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Advanced terrestrial and celestial missions under spatial grasp technology

Abstract

The 21st century has an increasing activity in exploration of both Earth and beyond, also growing demands to local and global security, which will require advanced ground, air, and space operations. Many have to be distributed, cooperative, flexible, self-recovering, global goal-oriented, automated up to fully automatic, etc., with massive use of unmanned components. The latest version of high-level Spatial Grasp model and Technology (SGT) will be described which can effectively simulate, create, and manage large evolving infrastructures in both terrestrial and celestial environments. The technology can be readily implemented with communicating copies of its basic Spatial Grasp Language (SGL) installed in millions to billions of copies on Earth and in outer space, allowing us to observe and manage the whole world. Different kinds of space activity with current and planned missions are being investigated for SGT's applicability, including space surveillance networks, satellite and space communications, satellite Internet access, remote sensing satellites for digital earth, air traffic control, space and ground based instrumentation, ambitious plans to launch hundreds of new small satellites for different purposes, and others. Detailed investigations and concrete examples of effective use of SGT for parallel and distributed simulation, management and control will be provided for the following areas: a) Evolving space economy covering the area from Earth and up to Cislunar space, Mars, and beyond, which may bring significant strategic and global economic benefits for the whole mankind; b) Advanced space robotics with integration of AI technologies into space systems and collective behavior of multiple swarmed satellites; c) Global security on Earth and in space under the Space Development Agency's Next-Generation Space Architecture, with numerous satellites to be launched and multilayered space infrastructure created; d) Global missile defense, with tracking hypersonic threats from space, also arming satellites with lasers to shoot down missiles. The described global simulation and management approach, with its resultant parallel and distributed simulation and management technology, radically differs from traditional parts-to-whole, agents based, and interoperability principles and models, by offering dynamic holistic structural and spatial solutions which are more compact and powerful than with other approaches.

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Peter Simon Sapaty
Institute of Mathematical Machines and Systems, National Academy of Sciences, Ukraine

Correspondence: Peter Simon Sapaty, Institute of Mathematical Machines and Systems, National Academy of Sciences, Glushkova Ave 42, 03187 Kiev Ukraine, Email peter.sapaty@gmail.com

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Introduction

Humanity's interest in the heavens has been universal and enduring. Human space exploration helps to address fundamental questions about our place in the Universe and the history of our solar system. Through addressing the challenges related to human space exploration, we expand technology, create new industries, and foster peaceful connection between nations. Curiosity and exploration are vital to the human spirit and accepting the challenge of going deeper into space. We may expect space solar power plants, industrial exploration of the moon, eco-industry, recovery of natural resources, global weather management**,** large-scale artificial structures in space, using the raw materials of other planets, colonization of Venus and Mars, etc. A multitude of different kinds of current space activity can be found in.[1-25]

Philosophy, model, and technology oriented on holistic simulation and management of large distributed dynamic systems will be described, which may change, evolve and grow at runtime, reflecting of and adjusting to real world dynamics, while covering any terrestrial and celestial spaces. It has the "over-operability" nature while differing fundamentally from traditional parts-to-whole and interoperability approaches, also allowing us to grasp the whole of spatial phenomena from start in the form of integral distributed patterns which self-spread, self-cover and conquer the world in parallel. The latest version of Spatial Grasp Technology (SGT) and its high-level Spatial Grasp Language (SGL)[26-36] operating with fully distributed environments by parallel navigation and spatial grasping of their semantics is briefly presented. It allows us to combine simulation and management activities within self-organized holistic missions providing creation, modification, management and processing in the worlds covered. The spatial scenarios in SGL are often hundreds of times more compact and simpler than with other approaches originally oriented on communicating processes.

The paper briefs the evolving project under SGT and provides summaries on its different branches, which include: space activity, space missions and communications, evolving space economy, advanced space robotics, next-generation space architecture, and global missile defense with related space operations. Practical examples of using SGL are provided for tracing complexly moving objects by distributed sensor networks (including tracing cruise missiles by ground based sensors and also tracing hypersonic gliders by networked satellites), also using mobile virtual copies for effective matching of moving space objects**.**

Spatial grasp technology basics

General SGT idea

Within Spatial Grasp Technology (SGT),[26-31] a high-level scenario for any task to be performed in a distributed world is represented as an active self-evolving pattern rather than traditional program, sequential or parallel. This pattern, written in a high-level Spatial Grasp Language (SGL) and expressing top semantics of the problem to be solved, can start from any world point. It then spatially propagates, replicates, modifies, covers and matches the distributed world in parallel wavelike mode, while echoing the reached control states and data found or obtained for making decisions at higher levels and further space navigation. This inherently parallel and fully distributed spatial process is very symbolically shown in Figure 1.

