Spatial Grasp as a Model for Space-based Control and Management Systems

(New book extended contents)

Peter Simon Sapaty

Institute of Mathematical Machines and Systems National Academy of Sciences
peter.sapaty@gmail.com

Анотація. *З метою вирішення все більш складних проблем на Землі, а також у пошуках нових ресурсів поза її межами, людство активно освоює космічний простір. Цей глобальний процес, у якому має місце як співпраця країн, так і конкуренція між ними, є надзвичайно перспективним, але він також передбачає високі ризики та можливі збої у функціонуванні нових космічних систем. Під час їхньої розробки та введення в експлуатацію необхідно враховувати ймовірність виходу з ладу як окремих компонентів, так і системи в цілому. В основі таких космічних систем повинні знаходитися такі організаційні моделі і технології, які дозволили б зробити процеси їх створення, структурування, розвитку та управління досить гнучкими, динамічними та змінними у будь-який момент. Нова запланована книга, сьома з серії про розподілене управління та контролювання високого рівня, описуватиме космічно-орієнтовані рішення за допомогою Технології просторового захоплення (ТПЗ), в основі якої знаходиться контрольоване вірусоподібне покриття земних і космічних систем, які зможуть самостійно відновлюватися у випадках пошкоджень та втрати компонентів. Основна увага у книзі приділяється опису останньої версії ТПЗ, огляду новітніх космічних операцій, насамперед тих, що проводяться навколо Землі з використанням супутників на різних орбітах, а також тих, що стосуються проблем зв'язку та маршрутизації в інфраструктурах із багатьох супутників. У роботі розглядатимуться космічні проєкти як минулого, так і сьогодення, пов'язані з питаннями глобальної безпеки та оборони, способами вирішення їх ключових проблем у ТПЗ із паралельним відстеженням складних рухомих швидкісних об'єктів і постійним спостереженням із космосу за великими регіонами та інфраструктурами на Землі. Також описуватиметься, як за допомогою наземних мереж баз даних реєструвати та відстежувати численні космічні об'єкти, у тому числі й космічне сміття. Буде показано, як впровадження спеціальних віртуальних рівнів для космічних і наземних систем може вдосконалити процеси прийняття рішень у сферах глобального контролю і управління складними операціями та місіями в рамках ТПЗ. Зокрема, у книзі буде продемонстровано шляхи забезпечення високої цілісності, глобальної обізнаності і навіть свідомості розподілених космічних систем у межах ТПЗ. Інші можливості використання описаної технології стосуються сфер космічної економіки, прогнозування погоди та міжнародної безпеки. У роботі також описуватимуться можливості відтворення цієї технології навіть у стандартних університетських умовах.*
Ключові слова: *космічні системи, Земні орбіти, супутникові угрупування, нова космічна архітектура, Технологія просторового захоплення, мобільні рекурсивні сценарії, космічна безпека та оборона.*

Abstract. *Mankind is actively moving into space for solving increasingly complex problems on the Earth and finding new resources beyond it. This global cooperative and competitive process is extremely promising but also carrying fundamental risks and potential failures of the new space systems. In their design and implementation, the probability of failure of components, even the whole, should be taken into account as basic features. Such space systems need to be based on quite different organizational models and technologies allowing their creation, structuring, evolution and management to be flexible, dynamic and changeable at any moment. The planned new book, the seventh in a series on high-level distributed management and control, will describe space-oriented solutions with the help of Spatial Grasp model and Technology (SGT) based on virus-like covering and matching of terrestrial and celestial systems which*

will be able to self-recover from damages and loss of its components. The book will describe the latest SGT version, review the newest activities in space, especially those around the Earth which use different orbit satellites, and problems of communications and routing in multiple satellite infrastructures. It will review the space projects run in the past and some current ones related to global security and defense, and how to solve their key problems in SGT, including tracing of complexly moving high-speed objects and continuous observation of large regions and infrastructures on the Earth from space, as well as registering and tracing numerous space objects, including debris, by terrestrial database networks. It will be shown how the introduction of virtual layers for both celestial and terrestrial systems can improve solutions of global command and control of complex operations and missions under SGT. The book will also demonstrate how to provide high integrity, global awareness and even consciousness of distributed celestial systems under SGT. Other considered technology applications relate to space economy, weather prediction and international security. The book will also describe the possibilities of technology implementation which may be carried out even under standard university conditions.
Keywords: *space systems, Earth orbits, satellite constellations, new space architecture, Spatial Grasp Technology, mobile recursive scenarios, space security and defense.*

1. Introduction: Space conquest and international competition in space

Mankind is actively moving into space for solving increasingly complex problems on the Earth and finding the needed resources beyond it. This global cooperative and competitive process requires integrated distributed terrestrial and celestial systems with high dynamics and huge number of communicating components, for which advanced organizational models and technologies are needed – that is the main topic of the given book.

