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Architecture, algorithmic support and software development of aviation synthetic vision system for perspective transport civil aircraft

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Abstract. The paper considers the aviation onboard synthetic vision system that generates and outputs a three-dimensional (3D) external environment images to the cockpit multifunctional displays (MFD). Particularly, the system architecture, algorithmic support and software are designed. The synthesized images present 3D earth surface areas with high informativity in the real time scale. The example of generated 3D models of real geographic objects is provided.

1. Introduction

In the context of flight safety requirements increasing and the expanding of the onboard equipment complexes functionality, the priority task is the development and integration of the auxiliary systems for enhancement crew situational awareness and minimizing human mistake factor in critical situation [1, 2].

These include technical vision systems (TVS) providing pilots with the necessary information about vehicle spatial position relative to external environment in a visualized form convenient for human eyes.

There are the following types of TVS [3, 4]:

- enhanced vision systems displaying an infrared images according to the onboard cameras data;
- synthetic vision systems (SVS) that allow reconstructing an underlying earth surface 3D model taking into account obstacles and airport infrastructure objects;
- combined vision systems representing the symbiosis of the two mentioned TVS types and combining of sensory and synthesized information;
- enhanced flight vision systems based on infrared cameras data (as well as enhanced vision system) and projecting the resulting image on the head-up display.

Among listed TVS, SVS is the most preferred in terms of integration, as it does not require the additional equipment installation on the aircraft.

The purpose of this work is to develop the SVS prototype for prospective transport civil aircraft using the integrated modular avionics (IMA) concept.



2. Purpose and architecture of SVS

To ensure the SVS main function – generating and outputting the 3D environment image observed from the cabin to the MFD – it is necessary to solve the following tasks in the real time scale:

- receiving the aircraft current position from the onboard navigation systems;
- extracting an underlying surface database (DB) tiles in accordance with received coordinates;
- obtaining information about obstacles representing a potential danger to the aircraft during the current flight phase and the airport infrastructure objects;
- synthesizing a 3D image of a terrain observed from the cockpit based on the above mentioned data;
- generating of mnemonic warnings about dangerous situations (collision, obstacles, etc.);
- displaying of the resulted image.

The listed tasks solving determines the SVS purpose are as follows:

- providing a crew situational awareness relative to the surrounding space in case of low visibility conditions (for example, at night, fog);
- reducing a crew load due to the possibility of quick assessment and prediction of the aircraft spatial position.

The main elements of the developed SVS architecture are the computer unit and the displays directly realized the SVS basic function. However, it is impossible to ensure this without the following input data:

- DBs of the underlying surface, obstacles, airport infrastructure objects, loaded into the onboard data server before a departure according to the flight plan;
- aircraft current spatial position (latitude, longitude, absolute altitude) from GPS / GLONASS, and pitch, yaw and roll angles from inertial navigation system (INS);
- information about departure, landing and alternative airports provided from the flight management system (FMS);
- visual information about the hazardous proximity to the terrain issued by a terrain awareness and warning system (TAWS).

Navigation data supplied by the GPS / GLONASS, INS, FMS, TAWS and actual DBs tiles are transmitted to the computer unit, synthesizing an external environment 3D image. The output image displayed on the MFD. The control panel provides the crew ability to enable and disable the SVS function.

The developed SVS architecture is presented in figure 1.

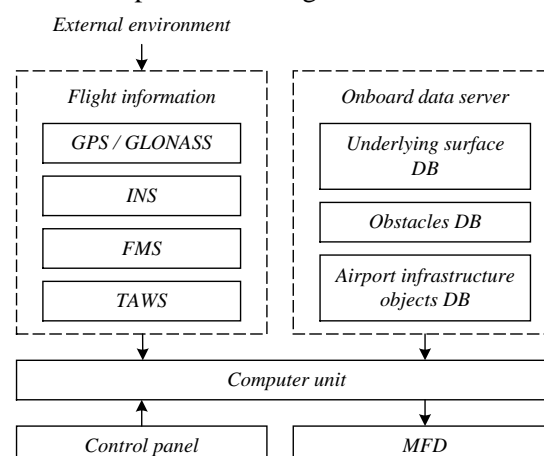


Figure 1. Developed SVS architecture

The proposed SVS architecture is based on IMA concept with an open network and a unified computing platform [5]. The SVS function is implemented as distributed software on the IMA platform, which is a distinctive feature of the developed prototype with respect to analogues.