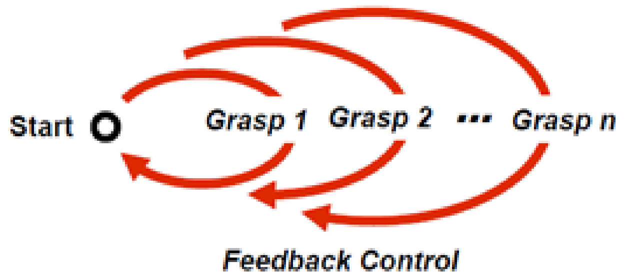

Figure 1 Controlled navigation & matching & grasping of distributed spaces.

Many spatial processes in SGL can start any time and in any places, cooperating or competing with each other, depending on applications. The self-spreading & self-matching SGL patterns-scenarios can create knowledge infrastructures arbitrarily distributed between system components which may cover any regions, the whole world including, as in Figure 2. The created infrastructures, which may remain active any time, can effectively support or express distributed databases, advanced command and control, situation awareness, autonomous and collective decisions, as well as any existing or hypothetical computational and or control models.

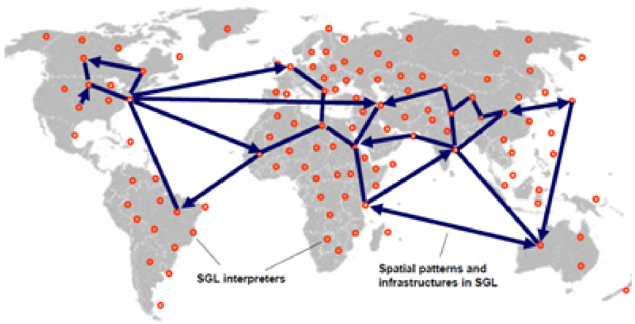

Figure 2 Spreading spatial patterns and creation of distributed infrastructures.

Spatial grasp language

General SGL organization is as follows, where syntactic categories are shown in italics, vertical bar separates alternatives, parts in braces indicate zero or more repetitions with a delimiter at the right if multiple, and constructs in brackets are optional:

***grasp* → *constant* | *variable* | [*rule*] [({ *grasp*,})]**

From this definition, an SGL scenario, called *grasp*, supposedly applied in some point of the distributed space, can just be a *constant* directly providing the result to be associated with this point. It can be a *variable* whose content, assigned to it previously when staying in this or (remotely) in other space point (as variables may have non-local meaning and coverage), provides the result in the application point too. It can also be a *rule* (expressing certain action, control, description or context) optionally accompanied with operands separated by comma (if multiple) and embraced in parentheses. These operands can be of any nature and complexity (including arbitrary scenarios themselves) and defined recursively as *grasp*, i.e. can be constants, variables or any rules with operands (i.e. as grasps again), and so on.

Rules, starting in some world point, can organize navigation of the world sequentially, in parallel or any combinations thereof. They can result in staying in the same application point or can cause movement to other world points with obtained results to be left there, as in the rule's final points. Such results can also be collected, processed, and returned to the rule's starting point, the latter serving as the final one on this rule. The final world points reached after the rule invocation can themselves become starting ones for other rules. The rules, due to recursive language organization, can form arbitrary operational and control infrastructures expressing any sequential, parallel, hierarchical, centralized, localized, mixed and up to fully decentralized and distributed algorithms. These algorithms, called *spatial*, can effectively operate *in*, *with*, *under*, *in between*, *over*, and *instead of* (as for simulation) large, dynamic, and heterogeneous spaces, which can be physical, virtual, management, command and control, or combined.

