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PROGRAM SYSTEM FOR SPACE MISSIONS SIMULATION- FIRST STAGES OF PROJECTING AND REALIZATION

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Abstract: *Space mission design and analysis is concerning with determination of broad multitude satellite's and scientific instrument's parameters. The possibilities for different experiments or measurements conduction depends on different geometrical or physical constrains satisfaction. The successful realization of the experiments' aims on low cost is possible by applying of computer simulation methods. Besides specialized software programs developed "ad hoc" much more universal software tools are developed as power instruments for approaching of these aims. Such tools may be applied to experiments and evaluation of new algorithms for situation analysis too. The structure, modules, modes, activities and some insights reflecting the present stage of the development are presented. "Orbits integration", "physical model's parameters calculation", "situation analysis", "mechanical separation satellite-sub-satellite", "visualization", "writing of results" modules are under developing.*

Introduction

Space mission design and analysis is concerning with determination of broad multitude satellite's and scientific instrument's parameters. The possibilities for different experiments or measurements conduction depends on different geometrical or physical constrains satisfaction. The successful realization of the experiments' aims on low cost is possible by applying of computer simulation methods [1-3]. Simulation helps to improve the process of satellite experiments design and verification and validation on operation stages.

Different software tools for computer simulation are known. FreeFlyer mission analysis and design tools are developed from AI Solutions [4]. General Mission Analysis Tool (GMAT) is undertaken from NASA as an open source project [5]. Satellite Tool Kit (STK) is developed from Analytical Graphics (AGI) [6]. Multi Mission Satellite (MMSAT) tool is developed on Satellite Situation Center, SRI, RAS. Advanced High Precision Orbit Propagator (HPOP) is developed on Microcosm [7]. Some of these programs are very powerful tool kits capable to simulate very complicated satellites missions. They may be applied to high fidelity satellite motion calculation based on different propagation models. Different geometrical and physical situations could be determined. Each of these software tools has an advantaged in some aspects.

Initial stage of software tool for simulation of multi-satellite experiments is presented in the paper. The software will be developed as platform for design and analyze of multi-satellite space missions. One of primary aims of the software is different kinds of experiments simulation. Approach for situation problem presentation and formulation is described.

Scientific problems definition

A). The describing of scientific problems in the frames of developing system begin with project initialization when the project is entitled. An old variant of simulation model (if exist) is selected or new one is used as input. An important part of this stage is related to pointing satellites number, their orbital parameters and propagation models for every of them. The following variants for selection of gravity field are developed:

- Central gravity field;
- Normal gravity field;
- Only first six zonal harmonics [7];
- Zonal harmonics (≤20) [8];
- Mixed harmonics- zonal, tessarial/<u>tesseral</u> and sectorial (<21) [8];

A simplified gravity model may be enough on opening stage of mission design. More precise propagation models could be applied in cases when mutual configuration between two satellites and the evolution of this configuration is significant for simulated experiments (for example experiments Activen and Rezonans). This is very important especially on low satellite orbits.

Taking into account atmosphere drag especially on low orbits is very imperative. A simplified atmosphere model could be included on this stage [8,9]. Taking into account of satellite orientation and stabilization system may be important for satellite effective section when solar pressure is used. Solar and lunar perturbations are important in propagation model on high apogee orbits [8].

Special developed parallel ordinary differential equation systems integrator is applied for satellite orbital motion determination [10].

General functional scheme of presented system is shown on figure 1.

B). Geometrics and physical model orbital (along the orbits) parameters calculation. Different geometric and physical model parameters with general purpose are calculated for all satellites and positions on orbits. These parameters (environmental model parameters) are calculated in separate/specific program module and may be used later many times when different situation problems and simulations are solved.

C). Space experiments simulation module. Separate module for simulation of different aspects of space instruments operation is under development. Model of optical astronomical instrument which simulates moving field of view is ready and will be included in the system. Algorithms for Earth's surface remote sensing simulation are under development, as well as. Simulation of active experiments concerning electrons injection and simulation of their interaction with ionosphere environment and resulting glow is under finalization. Simulation of glow observation with optical instruments based one on sub-satellite and other on the ground in addition will be developed (experiment Activen).

