FLIGHT TESTS WITH COMPUTER GENERATED SYNTHETIC VISION FOR IMPROVING POOR VISIBILITY OPERATIONS

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Abstract

A flight test program consisting of three test series is considered. The flight tests are concerned with the application of computer generated synthetic vision for different control tasks (precision approach and landing, curved and steep approaches, low level flight in a demanding environment). The synthetic vision system provides the pilot with full visual information consisting of a three-dimensional image of the outside world and an integrated guidance symbology. A precision navigation system using differential global positioning and inertial sensor data is applied to achieve a high position accuracy.

Introduction

Poor visibility yields a great restriction to aircraft operations in flight close to the ground. This concerns flight tasks such as approach and landing as well as low level flight. Complex systems both on board of the aircraft and on the ground are nowadays required to alleviate this situation.

New concepts known as "Synthetic Vision" or "Enhanced Visions" are considered for providing the pilot on board of an aircraft with artificial visual cues and aids to improve flight operations in poor visibility conditions (Ref. 1). Some systems employ sensor based information like radar or optical sensors (Ref. 2).

In this paper, a concept is considered which employs synthetic vision generated by a computer, Refs. 3, 4. It features a realistic three-dimensional image of the terrain and an integrated guidance symbology which includes innovative elements such as a tunnel display for curved trajectory following. Based on this concept, an experimental synthetic vision system was developed and flight tested in a test program showing realistic and demanding control tasks for the pilot.

Synthetic Vision Concept and Experimental Setup

The synthetic vision concept comprises as basic elements (Fig. 1):

- synthetic vision computer
- display for the pilot
- precision navigation system

The synthetic vision computer generates a three-dimensional image of the terrain including its features. A stored data base is used which contains all information for elevation and surface characteristics as well as three-dimensional objects on the ground. A guidance symbology is integrated in the synthetic vision imagery for providing the pilot with information about flight condition and nominal trajectory.

In Fig. 2, a synthetic vision image of an approach condition in a mountainous area (Lugano airport) is depicted. This Figure provides an impression of the kind of three-dimensional image presented to the pilot. It also shows the integrated guidance symbology which includes a tunnel display for curved approach trajectory following.

The synthetic vision computer needs position and attitude input data for generating an image according to the actual field of view of the pilot (Fig. 1). For this purpose, a high navigation accuracy is required. This accuracy is achieved by a high precision navigation system which couples differential satellite navigation and inertial sensor data.

The test vehicle is a Dornier 128 aircraft (Fig. 3) operated by the Institute of Flight Guidance and Control of the Technische Universität Braunschweig as a research aircraft. It is equipped with a precision navigation system providing the required high position accuracy. The precision navigation system was developed by the Institute of Flight Guidance and Control of the Technische Universität Braunschweig (e.g., Ref. 5).

A Silicon Graphics Onyx computer was installed on board of the test aircraft to generate the synthetic vision. With the use of a dedicated software, it was possible to achieve a real-time image generation with an update rate of 30 frames per second.

The synthetic vision image is presented to the pilot using a head mounted display. The motion of the head mounted display was tracked by a head tracking device. The measured data were transferred to the synthetic vision computer which generated an image in accordance with the actual field of view of the pilot.

Flight Test Program

The test program consisted of three flight test series. According to the different test purposes, three test areas were chosen (Fig. 4):

- Precision approach and landing flight tests, Braunschweig airport (Germany), October 10-14, 1994
- Low level flight tests, Altmühl river valley (Germany), December 12-16, 1994
- Curved and steep approaches in mountainous area, Lugano airport (Switzerland), July 31-August 4, 1995

The flight tests at Braunschweig airport were concerned with the precision approach and landing flight task. Because of the lack of experience with synthetic vision, comprehensive preparations both with simulation on the ground and with flights at some altitude were conducted before the actual flight testing for precision approach and landing begun. The following test flights were very successful and the goals of the flight test program were fully achieved. Results of some test flights are shown in Fig. 5. They show that the pilot precisely controlled the aircraft and closely followed a reference trajectory which was indicated in the synthetic vision image via a flight director.