SGL full syntax description, as of its latest version, is as follows, with the words in Courier New font being direct language symbols (boldfaced braces including).

grasp	→	*constant* | *variable* | [*rule*] [({ *grasp*,})]
constant	→	*information* | *matter* | *custom* | *special* | *grasp*
information	→	*string* | *scenario* | *number*
string	→	'{*character*}'
scenario	→	{{*character*}}
number	→	[*sign*]{*digit*}[.{*digit*}[e[*sign*]{*digit*}]]
matter	→	"{*character*}"
special	→	thru | done | fail | fatal | infinite | nil | any | all | other | allother | current | passed | existing | neighbors | direct | forward | backward | synchronous | asynchronous | virtual | physical | executive | engaged | vacant | firstcome | unique | usual | real | simulate
variable	→	*global* | *heritable* | *frontal* | *nodal* | *environmental*
global	→	G{*alphameric*}
heritable	→	H{*alphameric*}
frontal	→	F{*alphameric*}
nodal	→	N{*alphameric*}

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environmental → TYPE | IDENTITY | NAME | CONTENT | ADDRESS | POINT | QUALITIES | WHERE | BACK | PREVIOUS | PREDECESSOR | DOER | RESOURCES | LINK | DIRECTION | WHEN | TIME | STATE | VALUE | IDENTITY | IN | OUT | STATUS | MODE | COLOR

rule → *type* | *usage* | *movement* | *creation* | *echoing* | *verification* | *assignment* | *advancement* | *branching* | *transference* | *exchange* | *timing* | *qualifying* | *grasp*

type → global | heritable | frontal | nodal | environmental | matter | number | string | scenario | constant | custom

usage → address | coordinate | content | index | time | speed | name | place | center | range | doer | node | link | unit

movement → hop | hopfirst | hopforth | move | shift | pass | return | follow

creation → create | form | linkup | delete | unlink

echoing → state | rake | order | unit | unique | sum | count | first | last | min | max | random | average | sortup | sortdown | reverse | element | position | fromto | add | subtract | multiply | divide | degree | separate | unite |attach | append | common | withdraw | increment | decrement | access | invert | apply | location

verification → equal | nonequal | less | lessorequal | more | moreorequal | bigger | smaller | heavier | lighter | longer | shorter | empty | nonempty | belong | notbelong | intersect | notintersect | yes | no

assignment → assign | assignpeers | associate

advancement → advance | slide | repeat | align | fringe

branching → branch | sequence | parallel | if | or | and | choose | quickest | cycle | loop | sling | whirl | split

transference → run | call

exchange → input | output | send | receive | emit | get

timing → sleep | allowed

qualification → contain | release | free | blind | quit | abort | stay | lift | seize

SGL interpreter

The SGL interpreter main components and its general organization are shown in Figure 3.

The interpreter consists of a number of specialized *functional processors* (shown by rectangles) working with and sharing specific data structures. These include: Communication Processor, Control Processor, Navigation Processor, Parser, different Operation Processors, and special (external & internal) World Access Unit directly manageable from SGL. Main *data structures* (also referred to as *stores*) with which these processors operate (shown by ovals) comprise: Grasps Queue, Suspended Grasps, Track Forest, Activated Rules, Knowledge Network, Grasps Identities, Heritable Variables, Fontal Variables, Nodal Variables, Environmental Variables, Global Variables, Incoming Queue, and Outgoing Queue. SGL interpretation network generally serves multiple scenarios or their parallel branches simultaneously navigating the distributed world, which can cooperate or compete with each other.

