EMERALD POINTS

THE SPATIAL GRASP MODEL

Applications and Investigations of Distributed Dynamic Worlds

PETER SIMON SAPATY

THE SPATIAL GRASP MODEL

This page intentionally left blank

THE SPATIAL GRASP MODEL

Applications and Investigations of Distributed Dynamic Worlds

BY

PETER SIMON SAPATY
National Academy of Sciences of Ukraine, Ukraine

emerald PUBLISHING

United Kingdom – North America – Japan – India
Malaysia – China

Emerald Publishing Limited
Howard House, Wagon Lane, Bingley BD16 1WA, UK

First edition 2023

Reprints and permissions service
Contact: permissions@emeraldinsight.com

British Library Cataloging in Publication Data
A catalog record for this book is available from the British Library

ISBN: 978-1-80455-575-0 (Print)
ISBN: 978-1-80455-574-3 (Online)
ISBN: 978-1-80455-576-7 (Epub)

ISOQAR certified Management System, awarded to Emerald for adherence to Environmental standard ISO 14001:2004.

ISOQAR REGISTERED
Certificate Number 1985
ISO 14001

INVESTOR IN PEOPLE

To my family members for their lasting encouragement and support, also exciting common trips to the unknown and dangerous words.

This page intentionally left blank

CONTENTS

This page intentionally left blank

LIST OF FIGURES

ABOUT THE AUTHOR

Dr Peter Simon Sapaty, Chief Research Scientist, Ukrainian Academy of Sciences, has worked with networked systems for five decades. Outside of Ukraine, he worked in the former Czechoslovakia (now Slovak Republic), Germany, the United Kingdom, Canada, and Japan as a group leader, Alexander von Humboldt researcher, and invited and visiting professor. He invented a distributed control technology that resulted in a European patent. He has published more than 260 papers on distributed systems and has been included in the Marquis Who's Who in the World and Cambridge Outstanding Intellectuals of the twenty-first century.

This page intentionally left blank

FOREWORD

This is a sequel to the previous seven books on high-level management of large distributed systems. Born half a century ago, well before the internet, and called WAVE in its infancy, the developed model and technology was tested on numerous applications in different countries. The book is oriented on their extended applications including new worlds of terrestrial and celestial nature, global systems, and NASA strategic research areas and technologies. It presents main ideas of the Spatial Grasp (SG) paradigm and details of its key Spatial Grasp Language (SGL), including its philosophy, methodology, syntax, semantics, and interpretation in distributed systems. The scenario-pattern in SGL spatially propagates, replicates, modifies, covers, and matches distributed worlds in parallel wavelike mode, allowing us to evaluate large distributed phenomena by their physical or virtual coverage. The solutions in SGL contain investigation of the regions of interest like hurricanes and forest fires, with similar techniques applicable for celestial cases, and show how to find images in arbitrary distributed networks using spatial graph-pattern matching technique. It provides investigation of group behavior of ocean animals, discovery of unknown terrain features, and path-findings in large transport networks. Comparison of SGL with other programming, specialized, and natural languages shows simplicity and compactness of obtained solutions, due to SGL operating directly on distributed networked bodies in a holistic, parallel, and pattern matching mode. Relation of SGL to some higher mental concepts has been investigated by showing how to simulate gestalt psychology principles and maintain global awareness and consciousness of distributed systems by SGL recursive virus-like spatial coverage. The results confirm potential applicability of the developed paradigm, language, and technology for solving much broader classes of problems related to large unknown worlds. The approach can also be used for high-level formulation of key problems and their solutions instead of natural languages, due to clarity and compactness of the resulting descriptions.

Peter Simon Sapaty

This page intentionally left blank

PREFACE

The world around us as individuals, collectives, countries, and continents, around the Earth, the Sun, other planets, stars, and galaxies is enormously large, diverse, and fully distributed. It is impossible to see and comprehend it from any separate point or points (whether physical, virtual, or combined) and at any levels, And for achieving this we should develop radically new space-related philosophies, paradigms, models, technologies, and languages, on which the current book is oriented, while continuing our previous work on spatial intelligence and technologies described in previous publications, seven books from Wiley, Springer, Emerald, and Taylor & Francis including.