A particular difficulty of the control task concerns the landing gear configuration of the aircraft which is equipped with a tail wheel. This type of landing gear requires that a three-point landing is performed which poses an extra demand on the ability of the pilot in controlling the vehicle.

The low level flight tests conducted in the Altmühl river valley concern a test track which consisted of a highly curved trajectory (Fig. 6). The river valley is rather narrow and shows steep banks. The pilot had to follow the course of the river at an altitude of about 300 ft above ground level.

A particularly demanding section is illustrated in Fig. 7 in some detail, showing a turn with a change in flight path direction of more than 180 deg. The pilot successfully performed the control task. The deviations from the nominal track were mostly smaller than 5 m, with some excursions up to 8 m.

Flight tests for curved and steep approaches were performed at Lugano airport in a mountainous area (Fig. 8). The aim of the tests concerned new instrument approaches and departures which are better adapted to the topographic features of the surroundings of the airport than flight routes currently in use. Of particular concern are mountains in the extended centerline of the runway. Different possible routes indicated in Fig. 8 as parts A, B and C were evaluated and flight tested. The test results show that the pilot successfully accomplished the control tasks and accurately followed the specified approach profiles.

In the flight tests, the differential global positioning system DGPS was operated in two different modes (Figs. 9 and 10). A local area DGPS navigation was used for the approach and landing flight tests (Fig. 9) where an accuracy in the submeter range smaller than 0.5 m was required. The reference station on the ground was closely located to the runway. The GPS correction data was transmitted via an UHF-datalink. A wide area DGPS navigation was used for the Altmühl river valley flight tests where an accuracy of 5 m or better was sufficient (Fig. 10). The reference station using a transmitter operated by the Deutsche Telekom was located at a place near Frankfurt/Main, about 200 km away from the flight test area (Fig. 4). The signal transmitting technique which was provided by the Institute of Applied Geodesy in Potsdam uses the low frequency band (Ref. 6).

Conclusions

A flight test program is considered for testing for the applicability of computer generated synthetic vision for tasks of high control demand. This program concerns precision approach and landing flight tests, low level flight tests in a highly curved narrow river valley and steep and curved approaches in a mountainous area.

A computer generated synthetic vision system presenting a realistic three-dimensional image of the terrain and an integrated guidance symbology was used to provide the pilot with full visual information for controlling the aircraft. A precision navigation system using differential sattelite navigation and inertial sensor data was applied for achieving a high position and attitude accuracy required for synthetic vision.

The flight test results show that the pilot successfully accomplished the demanding control tasks and closely followed the reference trajectories indicated in the synthetic vision image.

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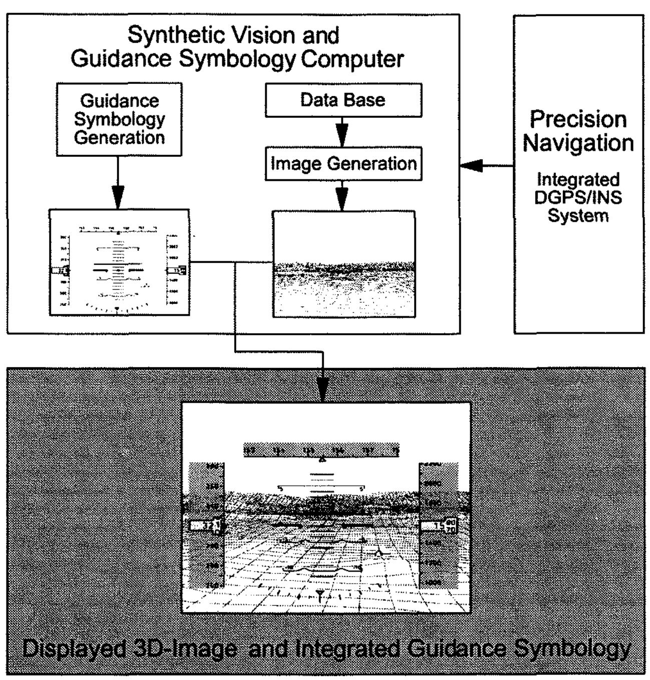