2. Spatial Grasp Model of direct perception of physical and virtual spaces

A high-level holistic model is described allowing us to directly exist and operate in united physical and virtual spaces. Influenced by the author's practicing in art and gestalt theory research, it is not based on traditional treating systems as communicating parts/agents, but rather uses self-covering of distributed spaces by recursive wavelike mobile scenarios in a spatial pattern-matching mode, with compact system solutions obtained at the semantic level.

3. Spatial Grasp Language, Technology, and their implementation

The basics of Spatial Grasp Technology (SGT) and its key Spatial Grasp Language (SGL) are described with the details of their implementation. From a million to several billions of communicating copies of SGL interpreter can be installed throughout terrestrial and celestial environments and integrated with existing systems and networks, while converting the whole universe into a powerful spatial engine capable of solving any problems by parallel SGL scenarios.

4. Classification of different orbit satellites and organizational problems of their usage

Geostationary orbit (GEO), Medium Earth orbit (MEO) and Low Earth orbit (LEO) are the most considered ones for different purposes. GEO satellites provide constant observation of the same vast Earth areas but they need powerful equipment, and LEO satellites, despite having the highest resolution, can observe the same points only for several minutes. As a result, it has to cooperate with other satellites and nontrivial organizational solutions this book is oriented for.

5. Dynamic routing in multi-satellite constellations under SGT

Many works on routing in multiple satellite networks are hierarchical, using two or even three mentioned above orbits. But advanced projects for global security and defense are mostly oriented on large constellations of LEO satellites which may have rapidly changing topologies with so

far unresolved problems of effective communications and routing in them. The chapter shows how to organize such communications in SGL, including the use of dynamic routing tables.

6. Global space security projects: SDI in the past and SDA new architecture

The chapter briefs Strategic Defense Initiative (SDI) launched in 1984 and famous for its small operational satellites called Brilliant Pebbles, and multifunctional seven-layered Next-Generation Space Architecture which has been announced recently by Space Development Agency (SDA) and which is mostly oriented on cooperating constellations of LEO satellites. Some solutions inspired by SDA are considered in the subsequent chapters, especially those related to its tracking and custody layers.

7. Tracing complexly moving terrestrial and celestial objects under SGT

Tracing, analyzing and elimination of complexly moving objects in distributed spaces, with sensors that have limited visibility, is a complex defense problem that may become even more complicated if many such objects move simultaneously. This can be effectively managed by mobile SGT intelligence that uses sensor networks to virtually follow physical objects during their move, as shown in SGL for cruise missiles and hypersonic gliders with the use of a cooperating radar or satellite networks.

8. Continuous observation of terrestrial objects by LEO satellites under SGT

Observation of earth locations/objects seems attractive with the use of LEO satellites which have high image resolution, but there may be some difficulties if the observation has to be continuous, because satellites stay above only for a short period of time. But this can be perfectly managed by the mobile intelligence using the solution in the previous chapter in an upside-down manner, with earth stationary objects now considered as themselves moving through the satellite network, as well as a mobile one, as shown in SGL.

9. Introducing a virtual layer for observation of large infrastructures under SGT

Introduction of a special virtual layer in a satellite network with semantically linked nodes corresponding to certain objects on the Earth and their regular relocation between moving satellites for continuous observation, arbitrary large territories and infrastructures can be constantly observed and managed as a whole. It is shown how this can be expressed in SGL at the application level or by proper adjustment of the language networked interpretation mechanisms.

10. Registration and observation of space objects by terrestrial systems under SGT

Such multiple objects like satellites and large debris found around the Earth can be potentially observed from the Earth through the use of different equipment. They can be traced, analyzed and properly registered in terrestrial database networks by SGT mobile intelligence in a manner similar to Chapters 7 and 8, and in a more advanced form to Chapter 8 by creating for each of them a virtual node copy constantly following movement of the related space object via the world database network.

11. Examples of other SGT space applications

Using the results of SGT applicability for space-related problems in previous chapters, as well as the solutions revealed in previous books, the chapter outlines other possible technology applications which include space economy, space collective robotics, space-based weather prediction, global command and control of different terrestrial and celestial missions and campaigns. Many of them can benefit from using virtual layers like those analyzed in Chapters 9 and 10.

12. Providing integrity, awareness and consciousness for space systems under SGT

SGT can provide high intelligence and integrity for advanced terrestrial and celestial systems with gestalt-based holistic solutions investigated in previous books, as well as supply multi-satellite collectives with global awareness and even a sort of spatial consciousness. There will be shown an example on how distributed awareness and consciousness of a satellite constellation with damaged components restores its functionality through the use of a migrating self-recovering SGL code.

13. Conclusions

Rapid advancement of humans into space is an extremely promising process which at the same time carries some risks and potential failures of the new space systems. Using the proposed self-evolving spatial grasp model and technology, which itself has symbolic super-virus power for both creating useful and destroying malicious systems, can believably be the right way in this global space-conquering process. Opportunities of SGT implementation, which is possible even under standard university conditions and which was done for its previous versions in different countries under the author's supervision, are also discussed.

Previous books & a patent

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