The current book actually inherits practical works on creation of citywide computer networks in Kiev, Ukraine, from the end of 1960s, well before the internet, which were integrating different institutes of the National Academy of Sciences and other organizations. They resulted in a new management concept and distributed control methodology and technology which were further developed in different countries including Ukraine, former Czechoslovakia, Germany, the United Kingdom, United States, Canada, and Japan. The investigated applications covered intelligent network management, industry, social systems, collective robotics, military command and control, crisis management, national and international security, defense, distributed simulation, physical–virtual symbiosis, space-based systems, and even biology, psychology, and art.

The current book presents main ideas of the developed SG paradigm and details of its key SGL, including their philosophy, methodology, syntax, semantics, and interpretation in distributed systems. The scenario-pattern in SGL spatially propagates, replicates, modifies, covers, and matches distributed worlds in parallel wavelike mode, allowing us to evaluate large distributed phenomena by their physical or virtual coverage. The presented solutions in SGL contain investigation of the regions of interest like hurricanes and forest fires, with similar techniques applicable for celestial cases, and show how to find images in arbitrary distributed networks using spatial graph-pattern matching technique. They also include investigation of group behavior of ocean animals, discovery of unknown terrain features, and path-findings in large transport networks.

Comparison of SGL with other programming, specialized, and natural languages showed simplicity and compactness of obtained solutions, due to SGL operating directly on distributed networked bodies in a holistic, parallel, and pattern matching mode. Relation of SG paradigm to some higher mental concepts has been investigated by showing how to simulate gestalt psychology principles and maintain global awareness and consciousness of distributed systems. The results confirmed potential applicability of the developed model, language, and technology for solving much broader classes of problems related to large unknown worlds. The approach can also be used for high-level formulation of key problems and their solutions instead of natural languages, due to clarity and compactness of the resulting descriptions.

Kiev, Ukraine
July 2022
Peter Simon Sapaty

ACKNOWLEDGMENTS

With special thanks to my good colleagues and friends for their lasting support and active discussions of the main ideas of this book:

Prof. **John Page**, University of New South Wales, Australia

Prof. **Steve Lambacher**, School of Social Informatics, Aoyama Gakuin University, Tokyo, Japan

Prof. **Kohei Arai**, Saga University, Japan

Also: **Svitlana Tymchyk**, **Nataliia Karevina**, and **Yevheniia Petruk** for the years of good cooperation with this wonderful editorial team of *Mathematical Machines and Systems* journal (ISSN 1028-9763) of the National Academy of Sciences of Ukraine.

This page intentionally left blank

1

INTRODUCTION

1.1 BACKGROUND AND HISTORY OF THE APPROACH

This book actually inherits practical works on the creation of citywide computer networks in Kiev, Ukraine, from the end of 1960s, which were integrating different institutes of the National Academy of Sciences and other organizations with active participation of the current author [1–4]. By spreading a fully interpreted scenario code in a wavelike mode between different computers, we were able to solve complex analytic-numerical problems on heterogeneous computer networks that were difficult to organize on individual computers. These works resulted in a new management concept and distributed control methodology and technology which were further developed in different countries (including Ukraine, former Czechoslovakia, Germany, the United Kingdom, United States, Canada, and Japan). The applications and resultant publications included such areas as: intelligent network management, industry, social systems, collective robotics, military command and control, crisis management, national and international security, defense, distributed simulation, physical–virtual symbiosis, space-based systems, and even biology, psychology, and art, see also (the list is far from being full) [5–57, 59–76], which includes European patent [10], and Wiley, Springer, Emerald, and Taylor & Francis books [11, 13, 52, 53, 55, 58, 76].

The technology-based international projects were supported by Siemens and Alexander von Humboldt Foundation in Germany, Ericsson and Defense Research Agency in the United Kingdom, Japan Society for the Promotion of Science, and Distributed Interactive Simulation project in the United States which hosted Special Interest Group on Mobile Cooperative Technologies chaired by the author. The developed concept was demonstrated at the Universities of Braunschweig and Karlsruhe in Germany, Oxford and Surrey in the United Kingdom, British Columbia in Canada, Oita and Aizu in Japan, and California at Irvine in the United States. A number of successful implementations had been made of this approach in such programming languages as Analytic, Fortran, Lisp, and C.

