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Modeling of the pilot's depth perception algorithm to avoid collisions with obstacles for commercial aircraft landing

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ABSTRACT: This paper proposes a novel method for depth perception based on the performance of the human eye in the landing phase navigation of a fixed-wing aircraft. The proposed system is designed for situations where visibility is limited, there is no necessary infrastructure at the airport or navigation instruments that have problems and provide incorrect information. The inertial measurement unit and digital elevation model data are integrated to estimate the position of the aircraft and simulate the landing area at more than 200 feet. Reducing the height to 200 feet, the forward-looking infrared camera data is added to the system input. So, the environment map is updated in real-time in landing. At this stage, to depth perception, accommodation cue of the human eye is added to the simulation. In this study, the post-rendering Gaussian method to implement depth of field is used. Simulation results evaluated by using the standard of quality measurement of the visual system of flight simulation training devices and the results confirm the accuracy of the proposed method in terms of resolution, the field of view, frame per second and latency.

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1. Introduction

Today, aeronautical science seeks to overcome the problems associated with limited pilot visibility outside the cabin by introducing many new aviation systems. However, landing is still one of the most accident-prone flight phases, with a relatively high percentage of fatal and non-fatal air accidents [1]. It has been reported that almost half of plane crashes occur in the approach and final landing stages [2]. If visibility is limited, the pilot will land using navigation instruments. But if these devices are damaged or non-existent or in bad weather, this will mislead the pilots and lead to accidents on controlled flight into terrain. In commercial air transport alone, more than 30% of fatal accidents are classified in this category, where the aircraft hits the ground or obstacles because of the lack of external visual reference or knowledge of the ground/danger situation.

On the other hand, the weather conditions below the amount required for visual flight rule operations are the biggest factors influencing airport delays and reduced runway capacity [3]. In fact, low visibility is the main cause of flight accidents and disorder in flight planning [4]. Therefore, it is clear that the pilot needs help to land safely in any weather conditions and any area. Reports show the shortcomings of current navigation systems in perception of low-altitude, approach and landing distances. These represent visual-based landing navigation [5], so that the outside of the cabin is created to view the pilot virtually.

In creating and displaying images, the issue of depth perception is a concern of researchers. One way to depth perception is to accommodate the lens of the eye or change the muscle tension to adjust the focal length of the eye. Focusing the eye on the target is called depth of field and is similar to the camera's focusing performance.

The main purpose of this research is to create a system that, without installation on the pilot's head, without the need or dependence on natural vision, the landing environment is shown to help the pilot have a safe landing in the approach phase. This method will not take the pilot display out of normal mode. Since the important part of the landing is to observe the runway and objects, the main focus of this article will be on the approach section in landing. We use the IR sensor due to its proper performance in the variety of ambient light and all weather conditions to identify objects on the runway. The simulated environment is following the natural vision so that one of the cues of human depth perception has been implemented in it. The depth of field is a cue used by humans to distinguish between near and far objects. Finally, the simulation will be evaluated by visual standards of Flight Simulation Training Device (A) certification.

2. Method

- Overview of the method

The algorithm for accurate landing of commercial aircraft in all weather conditions is shown in Fig. 1.

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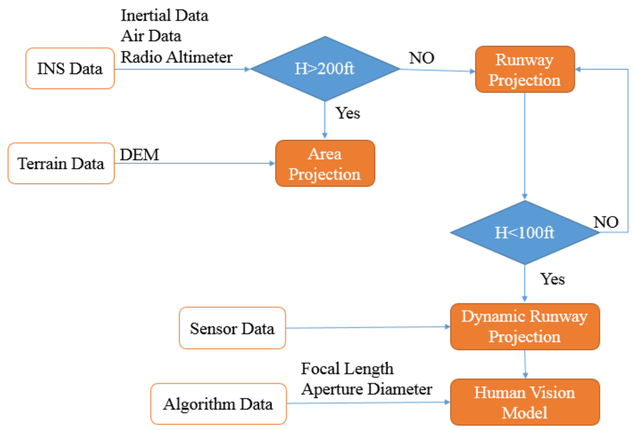