Fig. 1 Computer generated synthetic vision concept

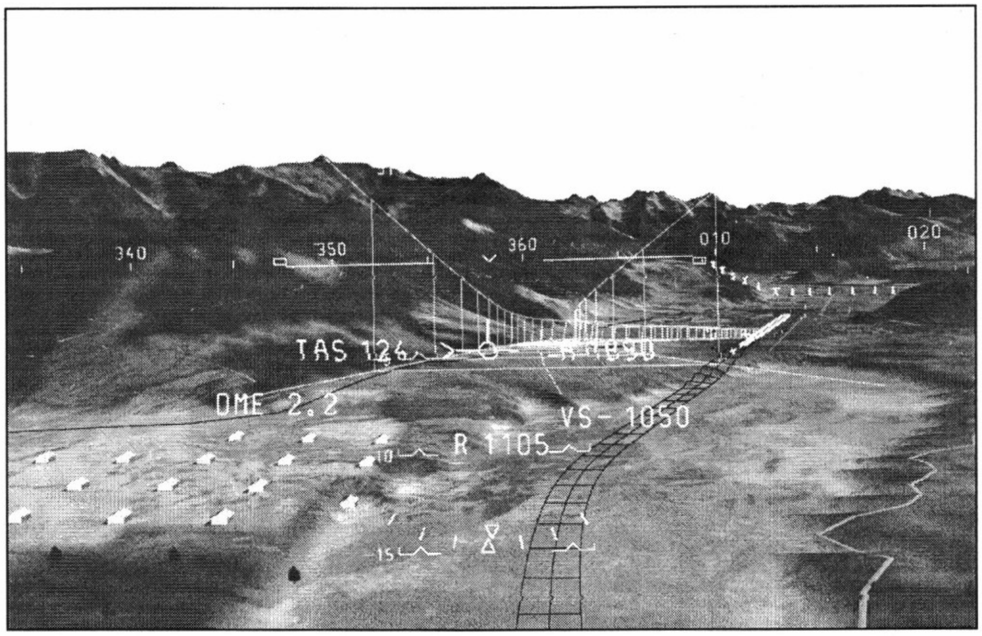

Fig. 2 Computer generated synthetic vision with integrated guidance symbology including a tunnel display for curved trajectory following

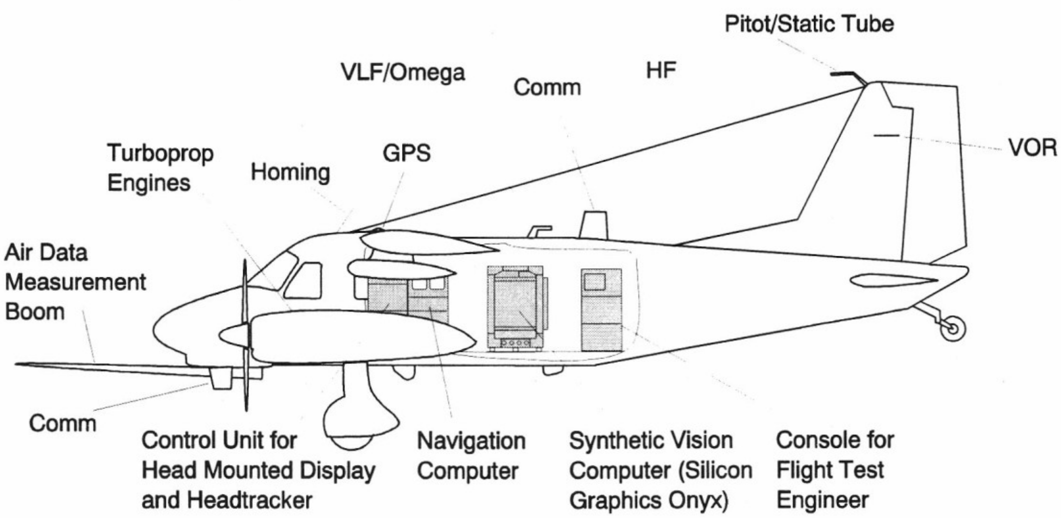

Fig. 3 Research aircraft of the Institute of Flight Guidance and Control of Technische Universität Braunschweig with synthetic vision and precision navigation systems