D). Situational problems solving module. Software processor for situational problems solving is under development. The number of situational problems depends on complexity of observed model - number of satellites and space instruments on them, investigated objects, mutual configurations, physical, spatial and timed constrains. The module will allow application of different optimization algorithms for every situational problem.

Situational problem description

Every situational problem (SP) represent multitude of elementary restrictions/constrains conditions ξ_k :

$$ST_l = ST_l\{\xi_0, \xi_1, \xi_2, \dots \xi_k\}$$

Two-dimensional areas, which elements are derived and structured, are used for description of situational problems. Every column of such area contains separate situational problem. Since number and character of attributes of all situational conditions are different, the language construction of program language Fortran 95 could be used, as showed on figure 2. The application of two-dimensional areas from structures seem ineffective relatively to storage using, but it is very effective relatively to execution time and algorithm's simplicity.

Every ξ_k is defined with set of specific attributes. Structure of follow type is applied for presentation of every situational condition:

$\xi_{k,l}$= {situation_code, satellite_serial_(running)_number, atr_1, atr_2, …, $atr_n\}_k$.

ξ_0 don't describe situational condition but contain set of attributes related to the situational problem:

$\xi_{0,l}$= { number_of_conditions, satisfaction_code, optimization_code (for k>1), (t_1,t_2)}

The first attribute sit_cond%**max_cond** points the number of situational conditions of the problem, the second attribute sit_cond%**flag** – fulfilling situational condition for moment of system time t. The third one points optimization algorithm for solving situational problem, which is possible when situational conditions are more than one. Specific routine (software processor) for solving situational problems is under development. The processor distinguishes every situational condition by its distinctive code. The Respective function checks up fulfilling of the situation condition. The check of condition is based on satellite coordinates, different trajectory calculated model parameters