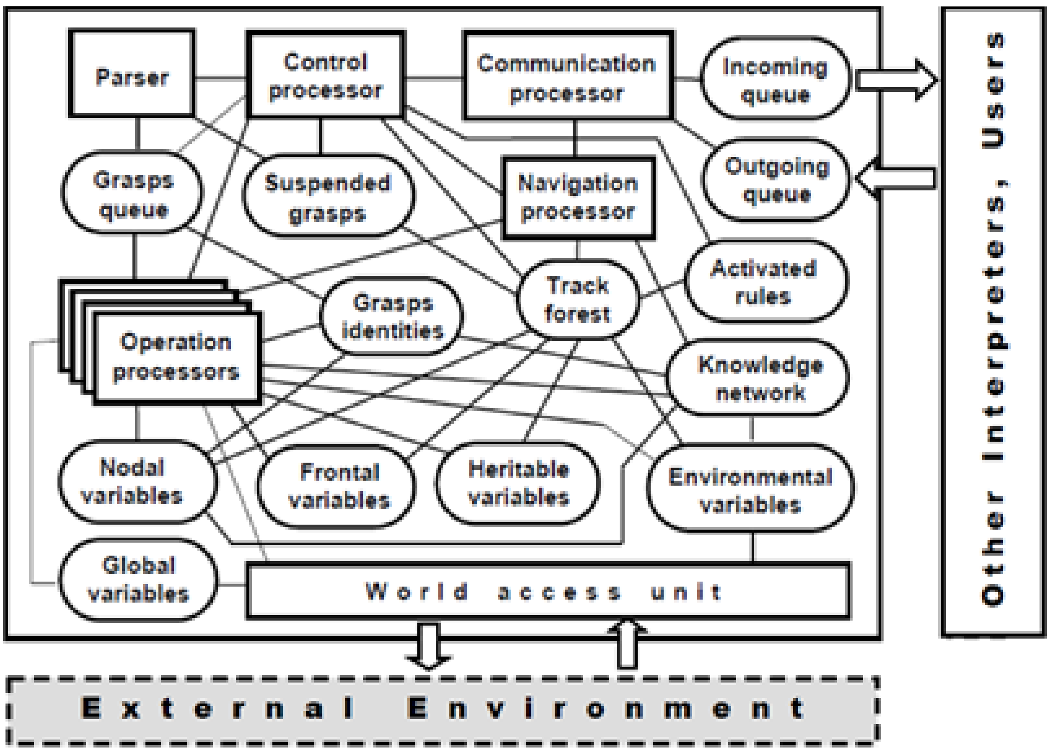

Figure 3 SGL interpreter main components and their interactions.

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Each interpreter can support and process multiple SGL scenario code which happens to be in its responsibility at different moments of time. More details on SGT, SGL, its implementation and investigated and tested applications can be found elsewhere, including.[26-36] Implanted into any distributed systems and integrated with them, the interpretation network (having potentially millions to billions of communicating interpreter copies) allows us to form spatial world computer with practically unlimited power for simulation and management of the whole mankind.

SGT as a spatial brain and its capabilities

Communicating SGL interpreters can be implanted into sensitive points of different systems (like social, industrial, military or space-based) on agreements or in a stealth manner, depending on applications and permissions. These interpretation networks, actually as a sort of spatial brain, can collect and extract important, peculiar, and sensitive information on numerous events, also discover and analyze different kinds of distributed infrastructures which may be benign or malicious. This is achievable by self-evolving, self-growing, self-replicating and self-spreading patterns written in SGL, which can be applied from any world point, while creating higher-level holistic operational and awareness infrastructures dynamically covering and matching any social areas.

By using active intelligent networks directly accessing the freshest information in numerous places it is possible to simulate different developments of many systems under realistic or hypothetical circumstances, also launch controlled local and global experiments. This can be helpful in solving a variety of hot problems emerging on national and international levels. Special attention can be paid to important problems directly or indirectly influencing social welfare, like future transportation infrastructures with multiple driverless cars and advanced road traffic management or security issues using ground and aerial robotics and integrated air and missile defense. Of particular interest and effectiveness may be allowing for seamless embedment of massive robotics into human societies, with robots taking care of dangerous and critical situations while acting cooperatively with humans and among themselves under global goals and unified control, which can be provided by SGT.

Summary of the project currently developed under SGT

We are briefing here on some areas of the new project being developed under SGT, with fresh publications (two books including) and new technology patent planned.

a. Space activity, orbits, missions, and communications with potential use of SGT

This plans a review of different existing practical space activities[1-5] where SGT with its holistic spatial nature may be particularly useful, along with analyzing parameters of different Earth orbits and comparative features of LEO and GEO space satellites. It will provide general analysis of possible SGT application for space surveillance network, satellite and space communications, satellite Internet access, space mission analysis and design, remote sensing satellites for digital earth, communicating sensors for aerospace and automotive applications, space and ground based instrumentation, air traffic control operation systems, as well as plans to launch hundreds of new small satellites for different purposes.

b. Evolving space economy under SGT

So far human spaceflight was limited to low Earth orbit and space stations (also years ago visiting the Moon), and only went further with robotic scientific missions. This is about to change, and we may face quite different space missions which, despite high costs at start, may bring significant strategic and global economic benefits.[6-9] Developments in the space industry will be briefed from reusable rockets to asteroid mining and Cislunar economy production, which may form a new economic system. Space mining may appear as the next gold rush, off-Earth manufacturing and new markets will require advanced transportation network, and settlement on the Moon will mark the first step in the expansion into the Solar System. Different exemplary solutions in this broad area will be outlined with exemplary scenarios shown in SGL.