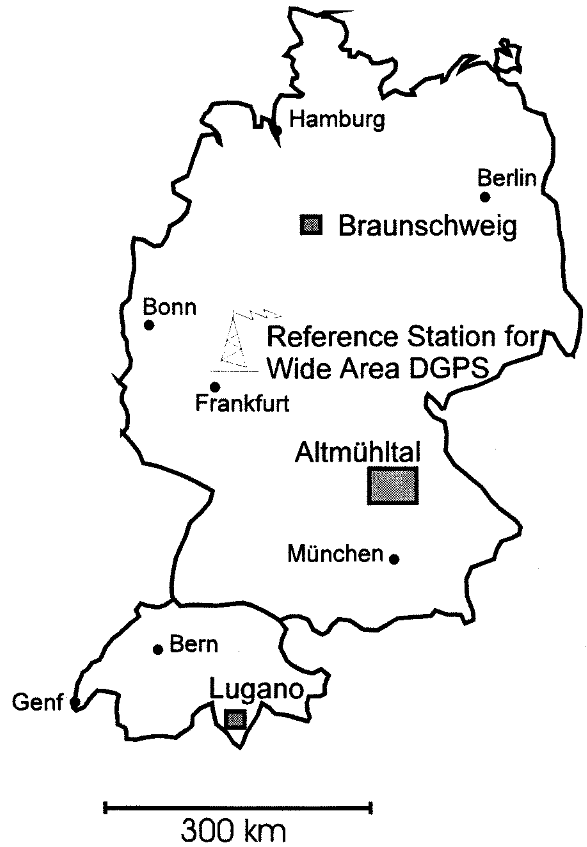

Fig. 4 Test areas for synthetic vision flight test series

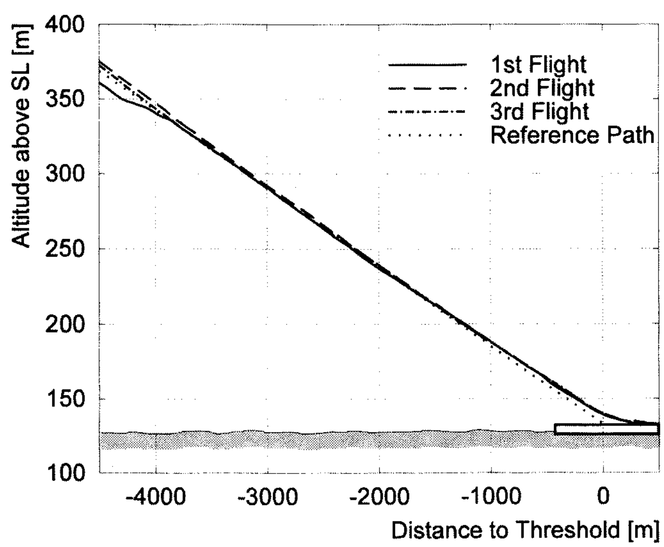

Fig. 5. Precision approach and landing flight tests at Braunschweig airport