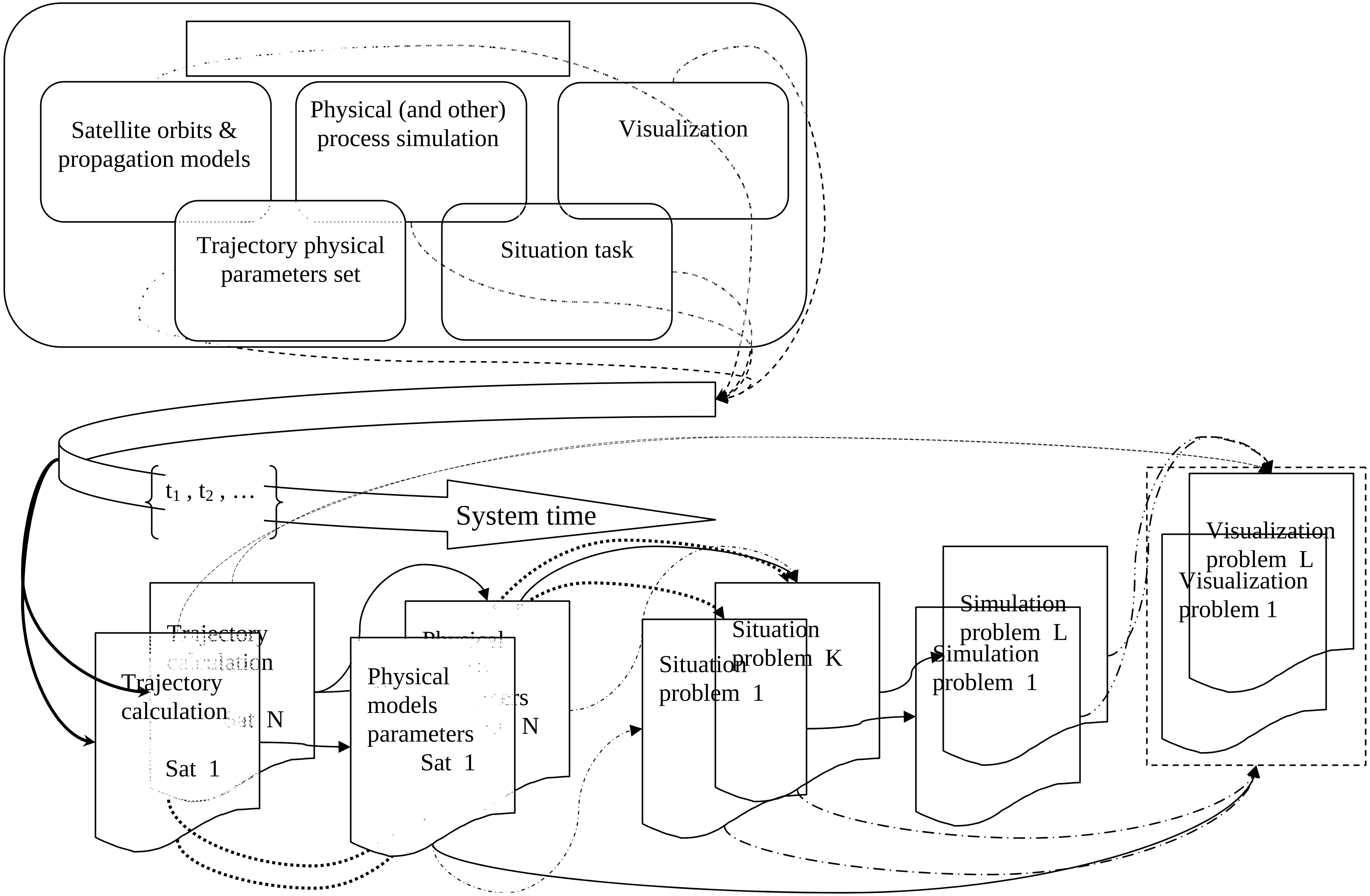

Figure 1. Functional scheme of simulation system

(geographic coordinates, magnetic field, atmospheric/ionospheric parameters), condition's attributes or additional calculations. Figure 3 shows fragment of situational processor.

```
MODULE     RN
 type     SitCond
   integer       sit_code      ! code of the situation condition; every situation have some code
   integer       sat_num       ! which satellite concern this situation task[condition]
   logical       flag          ! satisfaction of sit.cond: .false. or .true.
  union
   map                      ! Sit__1: Pass over circular region of Earth surfase with centre (lati,longi)
     integer    reg_num            ! running number of a region- actual number
     real        lati_r            ! latitude of the centre
     real      longi_r             ! longitude of the centre
     real      angle_r             ! angle of regions
   end map
   map                      ! Sit__2: visibility of a satellite from ground base station(lati,longi)
    integer    grbstat             ! ground based stations numbers (0) and codes
    real            lati           ! latitude of the centre
    real          longi            ! longitude of the centre
    real          angle            ! angle of regions
   end map
  …! maps for other sit.cond.………….
   end union
 end type  SitCond
!___________________________________________________________
  type     sit_task
  union
   map                             ! Only for sit.tasks control- contain number of situation conditions
     integer    max_cond         ! maximum number of sit.cond for every sit.task
     logical    flag             ! satisfaction of sit.task: .false. or .true.
     integer    opt_level        ! Optimization algorithm: 0- none, 1/2/3
     real*8      t1,t2           ! determine the last time interval vere the sit.task was satisfied
  end map
  map
     type (SitCond) sit_cond     ! determines a field containing situation condition described above
  end map
  end union
 end type  sit_task
END MODULE  RN
```

Fig. 2. Fragment of situational problem describing module

Editor for situational problem formulation is under development. It will allowed situational problem to be composed on the base of elementary situational conditions. The editor offers set of preliminary developed elementary situational conditions.