3. SVS algorithmic support and software

Before SVS prototype starting, it is required to download underlying surface DB tiles from the Internet in accordance with the flight plan. The publicly accessible Earth digital elevation model SRTM was chosen as listed DB. Further, if the SVS is enabled, a 3D model of the terrain is synthesized based on the loaded two-dimensional data. The image obtained in geographical reference system (GRS) could be converted to the UTM if necessary.

The final 3D image displayed on the MFD. When aircraft changes the position, the correction of the 3D scene in accordance with the updated navigation data is provided.

The common algorithm of the SVS prototype operation is shown in figure 2.

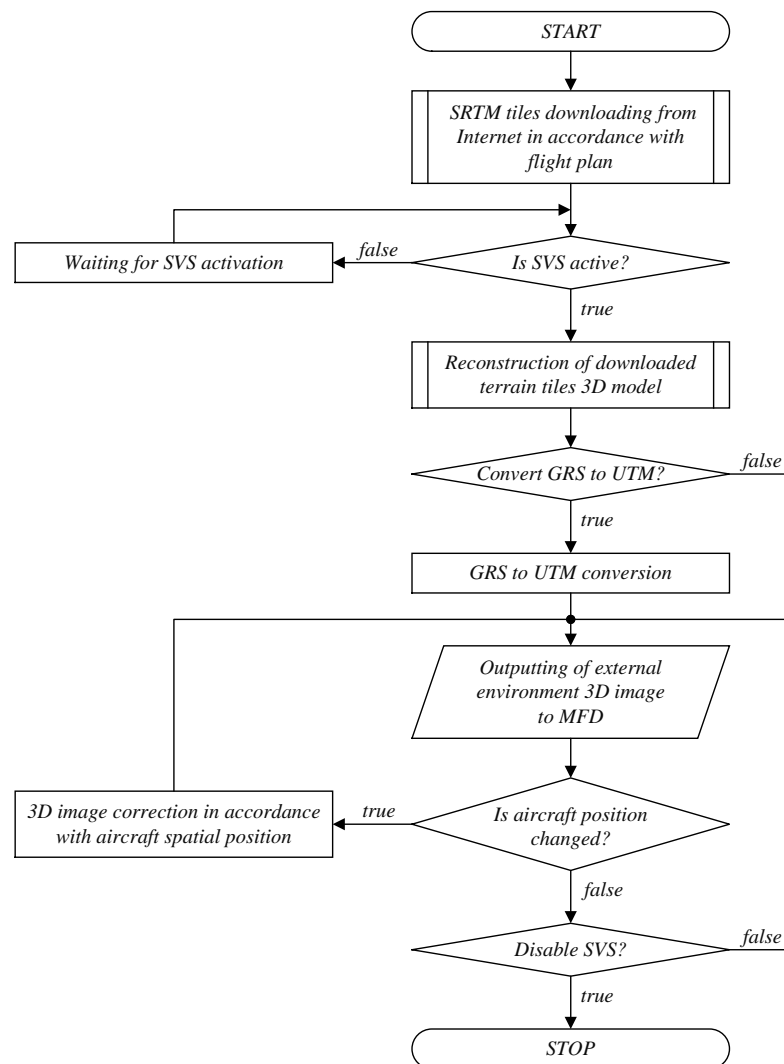


Figure 2. Common algorithm of the SVS prototype operation

To obtain a SRTM tiles corresponding to the flight plan the coordinates of the required rectangular earth's surface area should be specified. Next, the SRTM data is checked for validity. If the inputted coordinates match with a SRTM valid range, terrain tiles download is performed.

The block diagram of the SRTM tiles download algorithm in accordance with flight plan is presented in figure 3.