Fig. 1. Frame of proposed landing navigation

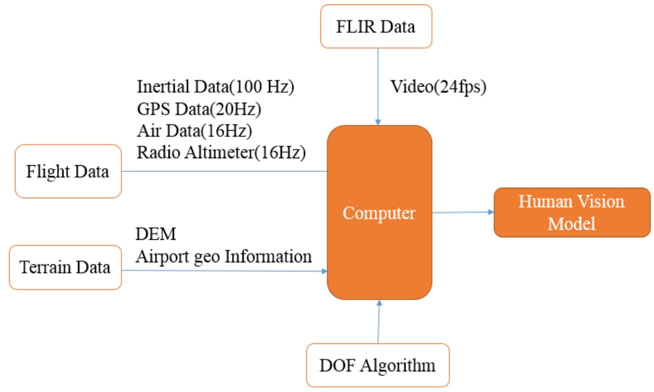

Fig. 3. Block diagram of the depth perception cue implement

- Depth of Field

There are two main approaches to implement depth of field in 3D rendering applications: the object-space and image-space. The image is first rendered with full focus, and the depth map is used to calculate the amount of blur to be applied to each pixel. Image-space approaches are much faster than object-space approaches, but they will not work well in all situations [6]. Because speed is important in our intended application and depth map of all situations is available, image space approaches are selected.

3. Simulation

Unity software has been used to simulate the approach. In this environment, the movement of the camera is in line with the movement of the aircraft. Fig. 2 shows the implementation of the algorithm.

The block diagram of the depth perception cue implement has been shown in Fig. 3.

An object on the runway will be visible with this method similar to human vision

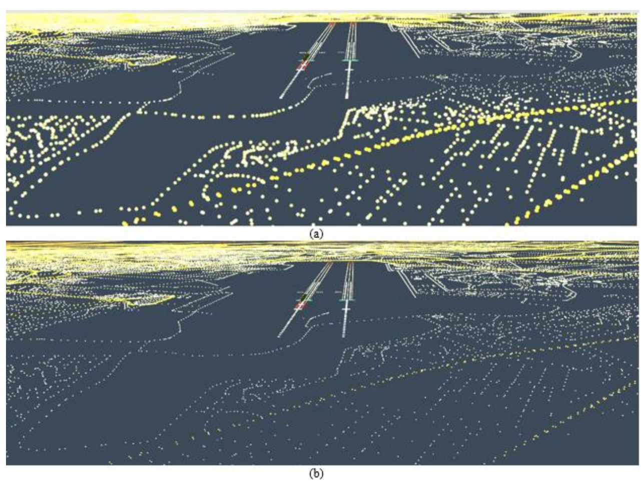

Fig. 2. Simulation of flight area: (a) with depth perception cue; (b) without depth of field

4. Validation of Results

In this section, items such as: field of view angle, number of frames per second and resolution in the simulation are evaluated.

- The visual field of view

The field of view in the simulated environment is all 360 degrees. According to Certification Specifications for Flight Simulation Training Device(A) (Classes A and B: 45 ° horizontal and 30 ° vertical viewing angles - Class C & D: 180 ° horizontal and 40 ° vertical), this constraint cannot be a problem Because this camera is used to complete the runway information at low altitudes.

- Frames per second

The frame rate in the flight simulator is 150 milliseconds. The camera's shooting rate per second and frames per second in the simulated environment is 24 frames, so this simulation satisfies Flight Simulation Training Device Certification.

- Resolution

According to the pixel resolution of 1366 768 for the 13-inch display, and assuming the distance to the display is 11.81 inches, we will have a pixel size of 0.00828 and an angle resolution of 0.04. Since the Flight Simulation Training Device certification standard say the maximum angular resolution is 2 arcmins, that hardware and software have been able to meet this requirement.

5. Conclusions

The paper proposed a new depth perception method in the landing phase of fixed-wing aircraft in all weather conditions. The proposed cue uses data from inertial instruments and onboard sensors. The implementation of the method was performed using Matlab/Simulink and Unity. The simulation results are evaluated using the visual standards of Flight Simulation Training Device certification. As Table 1 shows, the results confirm the accuracy of the proposed method.

However, this study has limitations that make it out of real-time. The idea is for a commercial aircraft; Due to human and financial costs, we cannot test this idea. In the virtual implementation, we also had constraints, including (1)

Table 1. Evaluate the results

Parameter	Flight Simulator	Suggested Method
	Vertical/Horizontal	Vertical/Horizontal
The visual field of view	30/45	40/180
Frames per second	6.6	24
Resolution	2>	0.04

the unavailability of real-time test equipment of the idea. (2) Impossibility of practical testing of the idea in the simulator due to the unavailability of the pilot.

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