c. Advanced space robotics under SGT

Space robotics market[10-12] is predicted to expand to $3.5bn by 2025, with integration of AI technologies into space systems. Space robotics market is attributed to increasing number of space exploration experiments and projects. The new trend in Earth observation is to use sets of low-cost, simple and short development time satellites. Multiple satellites flying near one another in similar orbits are of growing interest. Their large swarms will introduce new space mission capabilities but also complexities as must operate as an integral unit. Examples of using SGT will be demonstrated for providing advanced swarming, distributed AI, and even a sort of spatial consciousness for multiple robotized formations in space, with corresponding examples written in SGL.

d. Next-Generation Space Architecture under SGT

The Space Development Agency is looking for technologies to build a network of satellites in low Earth orbit that would help to find targets on the ground and track enemy missiles in flight.[13-20] The SDA's notional architecture is predicated on the availability of a ubiquitous data and communications transport layer using small, mass-produced satellites. Seven layers are proposed within this architecture: Space Transport Layer, Tracking Layer, Custody Layer, Deterrence Layer, Navigation Layer, Battle Management Layer, and Support Layer. All these are considered how to be modeled and managed under SGT, separately and as a whole, with examples to be shown in SGL. There will also be comparison with the Strategic Defense Initiative (SDI) of eighties with the use of small satellites called "brilliant pebbles", which can be effectively modeled in SGL too.

e. Global missile defense and space operations under SGT

This project branch examines the nuclear dynamics and implications for strategic relations in a world where nuclear-armed states are developing strategic ballistic missile defenses (BMD).[21-25] It investigates how to fight growing space-based threats, to move quickly on hypersonic defense and how to track hypersonic threats from space, how to arm satellites with lasers to shoot down missiles, could thousands of satellites help prevent massive ballistic missile and hypersonic attacks, will competing in space be inevitable, and it may soon become a war zone, and so on. Examples of using SGT for different management and coordination solutions in the global missile defense area are being prepared in SGL, including discovery, tracing and elimination of hypersonic gliders with unpredictable routes by intelligent swarms of communicating satellites effectively programmed in SGL.

Some SGT application examples

We will be showing here only some elementary examples of using SGT for dealing with spatially moving objects and their control by self-spreading, self-evolving and self-matching mobile recursive code, whereas many other examples can be easily found in existing publications, like.[26-36]

Tracing complexly moving objects by distributed sensor networks

Tracing by ground based sensors

Distributed sensor networks operating under SGT can catch and follow moving objects, like cruise missiles,[21-24] throughout the whole region despite limitations of individual sensors, as in Figure 4. The figure symbolically shows some territory covered with a heterogeneous network of communicating radar stations, each having SGL interpreter installed, with presumably hostile objects like cruise missiles moving through the area.

The radar first seeing a new object (i.e. which is within the given visibility threshold) is becoming the start of a distributed tracing operation, after which the object can be seen by this radar for some time and then shifts in visibility to other sensors after being lost by the current one. Object's moving & behavior history can be collected & updated at each passed radar sensor by SGT-produced mobile spatial intelligence individually assigned to this object and following its physical move electronically via the radar network.

