Instrumental Landing Using Audio Indication

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Instrumental Landing Using Audio Indication

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Abstract. The paper proposes an audio indication method for presenting to a pilot the information regarding the relative positions of an aircraft in the tasks of precision piloting. The implementation of the method is presented, the use of such parameters of audio signal as loudness, frequency and modulation are discussed. To confirm the operability of the audio indication channel the experiments using modern aircraft simulation facility were carried out. The simulated performed the instrument landing using the proposed audio method to indicate the aircraft deviations in relation to the slide path. The results proved compatible with the simulated instrumental landings using the traditional glidescope pointers. It inspires to develop the method in order to solve other precision piloting tasks.

1. Introduction

Pilots of modern airplanes in the process of piloting have to analyze a great deal of visual information [1]. Besides, from late 70's up till nowadays, the gap between the physiological limits of a human operator and the opportunities of the technical facilities has increased considerably [1-3]. This is why the attraction of audio technologies in avionics has increased considerably.

The first experiments dealing with the audio application to the purposes of aircraft control took place in the middle of the last century [4]. From the very beginning such experiments were aimed at reducing the pilot's workload. It was assumed that a pilot is overloaded with the visual information [4], for which reason a supplementary audio channel is highly desirable.

In recent years, the growing interest to unmanned aerial vehicles (UAVs) has raised the demand for skillful operators. It is evident that the UAV operator is deprived of the sensual information, concerning accelerations, position and angular orientation of the vehicle, he cannot hear the sound, accompanying the operation of the engine, etc. Thus, the additional indication may be very useful to compensate the lack of information, associated with the remote piloting.

Within the last few years the efforts have been taken to improve the pilot cockpit's interface by means of the 3D- audio approach [5]. In this case the specially processed audio signals are fed to the pilot's left and right headphones. The signal processing is performed in such a way as to imitate the natural human perception of the direction towards the source of the sound. The experimental evaluation of this method accuracy, presented in [5], shows that it is sufficient to indicate the direction in general, but doesn't meet the requirements for precise piloting tasks. In other words, in the terms of the accuracy 3D- audio is very far from being compatible with the traditional visual indicators.

That is why in the present paper it is assumed, that in the problem of instrumental landing we should consider such distinctive and simple parameters of audio signal as loudness, frequency and modulation. The variations of these parameters are to present to the pilot the aircraft position relative to the glide path.

2. Description of the research

In order to study the audio indication channel as a source of flight information for a pilot, experiments were carried out to implement high-precision maneuvers at a flight research facility [5-8].

Experiments imitated the instrumental landing, that is the visualization of the environment outside the cockpit was turned off. Moreover the operator received information about the aircraft position relative to the glide path by audio indication channel only. To achieve this the glidescope pointers positioned on horizontal situation indicator (HSI), which normally show the aircraft deviations in relation to the glide path, were blocked and set to zero position.

Let us consider in more details the audio indication model, which we introduced specially for this research. Since the audio indication is a replacement to the HSI pointers, its inputs are connected to the unit which calculates vertical and horizontal angular deviations of the aircraft in relation to the glide path. The audio indication functions as follows. Above all, there are two "dead zones" for horizontal and vertical deviations, that is the audio channel produces no sound when both horizontal and vertical deviations are smaller than a predefined threshold. The level of this threshold was set to ±4% of the indication full scope, which in its turn reproduced the HSI glidescope pointers full range equal to ±1,6°. All this refers to both vertical and horizontal channels. The mismatches of greater level were indicated by sounds.

In this research we used three pre-prepared sound samples, which are well diverse modulated and attributed to "up", "horizon" and "bottom". The operator is to be trained a priory.

Figure 1 shows a phonogram "up" (A) "horizon" (B) and "down" (C) sounds. The figure shows that to indicate the sign of the vertical error the different sound fragment are used. To present the absolute value of the error the sound volume is used. When indicating the sign of horizontal error, sound is fed only to the left or right headphone, and the value of the horizontal error is encoded by frequency modulation of the sound. So the volume variations are reserved to the vertical channel only. In the area corresponding to the vertical "dead zone" only (when the horizon error exceeds the threshold) "horizon" fragment is used to be played at a fixed minimum volume, but the system keeps the frequency modulation for the horizon error value.