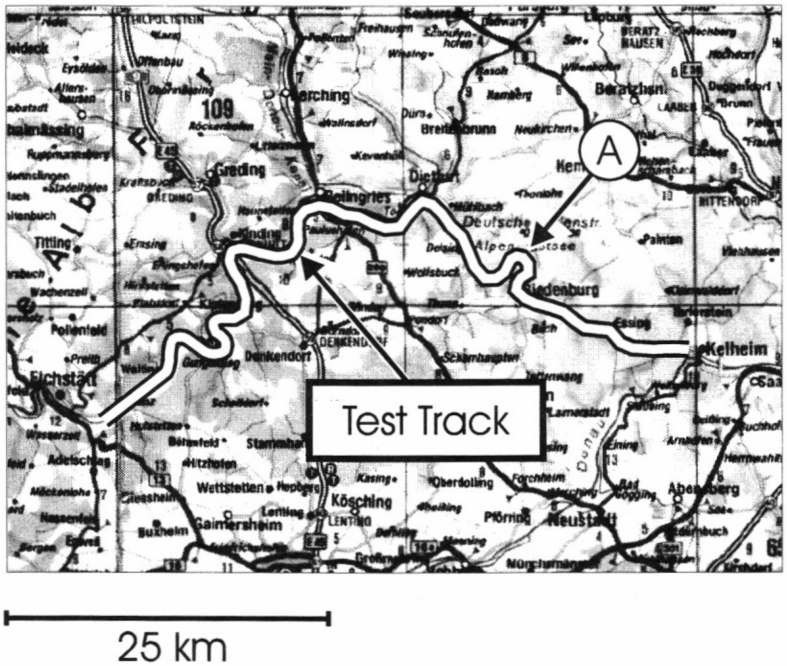

Fig. 6 Altmühl river flight test track

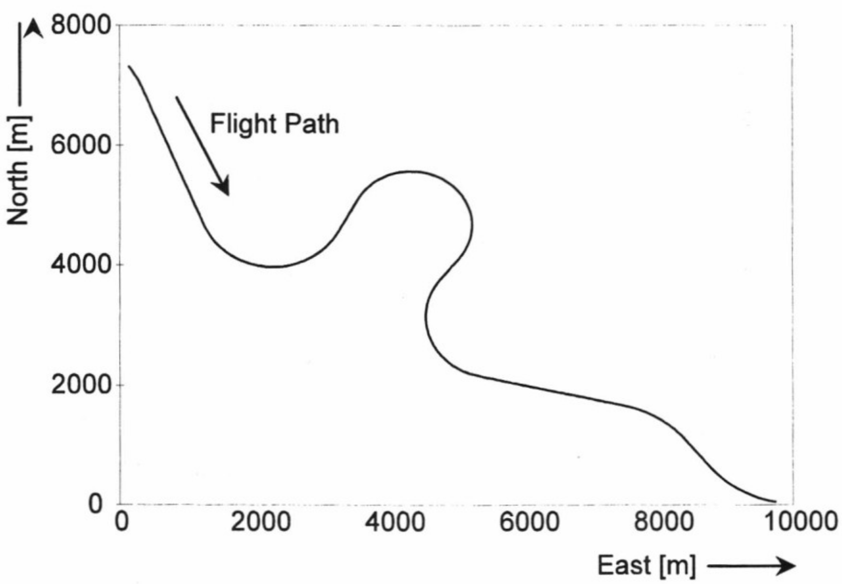

Fig. 7 Section of nominal trajectory in Altmühl river valley (indicated in Fig. 6 as section A)