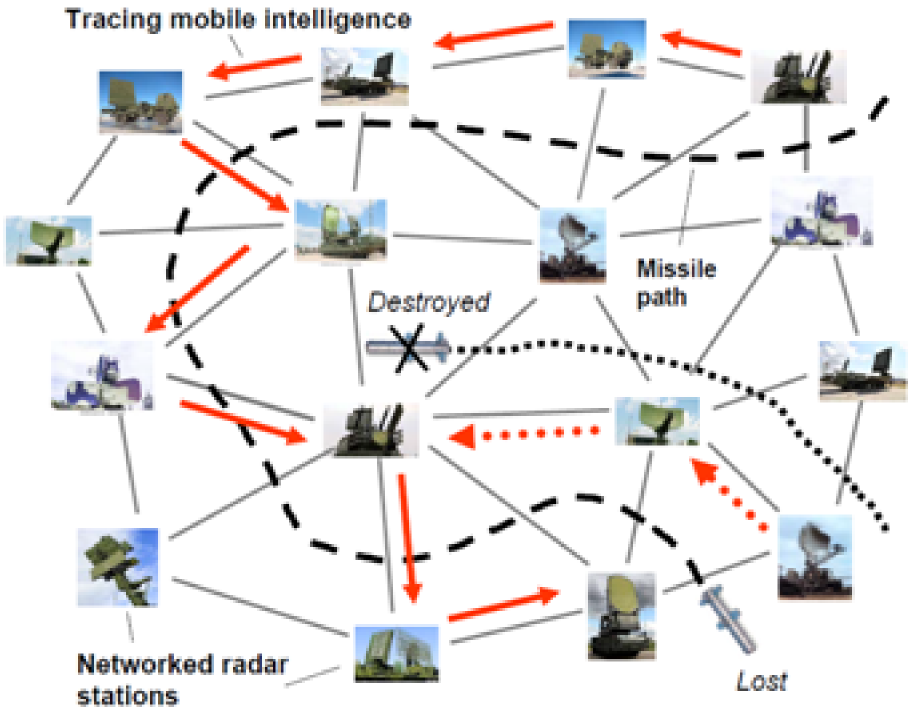

Figure 4 Distributed objects tracking by a sensor network in SGT.

Depending on the collected history, such object may be decided to be destroyed, it may also be finally lost after safely passing through the whole radar-controlled area. The SGL scenario below will be following the moving object wherever it goes, despite its possible complex and tricky route, like of a cruise missile. The scenario can operate with multiple moving objects appearing at any time, where sensors regularly search for new targets, and each new target is assigned an individual tracking intelligence propagating in distributed networked space in parallel with other similar intelligences.

```
hop(all_nodes);
frontal(Object, History, Threshold = …);
whirl(
  Object = search(aerial, new));
  visibility(Object) >= Threshold;
  free_repeat(
    loop(
      visibility(Object) >= Threshold);
      update(History, Object);
      if(negative(History), blind_destroy(Object)));
    max_destination(
      hop(all_neighbors); visibility(Object));
    if(visibility(Object) < Threshold,
      blind_output(Object, 'lost', History))))
```

The offered organization of tracing and impacting of multiple moving objects in distributed environments by networked sensors with embedded SGL interpreters and virus-like mobile intelligence operating without any (often vulnerable) central resources can also be effectively used in many other areas, like for complex space operations mentioned below.

Tracing hypersonic gliders by networked satellites

Hypersonic weapons are breaking all the rules of traditional missile defense, as they are much harder to be detected than traditional ballistic missiles. The advanced sensors mounted on satellites will have to detect the threat and then pass their data to the next LEO sensor, which will pick up the object as it travels around the globe at hypersonic speed. Allowing such data flow from sensor to sensor is absolutely essential to the effective operation of the system. Moreover, hypersonic weapons are maneuverable, meaning they can evade ground-based sensors as they traverse the globe toward their target. With speed surpassing Mach 7 and the ability to maneuver mid-flight, hypersonic weapons are potentially making the current defenses obsolete.

Similar to the previous example, with slight code changes, we can effectively organize large satellite

networks to trace the hypersonic missiles wherever they go, where self-propagating virtual images in

SGL will be keeping full control over them, as shown in Figure 5.

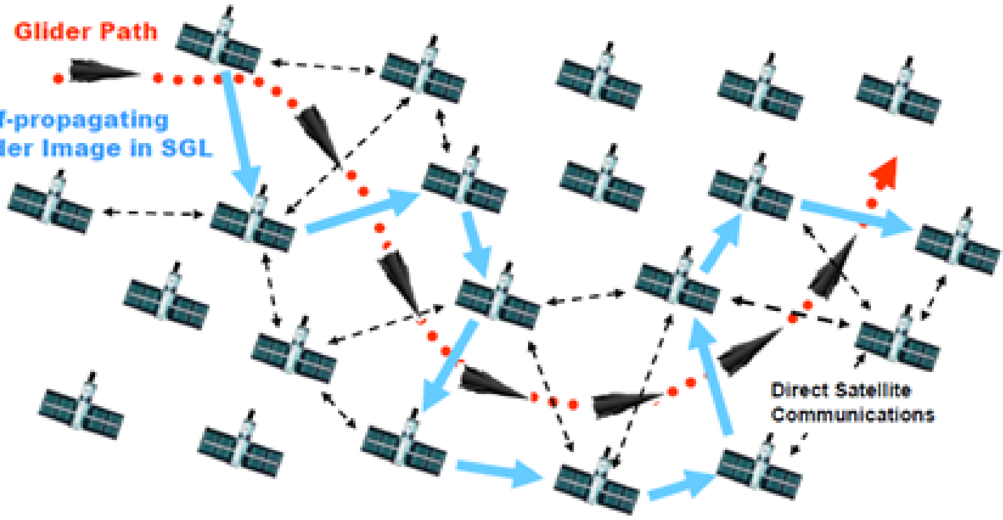

Figure 5 Hypersonic gliders followed and controlled by virtual mobile images in SGT.