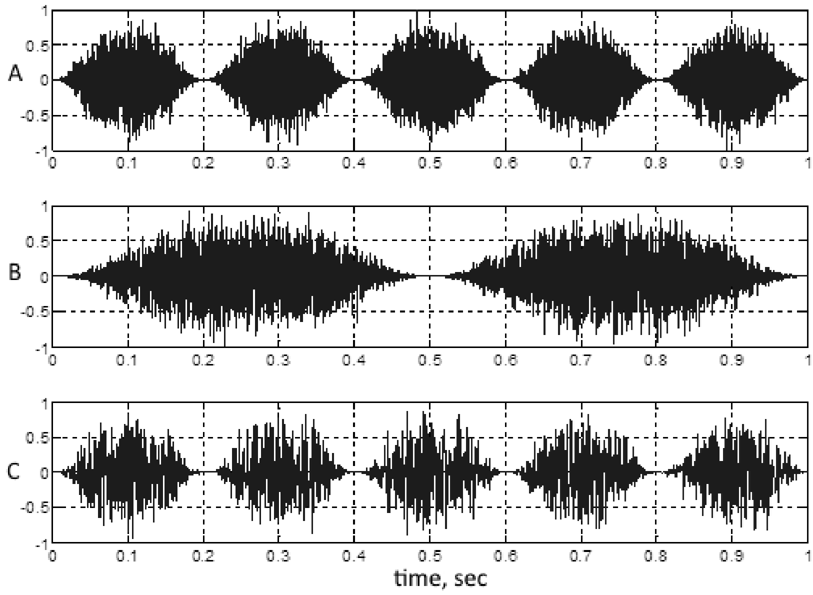

Figure 1. Phonograms of audio indication.

In the area corresponding to the horizontal "dead zone", the appropriate vertical sound is fed equally to the both headphones. So the vertical phonograms "up" (A) and "down" (C) are used in all cases except the vertical "dead zone" only, when the "horizon" (B) fragment is played.

The frequency of sound for horizontal error indication is modulated in accordance to the formula:

$$F = \frac{F_{base}}{2} + (2Amp_x - 1)P, \quad (6)$$

where F_{base} – the original sampling frequency of the audio track, Hz; F - the modulated frequency of sound, Hz; Amp_x – the normalized module of horizontal deviation; P – the scaling factor equal to 30,0 chosen according to the comments of the operator.

On figure 2 two-dimensional error domain decomposition is visualized.

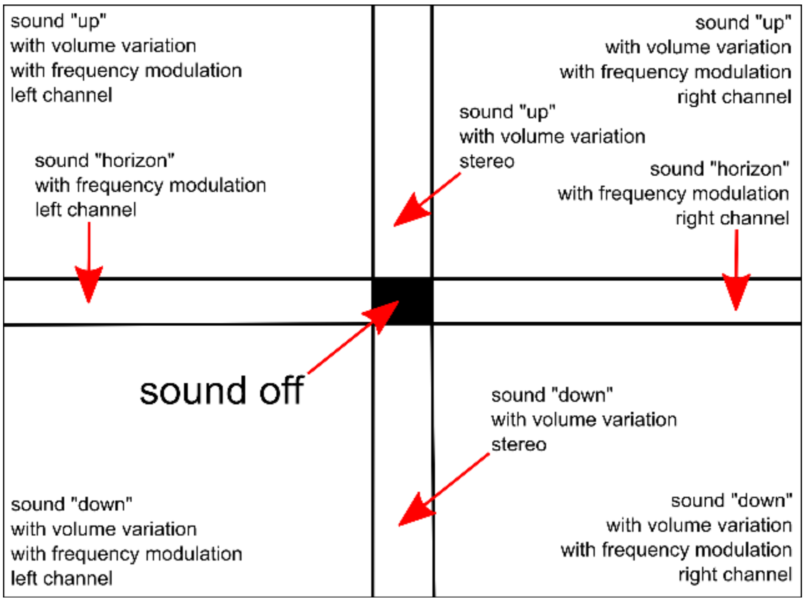

Figure 2. Two-dimensional error domain decomposition.

2. Results of the experiments

Figures 3 and 4 show the aircraft deviations in relation to the glide path obtained through the instrumental landing simulation using the glidescope pointers, while figures 5 and 6 plot the appropriate results for the landing simulation using audio indication only.

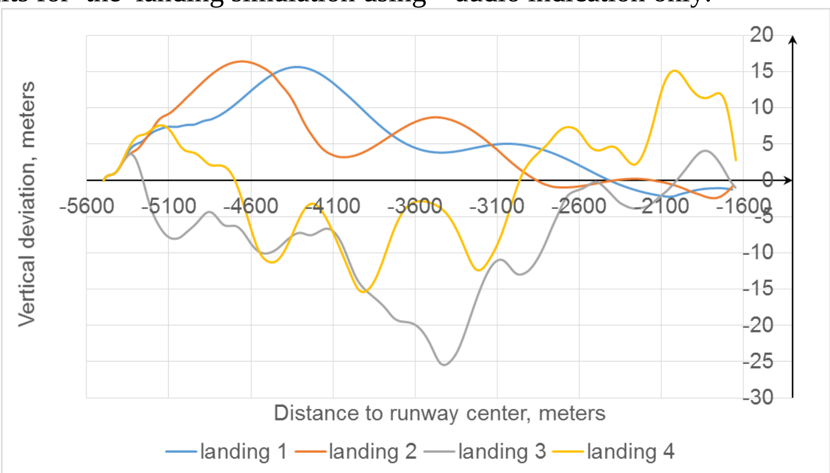

Figure 3. Vertical deviations for landing using the glidescope pointers.