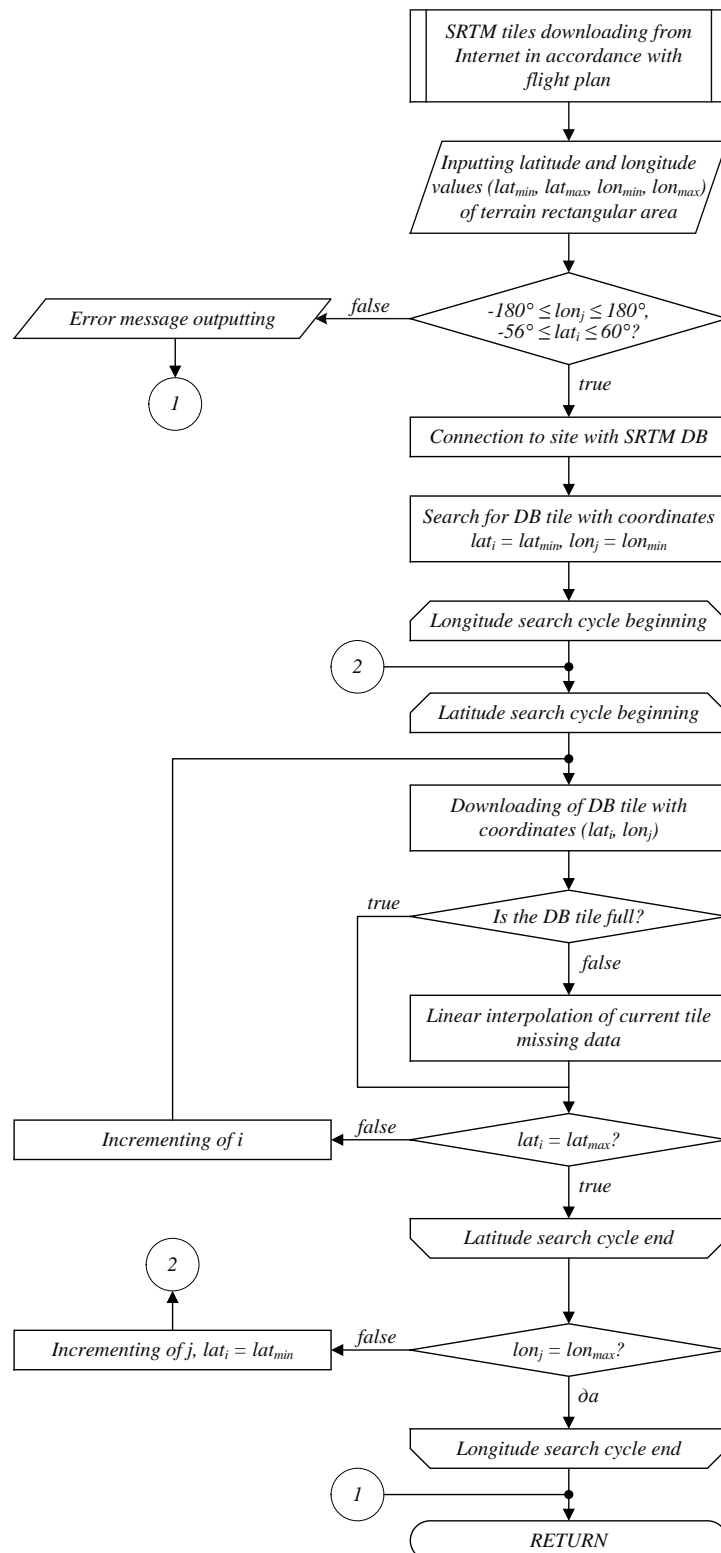


Figure 3. Block diagram of the SRTM tiles download algorithm in accordance with flight plan

The generating a 3D image of the underlying surface based on SRTM data is realized on polygonal modeling. The 3D scene is reconstructed by determining a parameterized surface defined by the matrices

$X(m, n)$, $Y(m, n)$, $Z(m, n)$, where: m, n – parametrization variables ($m, n \in \mathbb{N}$); $X(m, n)$, $Y(m, n)$, $Z(m, n)$ – 3D space coordinates matrices describing the surface.

The high informativity of the generated images (with small grid steps) and the ease of implementation led to the described method application in the SVS prototype algorithmic support development.

