Space objects localization and recognition using an adaptive optical observation system

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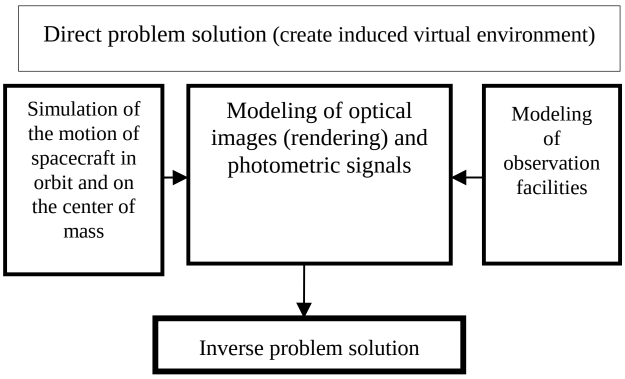
Abstract

The complex space systems are exposed to unforeseen failures and accidents. Given the high cost of development and maintenance of these systems, it is necessary to analyze the causes and consequences of accidents. Specificity of the given problems limits the publications on this theme. It is necessary to note materials of the conference Advanced Maui Optical and Space Surveillance System (AMOS) in which, unfortunately, are published only abstracts of articles. Great distance to the space objects (hundreds and even thousands of km) and essential influence of atmosphere makes quality of received images rather low, that does not allow to use the traditional methods of computer vision (offered, for example, in [11]). For the solving of inverse problems of localization and orientation estimation in our work we use methods of induced virtual environment, which principles are described in [3].

Keywords: *Space object, adaptive optics, localization, recognition*

1. INTRODUCTION

The task the space object state automatic monitoring is confined primarily to the determination of the stabilization and orientation estimation (localization in 3D space). Another challenge is to recognize the 3D form of an object using the database of space objects 3D models. The development of the physically adequate rendering technology[4,5,8] allows to use the corresponding algorithms not only for displaying the various peripheral devices [3], but also as a tool for simulation of direct problems [1,2]. Here is a schematic diagram of using the induced virtual environment in this task.



2. IMAGES PROCESSING OF ADAPTIVE OPTICAL SYSTEM

The problem of imaging is one of the crucial problems in the ground-based observations through a turbulent atmosphere. The most effective tool for compensation of phase distortions caused by fluctuations of refractive index of atmosphere is an adaptive optical system. The adaptive optical system consists of the wave front sensor and the active adaptive mirrors compensating the phase distortion measured by the sensor. The sensor and adaptive mirrors are connected by control feedback.

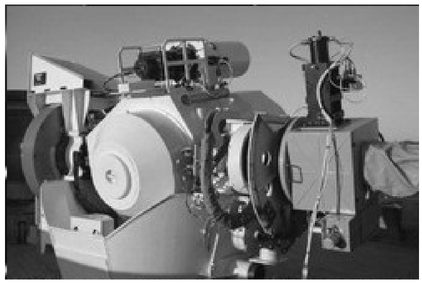


Figure 1: Russian telescope with adaptive optical system

In this paper, we use real images of space objects obtained through domestically developed adaptive optics system [9]. Despite significant improvement in the quality of images obtained, it is not possible to use traditional methods of computer vision. In the considered algorithms, we used the method of recognition based on the direct problem solving (model-based recognition).

The method for localization of the space objects implements the following [6,7,8]:

1. Hypothesis of stabilization selection (one of the prevalent hypothesis - focus on subsatellite point).
2. Set the starting rotation in the coordinate system and, if necessary, the rotation axis (this data is variation parameters).
3. According to orbital parameters the virtual scene is induced, calculating transformation matrices according the ballistic information of the stabilization system of space object and orientation of the telescope, as well as using a direction to the Sun vector and a local vertical vector (taking into account the suspension of the telescope). These matrices and vectors are determined for each frame of simulation video that provides calibration of images. In the ballistic data calculation, the modern astroballistic forecast software is used.
4. The calculated matrices and vectors is used in physically adequate rendering subsystem, replicating a sequence of ideal images (without atmosphere) This sequence of images is the aprioristic information for

elimination of ill-posedness issue. If there is the realization of photometric signal of this space object, images are converted into the photometric signal.

5. Using the obtained sequence of induced virtual images (taking into account the average residual dispersion function of the adaptive system) the variation criterion of an orientation estimation is formed. The criterion bases on sequences of the real measured and artificial induced images.
6. By the solution of the given variation problem the localisation and orientation state of space object with the maximum value of criterion is determined. The example of orientation estimation of spacecraft UARS (the unit vector of orientation, which corresponding to the maximum value of variation criterion is equal to (0.98, 0.03, 0.19) in orbital coordinate system) is shown below:

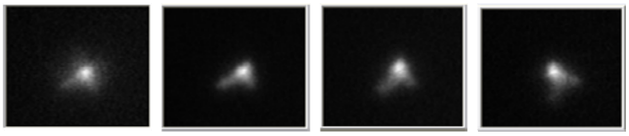


Figure 2: The sequence of real images of spacecraft UARS

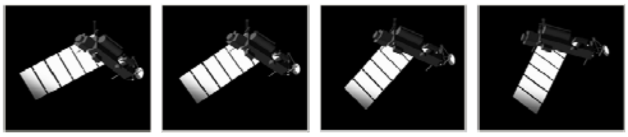


Figure 3: The sequence of artificial induced images of spacecraft UARS (orientation vector 0.98, 0.03, 0.19)

3. CONCLUSION AND RESULTS

In this article the results of researches are presented and the real optical observations obtained through domestically developed adaptive optics system are analysed. These measurements are made at the diffraction limit of the resolution and at the quantum limit of sensitivity. In addition to the problems of poor conditionality and ill-posedness according to Tikhonov, typical for linear inverse problems, there is a degeneration problem - presence of non-uniqueness of the solution. Software programs of space objects localization and orientation estimation are implemented on the basis of the induced virtual environment methods. The induced virtual environment is created using modern astroballistic forecasts and physically-adequate rendering. Wide experimental material (more than 100000 images) is processed using these programs and it is shown that the accuracy of space object localization may be several degrees at observation range from 300 to 1400 kilometers [9].

4. REFERENCES

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