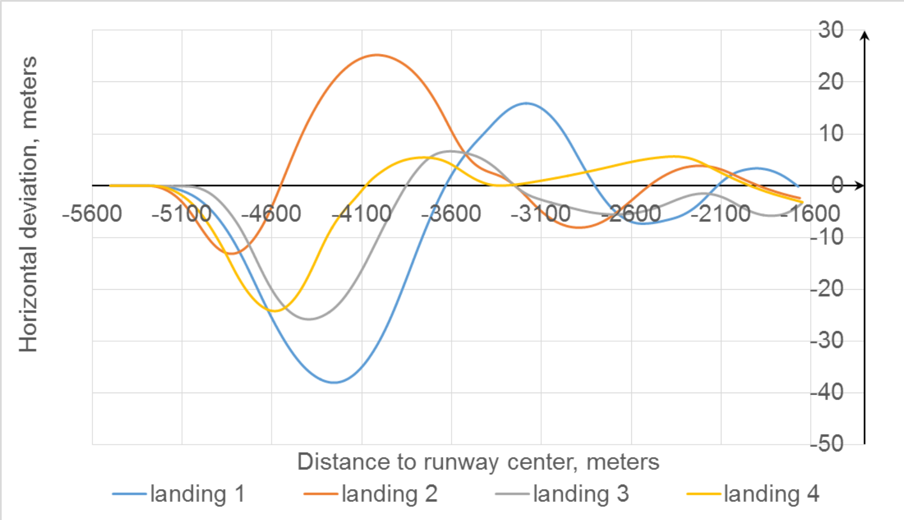

Figure 4. Horizontal deviations for landing using the glidescope pointers.

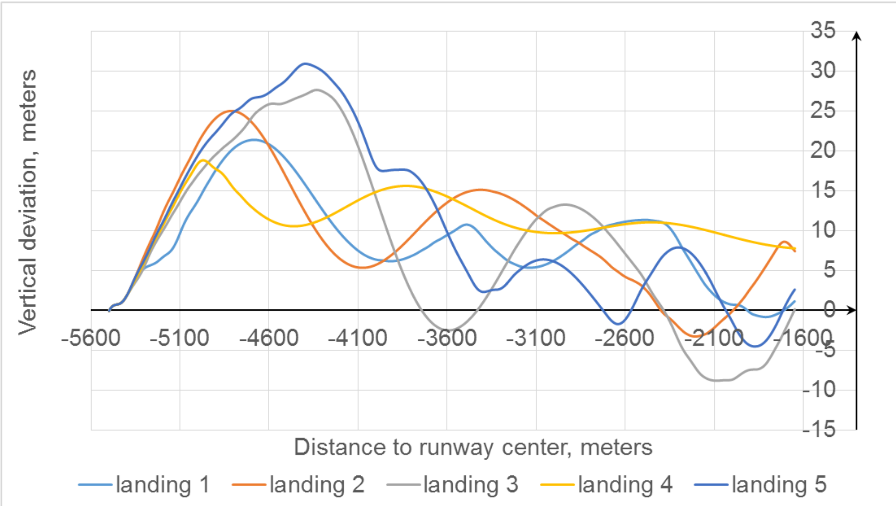

Figure 5. Vertical deviations for landing using audio indication only.

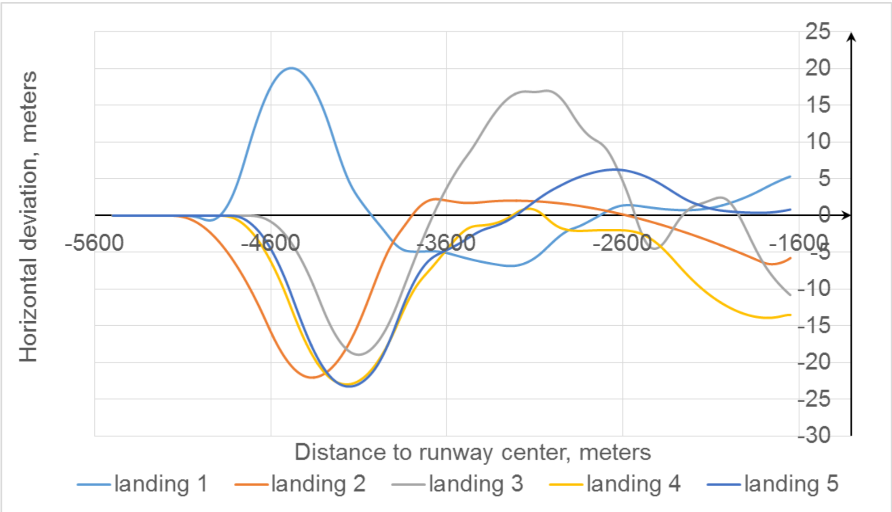

Figure 6. Horizontal deviations for landing using audio indication only.

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As one can see from the figures, the results confirm the capability of the proposed audio method. Naturally the accuracy of tracking the glide path using audio indication only has deteriorated if compared to HSI glidescope pointers, but not drastically. For example, the mean misses fixed at the runway end for the landing with glidescope pointers are 1,6421 m in vertical channel and 1,0533 m in horizontal, while appropriate results for audio indication only stay within acceptable limits and make 3,18 m 7,03 m in vertical and horizontal channels respectively.

It is reasonable to investigate the audio indication method for other precision manoeuvres such as in-flight refuelling, group flight, etc.

Acknowledgments

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