For coloring the resulting relief model, the hypsometric method was chosen. Adopted color scale has 58 gradations.

The analytical computing system MATLAB R2017a was used as the programming environment.

4. SVS operation simulation

To confirm the efficiency of the designed SVS prototype, it is required to obtain 3D images of the real geographic objects. Kunashir Island (Kuril Islands, Russian Federation) was chosen for this task.

The 3D image of the mentioned island taken from the Google Maps site is presented in figure 4.

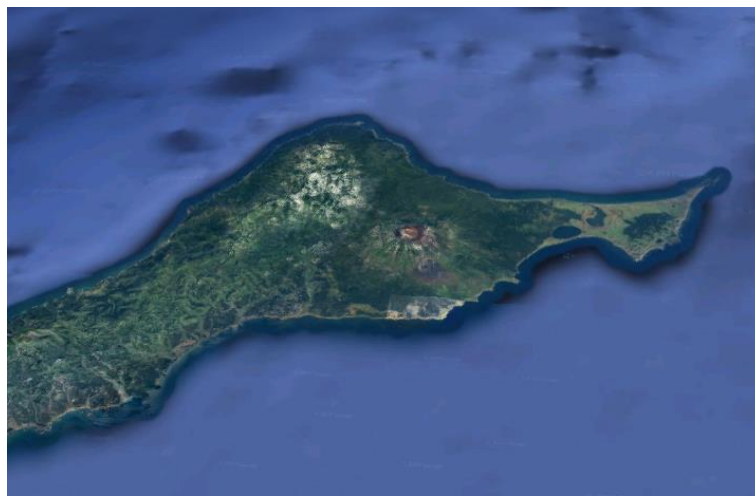


Figure 4. Kunashir Island 3D image taken from Google Maps site

The 3D image of Kunashir obtained in the developed SVS software operation result is shown in figure 5.

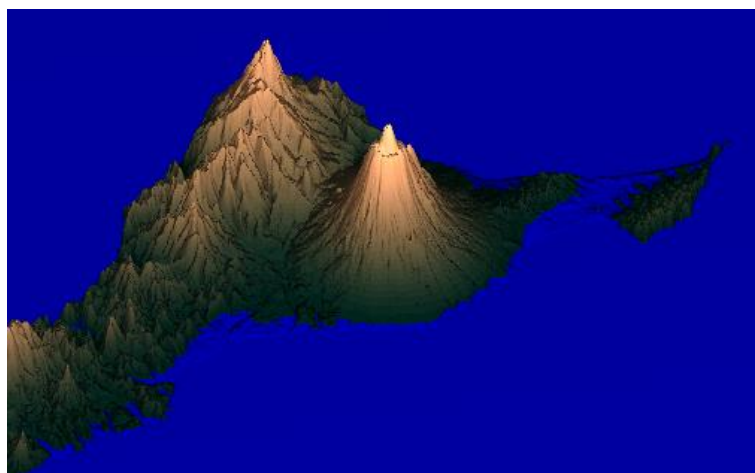


Figure 5. Reconstructed 3D image of Kunashir Island

The generated 3D terrain models meet the requirements of DO-315B aviation standard [7]. In particular, to confirm the fulfillment of the frame refresh rate requirement (15 Hz for a square tile with a side of 74.08 km), control series of experiments were conducted (50 groups of 100 objects each).

On average, the 3D image synthesizing of a single tile takes 0.031 s (with a standard deviation of 0.00907 s), that approximately equal to 32 Hz frequency.

5. Conclusion

The paper presents the results of the SVS prototype development and simulation for perspective civil transport aircraft using the IMA concept.

The proposed SVS architecture:

- It complies with the IMA standards requirements;
- It is implemented on the existing set of onboard equipment;
- It does not require a separate computing unit.

The created SVS prototype complies with the main development guidelines on the modern civil aircraft and TVS (in particular DO-315B [7], DO-200B [8], etc.).

The developed SVS software and algorithmic support generates 3D images of earth surface areas with a high informativity.

Used algorithms processing speed evaluation, based on the 5000 experiments, confirmed the fulfillment of the aviation standards requirements.

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