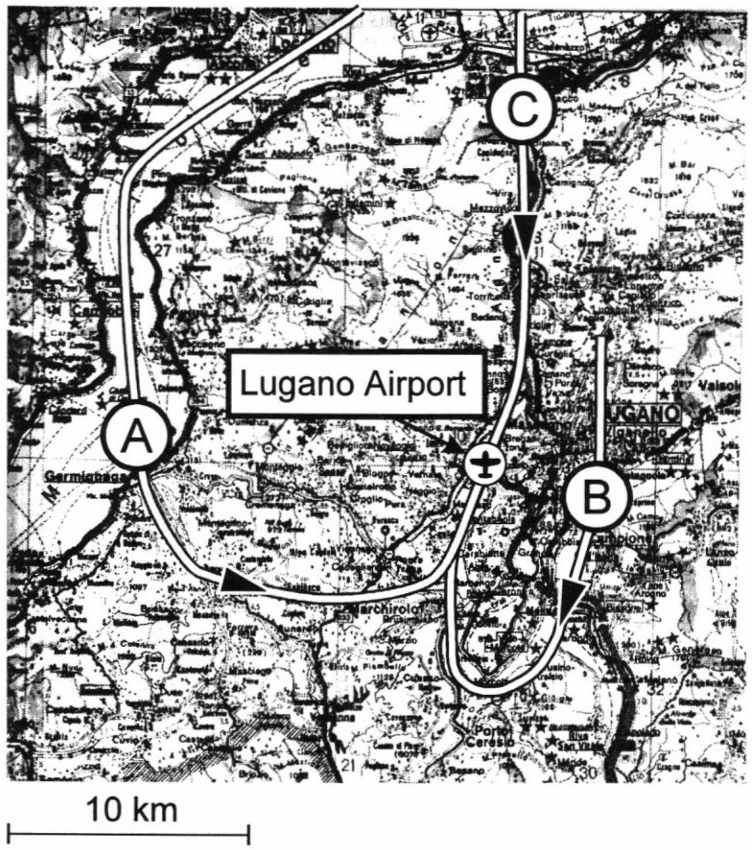

Fig. 8 Different routes for curved and steep approaches at Lugano airport

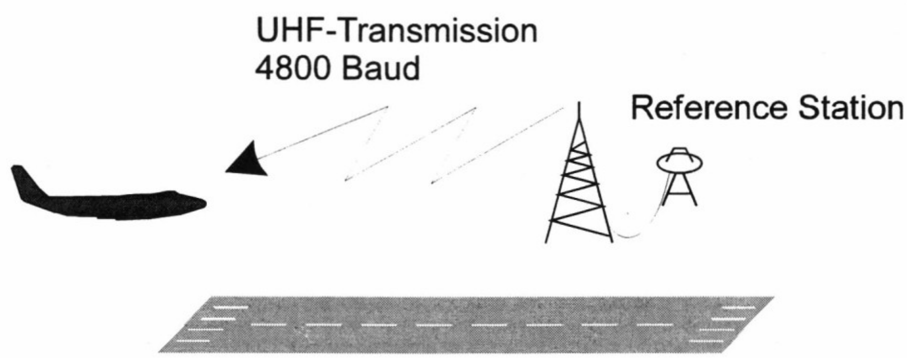

Fig. 9 Local area DGPS navigation for approach and landing flight tests (Braunschweig and Lugano)

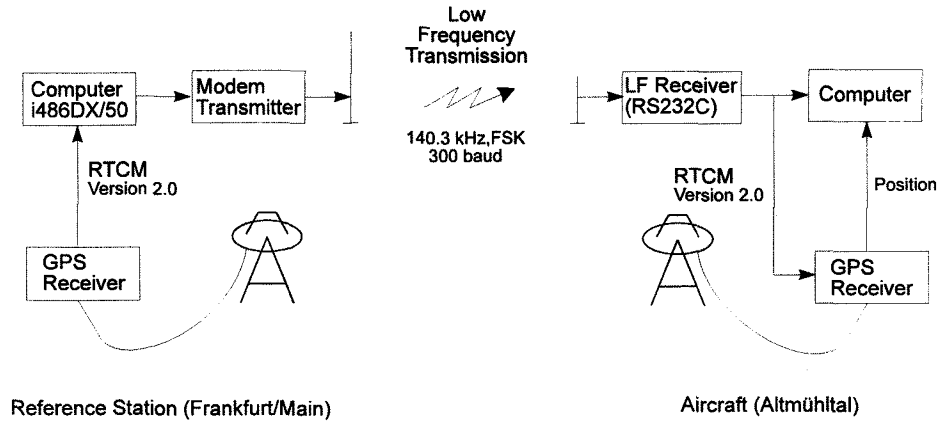

Fig. 10 Wide area DGPS navigation for low level flight tests (Altmühl river valley)