1.2 TOWARDS EXTENDED TECHNOLOGY APPLICATIONS

The current book is oriented on extended technology applications, especially for investigation of large and unknown terrestrial and celestial worlds, which may include large phenomena like hurricanes, forest fires, even galaxies, as well as finding arbitrary images in distributed networks. Basic environmental issues, global systems, discovering new worlds, Earth science, and planetary exploration activities at NASA are included too. Practical solutions related to different worlds which include investigation of group behavior of ocean animals, finding details of geographical terrain, management of transport networks are also considered. Comparison with other programming and specialized languages, natural language including, has been provided. Higher-level philosophical, psychological, and mental concepts related to gestalt theory, perception, global awareness, consciousness, and even soul have been discussed.

The world's richness, greatness, and diversity cannot be perceived and understood in any single points, only massively and simultaneously from numerous positions, and as a field rather than a location, also by not separate individuals but large human and robotic collectives behaving as a whole. And this should be done at a high level by working with spatial images covering large physical virtual and combined spaces, both terrestrial and celestial. This activity should integrate philosophy, psychology, languages, technologies, and practical solution methods. The humankind should obtain powerful mechanisms to see, understand, plan, and function as a whole.

1.3 SUMMARY OF THE BOOK CHAPTERS

1.3.1 Chapter 2: Investigating Terrestrial and Celestial Worlds

The Chapter describes extended research areas for the developed Spatial Grasp (SG) model and Technology applications, first listing traditional questions related to the existence of the world around us, highlighting the essence of science for world exploration. It discusses the existing major environmental problems, stating that our planet is on the brink of a severe environmental crisis, and by raising this awareness we can contribute to a more environmentally friendly place to live. The Chapter is also describing global systems as an economic and political construct in which capital, management, employment, knowledge, natural resources, and organizations are fully internationalized. It tells that Global Systems Science builds on the results from advances in complex systems, networks science, high performance computing, and other areas. It describes efforts in discovering new worlds, including a large number of new planets, which also helps us to better understand formation and origins of our solar system. NASA strategic research areas and technologies are briefed, with NASA JPL being the world leader in planetary exploration. It reviews numerous JPL briefings and publications received and collected by the National Academy of Sciences on the ongoing research and practical activities related to planet Earth and the outer space. At the end it highlights the necessity of new strategic philosophies, models, and technologies to study the worlds around us and far beyond, mentioning that this can be successfully done by intelligent spatial patterns summarizing different ideas and hypotheses, to be globally matched with the unknown worlds, which is the main theme of this book.

1.3.2 Chapter 3: Spatial Grasp Model and Technology Basics

The Chapter presents and discusses main ideas of the developed SG paradigm and resultant Spatial Grasp Technology (SGT). It starts with how traditional systems and solutions in them are organized, all being represented as parts exchanging messages. It also explains such widely used concepts as distributed system, distributed control system, message-based communication, distributed agents, distributed objects, and concurrent programming. SG, on the opposite, provides holistic, inseparable into parts, world coverage with parallel active code, as self-spreading, self-evolving, and self-matching pattern rather than a traditional program, sequential or parallel. It also gives details on physical, virtual, and executive worlds this paradigm operates with. After this, the Chapter explains basics of the recursive Spatial Grasp Language (SGL), with its main elements like constants, different types of spatial variables, and the most important and universal construct as rules, the latter covering any processing, management, control, and contextual capabilities. It also explains in detail how SGL scenarios evolve in distributed spaces while effectively using different control states issued in various world points to coordinate their spatial evolution and at different levels.

1.3.3 Chapter 4: Spatial Grasp Language Basic Organization

Further details of SGL and its organization, continuing from the previous chapter, are shown in textual and graphical form, which is universal, deeply recursive, and very compact. It may be easily extended for any application areas, just by adding new rules to it within the same language syntax. It describes basic SGL constants which include information, physical matter/ objects, special and customs items, as well as arbitrary complex structures which can be produced within the recursive SGL syntax. The Chapter describes different types of SGL variables which, like frontal, can be mobile in distributed spaces, heritable – shared by the subsequent operations only, nodal – shared in the same locations by different spatial processes, environmental – providing access to navigated environments or internal interpretation mechanisms, and most expensive, global, as serving any and multiple spatial processes regardless of their whereabouts. It then names all SGL rules belonging to such categories as: type, usage, seeing, movement, creation, echoing, verification, assignment, advancement, branching, transference, exchange, timing, qualifying, extension, and grasp (defined recursively). At the end it provides elementary programming examples in SGL covering operations in physical and virtual spaces, also just computational ones, which can be executed in any types of worlds.