Using virtual object copies for effective matching of movement space objects

The previous solution was on the level of networked sensor nodes through which spatial control in SGL was explicitly propagating and following the object's movement in physical space. In effective tracing of space objects under SGT we may also need a higher level of abstraction, associating with each physical object its unique virtual copy with appropriate name, which is *imaginably moving in physical space similarly to the physical object*. This organization is shown in Figure 6 for possible space objects orbiting the Earth, where virtual objects regularly update their space coordinates by frequently "seeing" their physical origins.

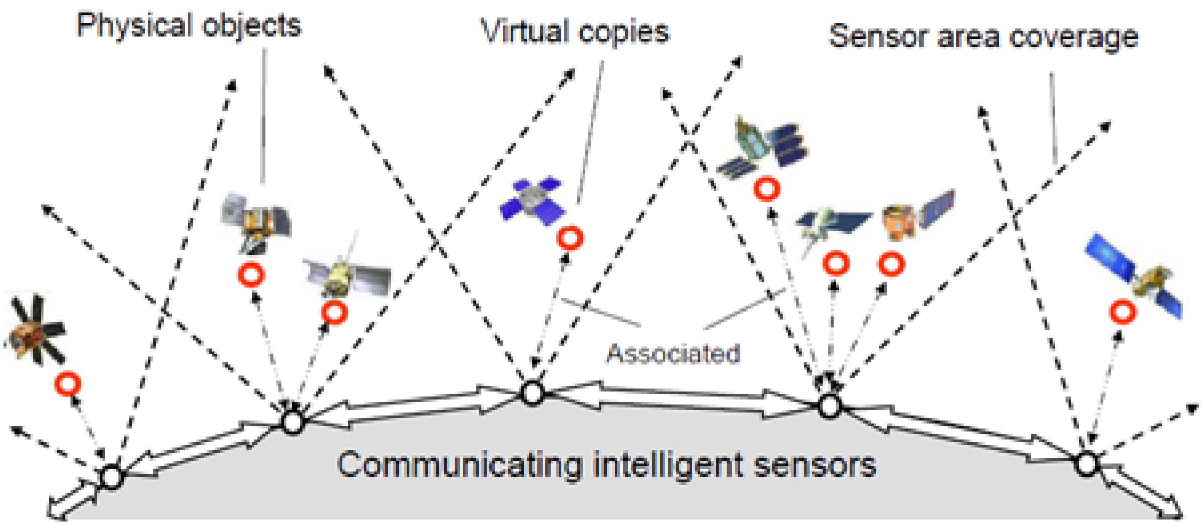

Figure 6 Simulating moving physical objects in space by their propagating virtual copies.

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Creating a virtual node copy of the physical object just discovered throughout the world with its identity given, and organizing the node's continuous simulated movement in space by matching the physical object's movement, can be expressed in SGL as follows. (This can also involve collection and regular update of the individual object's propagation history, also making corrections in stationary databases related to the sensors passed, and in the world's global space database, if needed.)

frontal(ObjectIdentity = …);

max_destination(

hop(all_sensor_nodes); visibility(ObjectIdentity));

visibility(ObjectIdentity) >= *Threshold*;

create_node(ObjectIdentity); nodal(History);

loop(

WHERE = check_coordinates(ObjectIdentity);

History = extend(History, WHERE, TIME);

update(DATABASE(ObjectIdentity), History);

sleep(*Delay*))

Conclusion

Various aspects of human activity in space and numerous tasks and problems emerging on this often complex and thorny way were considered. The SGT's self-evolving holistic parallel and distributed philosophy and model was found to be adequately matching the current and future plans of the space conquest. Spatially operating via its communicating interpreters installed in numerous (potentially millions to billions) copies in terrestrial and celestial environments, it actually acquires the power of ruling the world. Many other space-related tasks for SGT and its updated versions are planned to be considered in the following publications like, for example, dealing with numerous space debris. By the experience with tech's previous versions in different countries, it can be quickly implemented, at least is operating basics, even within standard university environments, with the author always ready to help with this.

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None.

Conflicts of interest

Author declares that there is no conflict of interest.

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