of the problem. The RAF IHMT has developed a simple and practical method of tracking aircraft without the need of sophisticated equipment and on board transponders.

The tracking system uses 3 video cameras to triangulate the aircraft's position. The recorded images are synchronized from a common time signal. Each frame of the video signal is overlaid by a computer generated grid and the aircraft is tracked using the computer mouse. The software determines the position of the aircraft's in space relative to the video cameras and calculates the propagation distance to the noise monitoring sites. The system has been calibrated during an actual field trial and it has been shown that the position of the aircraft can be established to within +/- 5%.

FUTURE DEVELOPMENTS

At present the aircraft is tracked for every single video frame. For a typical run lasting approximately 5 seconds a total of 125 frames must be digitized. Errors can therefore be unintentionally introduced by the operator. To overcome this problem, the tracking system will in future include an option to vary the time interval between accepting a frame for digitizing.

Currently the tracking system software requires all camera and microphone locations to be entered as map grid coordinates, for use in calculating distances and angles. For future noise trials a hand held Global Positioning System, which utilises navigation satellites, will be employed for entry of positions in terms of longitude and latitude.

Future projects using the tracking system will include the investigation of light aircraft noise and other routine monitoring where the source of the noise is required to be known accurately.

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