1.3.4 Chapter 5: Mechanisms of SGL Distributed Implementation

The Chapter reveals some important details of the SGL interpretation, which can be implemented in software, hardware, or combined. It discusses SGL interpreter organization, which consists of a number of specialized functional processors working with specific data structures, serving SGL scenarios or their parts which currently happen to be inside this interpreter and also organizing exchanges with other interpreters in case of mobile and distributed SGL scenarios. Communicating interpreters can be in arbitrary number of copies, up to millions and billions, which can be integrated with other systems and communications. Their dynamic networks can represent powerful spatial engines capable of solving any problems in terrestrial and celestial environments. The Chapter discusses the spatial tracking system of the distributed interpreter which provides hierarchical command and control and remote data and code access, as well as parallel spatial computation of the values reached. It also supports spatial variables and merges distributed control states for making decisions at higher levels. The Chapter gives some technical examples of the distributed interpretation mechanisms which include single and repetitive advancement in space, asynchronous or synchronized, feedback-based parallel computation using dynamically created track trees, and combination of feedback computation with forward advancement.

1.3.5 Chapter 6: Distributed Worlds Vision and Comprehension in SGL

The Chapter shows some examples of how to see, understand, and evaluate as a whole of very large distributed phenomena unobservable from any single point, by their massive and cooperative coverage under the SG paradigm. It first describes hierarchical spreading in a distributed space for finding border of a spatial image like hurricane or galactic, using for this self-growing spatial tree evolving through the local visibilities and finally collecting the global image in the starting node. It also provides virus-like spatial coverage randomly and in all possible directions for finding borders of very complex regions, for which it may be difficult to use the growing trees of the previous examples. The Chapter also shows how to discover arbitrary graph-based structures and images in a distributed network by their parallel wavelike matching with the network body. It then discusses different implementation possibilities for the mentioned scenario examples, which mostly expressed top semantics of the problems and their theoretical solutions, stressing that real equipment may be needed to operate effectively in realistic environments. The shown examples integrate two main functionalities of SGL scenarios: parallel self-spreading in distributed spaces with parallel grasping of the obtained solutions in a hierarchical feedback mode.

1.3.6 Chapter 7: Investigating Unknown Worlds in SGL

The Chapter provides examples of investigation of behavior of animals, solutions for unknown terrain, problems in large transport networks, and finally, in information networks. It shows how to investigate group behavior of ocean animals like sharks, by associating with individual animals of the special equipment having embedded SGL interpreters, which can communicate with each other. This may allow us to find minimum and maximum distances between animals over certain time, their average speed of movement, and also assess how large may be the area occupied by the whole group. Part of the Chapter is devoted to investigation of unknown terrain with finding heights and coordinates of all found hill/mountain summits, and, separately, the coordinates and height of the main summit, by using multiple robotic-type units with SGL interpreters which can communicate with each other and operate as swarms. It then shows how to investigate and solve problems in large transport networks like finding quickest paths from the source to the destination, and then organize physical car driving using the path found. The Chapter investigates large information networks, showing how to find multiple simple paths between start and end nodes under certain conditions. It also provides solutions for finding articulation points, as the network splitting nodes, and maximum cliques, as the strongest fully interconnected network structures.

1.3.7 Chapter 8: SGL Against Other Languages

The Chapter provides a short review of other programming languages, including currently most popular and also oriented on parallel, distributed, and mobile computing, showing SGL advantages for obtaining very natural and compact solutions due to its inherently parallel self-navigation of distributed environments. It shows how clear and short is expression in SGL of the shortest path problem against well-known Dijkstra's Shortest Path Algorithm in C++. Other extremely compact SGL solutions are presented for different paths between network nodes, articulation points, and discovery of arbitrary graph structures in distributed networks. It then compares SGL with Battle Management Language (BML) and its geospatial variant GeoBML, coming to conclusion that SGL can provide higher flexibility, functionality, and delivery-distribution of resources for launching and management of complex national and international campaigns. It then discusses possible relation of SGL to natural languages, showing how it can describe structures of arbitrary large, hierarchical, and very complex natural language sentences using its recursive syntax – by just adding new rules to their SGL repertoire. The Chapter concludes that SGL with its compact and formula-like expression of problems and solutions at any levels can be used, even from the very beginning, instead of natural languages.