Space experiments simulation

Some modules for simulation of optical astronomical observation are developed on this stage:

- Optical Observation of sky objects and field of view visualization;
- Remote sensing of Earth surface with some kinds of optical instruments (under development);
- Particle injection from one satellite and observation of related emission effects in ionosphere with optical instruments based on other satellite and other instrument on the Earth surface;
- Transferring information between ground-based stations and satellite.

Situational conditions which are under development

The followed elementary situational conditions are developed or under development:

– Satellite pass over Earth's surface region (circular, rectangular);
– Satellite pass through radio-zone of ground-based station;
– Satellite pas through visibility zone of ground based station and without Earth's shadow;
– Two satellites pass "one above the other" during time interval $\Delta\tau$ which characterizes investigated phenomenon;
– Two satellites pass in narrow solid angle over Earth surface in time interval Δt which characterize current processes;
– Possibilities for observation of area of a casp by based on satellite optical instrument (instrument UFSIPS, experiment INTERBALL)
– Evaluation of mutual configuration between two satellites (satellite-sub satellite) and possibilities for observation the interaction of injected from one satellite charged particles with ionosphere by optical instrument on the board of the second satellite (project Apeks); a possibilities for ground based observation of the same event.

```
SUBROUTINE     sitanal(num_sat,t,dt,xvn,xvk,inTrajectoryParam,sci_task,max_num_sit,num_sci_task)
 USE  RN
 type    (TrajectoryParam) inTrajectoryParam(num_sat)
 type    (sit_task)  sci_task(0:max_num_sit,num_sci_task)

a:DO  j=1,num_sci_task;
  b:DO i=1,sci_task(0,j)%max_cond !num_sit !
              IF(sci_task(i,j)%sit_cond%sit_code.EQ.  1) THEN; ! First situation condition
                  sit= Sit__1(t,inTrajectoryParam(sci_task(i,j)%sit_cond%sat_num)%lati,      &
                                  inTrajectoryParam(sci_task(i,j)%sit_cond%sat_num)%longi,   &
                                  sci_task(i,j)%sit_cond%lati_r,sci_task(i,j)%sit_cond%longi_r, &
                                  sci_task(i,j)%sit_cond%angle_r)
                      sci_task(i,j)%sit_cond%flag_r= sit
        ELSEIF(sci_task(i,j)%sit_cond%sit_code.EQ.  2) THEN; ! Second situation condition
          ! Other situation conditions
         ENDIF
       IF(i.GT.1.AND..NOT.sit.AND.sci_task(0,j)%opt_level.NE.0) THEN !
          CALL  optimization(sci_task(0,j))
         ENDIF
   END DO b
  END DO a
END SUBROUTINE  sitanal
```

Fig. 3. Fragment of situational problem processor

Development of interactive real-time control of the system

Approach for interactive control of calculation process is developed. A set of registers are used for switch on/off different modes and commands by system pop-up menus. A possibility for stopping simulation process for detail observation and analyzing graphic or textual presented results and its continuation was developed. A repetition of calculation from beginning with quick start without initial conditions and simulation model parameters definition is possible. Delay of calculations or their synchronization with the real time are useful possibilities which allow better perceiving of quick changing scenes. Operation system resources are used for system time control - events. This approach saves processor time. Including or excluding of sound signals which denote fulfilling of situational condition, scale of visualization change, satellite tracking on Earth's map, output or stop text results are possible on the present stage. Interactive real time control improves space experiments simulations.

Conclusion

The basic concept of design of space simulation tool is presented. The basic modules are shortly described. Two of them take basic place - ordinary differential equation systems integrator and situational problems solver.

The development of the present system aims assistance in the preparation of space experiments. Besides, it will be used for investigation of possibilities for application of parallel calculations and development of respective algorithms. Such example is integration of satellites motion equations. Investigation of the risk from direct collision between satellite and space debris is actual in the recent time. Investigation the possibilities for parallelization situational problems processor is other very interesting aspect/perspective concerning developing system.

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