1.3.8 Chapter 9: Relation of SGL to Higher Psychological and Mental Concepts

The Chapter analyses relation of SGL and SGT to some psychological, mental, and philosophical concepts. It starts with possible relation of SGL to gestalt theory laws, showing how to organize gestalt-based distributed vision under SGT for the Law of Proximity, by initial space seeing from a single or many points in parallel. Also discusses relation of the found results to the Law of Good Gestalt, by evaluating compactness of the obtained images in each group as their gestalt quality. The Chapter also shows how to simulate the gestalt's Figure/Ground Expression by finding a spatial figure surrounded only by spatial ground, with collection of figure's border addresses. It then shows how to organize a distributed and global awareness under SGT for the dynamic swarm of chasing units. This includes examples as elementary swarming with only local awareness, deeply embedded into the swarm a higher level awareness, independent and migrating global awareness, and the outside activated eternal awareness. At the end it shows how SGL may relate to higher mental and philosophical concepts like perception, consciousness, and even soul. A discussion is mentioned in the United States in the 1990s on differences between the previous public domain SGL version called WAVE simulating a sort of soul and the Prof. Minsky's *Society of Mind* concept and book, actually pursuing traditional agents-based organization.

1.3.9 Chapter 10: Conclusions

The investigations of this book have confirmed potential applicability of the developed paradigm, language, and technology for solving much broader classes of problems, especially those related to large and unknown worlds. The solutions may involve massive manned or unmanned devices working cooperatively and autonomously. The approach can also be used for high-level formulation of key problems and their solutions instead of natural languages, due to clarity and compactness of the resulting descriptions.

1.3.10 Appendix: Full SGL Details

Contains full details of syntax, semantics, and pragmatics of SGL constructs. It describes the following: Full SGL syntax; SGL constants representing information, physical matter, special constants, custom constants, compound constants; SGL variables named as Global Variables, Heritable Variables, Frontal Variables, Nodal Variables, Environmental Variables; and SGL rules named as Type, Usage, Movement, Creation, Echoing, Verification, Assignment, Advancement, Branching, Transference, Exchange, Timing, Qualification, Grasping.

REFERENCES

1. Bondarenko, A.T., Mikhalevich, S.B., Nikitin, A.I., Sapaty, P.S., Software of BESM-6 computer for communication with peripheral computers via telephone channels, in *Computer Software*, Vol.5, Inst. of Cybernetics Press, Kiev, 1970 (in Russian).
2. Bondarenko, A.T., Karpus, V.P., Mikhalevich, S.B., Nikitin, A.I., Sapaty, P.S., Information-computing system ABONENT, *Tech. Report No. B178338, All-Union Scientific and Technical Inform.* Centre, Moscow, 1972 (in Russian).
3. Sapaty, P.S., A method of organization of an intercomputer dialogue in the radial computer systems, in *The Design of Software and Hardware for Automatic Control Systems*, Inst. of Cybernetics Press, Kiev, 1973 (in Russian).
4. Sapaty, P.S., The WAVE-0 language as a framework of navigational structures for knowledge bases using semantic networks. Proceedings of USSR Academy of Sciences, Technical Cybernetics, No. 5 (1986) (in Russian).
5. Sapaty, P.S., The wave approach to distributed processing of graphs and networks. Proceedings of International Working Conference Knowledge and Vision Processing Systems, Smolenice, November 1986.
6. Sapaty, S., A wave language for parallel processing of semantic networks. *Computing Artificial Intelligence*, 5(4), 289–314 (1986).
7. Sapaty, P.S., Varbanov, S., Dimitrova, M., Information systems based on the wave navigation techniques and their implementation on parallel computers. Proceedings of International Working Conference on Knowledge and Vision Processing Systems, Smolenice, November 1986.