Studies in Systems, Decision and Control

Volume 300

Series Editor

Janusz Kacprzyk, Systems Research Institute, Polish Academy of Sciences, Warsaw, Poland

The series "Studies in Systems, Decision and Control" (SSDC) covers both new developments and advances, as well as the state of the art, in the various areas of broadly perceived systems, decision making and control–quickly, up to date and with a high quality. The intent is to cover the theory, applications, and perspectives on the state of the art and future developments relevant to systems, decision making, control, complex processes and related areas, as embedded in the fields of engineering, computer science, physics, economics, social and life sciences, as well as the paradigms and methodologies behind them. The series contains monographs, textbooks, lecture notes and edited volumes in systems, decision making and control spanning the areas of Cyber-Physical Systems, Autonomous Systems, Sensor Networks, Control Systems, Energy Systems, Automotive Systems, Biological Systems, Vehicular Networking and Connected Vehicles, Aerospace Systems, Automation, Manufacturing, Smart Grids, Nonlinear Systems, Power Systems, Robotics, Social Systems, Economic Systems and other. Of particular value to both the contributors and the readership are the short publication timeframe and the world-wide distribution and exposure which enable both a wide and rapid dissemination of research output.

** Indexing: The books of this series are submitted to ISI, SCOPUS, DBLP, Ulrichs, MathSciNet, Current Mathematical Publications, Mathematical Reviews, Zentralblatt Math: MetaPress and Springerlink.

More information about this series at http://www.springer.com/series/13304

Mikhail V. Belov · Dmitry A. Novikov

Methodology of Complex Activity

Foundations of Understanding and Modelling

Springer

Mikhail V. Belov
IBS Company
Moscow, Russia

Dmitry A. Novikov
V.A. Trapeznikov Institute
of Control Sciences
Russian Academy of Sciences
Moscow, Russia

ISSN 2198-4182 ISSN 2198-4190 (electronic)
Studies in Systems, Decision and Control
ISBN 978-3-030-48609-9 ISBN 978-3-030-48610-5 (eBook)
https://doi.org/10.1007/978-3-030-48610-5

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Introduction

Rationale. There exist different types of human activity, from those of entrepreneurs developing high-tech businesses (Elon Musk, for example, 1a), engineers (George Stephenson, 1b), or government or public figures (Franklin Delano Roosevelt, 1c), to the activity of a gas station attendant (2a), an orange sorter (2b), or an assembly worker on the shop floor of an aircraft manufacturer (2c).

It is easy to see that some people's work activity is complex and diverse (1a-1c), whereas those of others are monotonous and routine (2a-2c). Yet the activity of the second group is also sometimes "complex": no one would claim that the worker who assembles the cockpit of a modern aircraft (2c) is not involved in "complex" activity. What they have in common is that they are all examples of human activity. But where do the differences lie? How do we formally determine the similarities and differences among different types of activity? One distinctive characteristic is the uncertainty of an activity—the uncertainty of external factors or the uncertainty of the goals, methods, and behavior of the actors involved. In 2a-2c, the activity is completely determinate, or seen to be completely determinate: the actors react to external uncertainties by referring the problem to a higher level actor and are responsible for carrying out activity within the prescribed procedures as directed from above, in contrast to 1a, 1b, or 1c, who react to uncertainty in the external environment and are not bound by predetermined goals and established procedures. Their reaction is to organize and to launch new activity, first and foremost to create new methods and procedures; they themselves are responsible for the final result of the activity, including the activity of subordinates. And why does the "indeterminism" of the activity of 1a-1c appear and what does it constitute? Again, it is easy to see that the activity of the former (1a-1c) is not always "equally complex." How do we delineate these differences in complexity in the activity of one and the same person? It is intuitively clear that not all elements of activity are "equally complex and uncertain." Moreover, implementing elements of activity with a high degree of

complexity and uncertainty requires significantly higher costs (managerial and material resources and time) than do routine (less complex and uncertain) elements.

And what about management and organization activity? Is it possible to define specifically and formally what activity is included here? For example, a CEO may simply delegate tasks: what, then, is being managed? Is delegating a complex activity? And how about when the same CEO signs a contract? No one else has the right to sign, but the signing is almost a formality—based on previous discussions and others having already given their approval.

Current methodologies (the science of organizing activity) do not yet provide answers to these and similar questions. This book proposes a tool to do so.

Methodology of complex activity. This book introduces the idea of "*complex activity*"[1] as activity (where *activity* means meaningful human work or actions [97, p. 4]) with a non-trivial internal structure and with multiple and/or changing actors, methods, and roles of the subject matter of activity in its relevant context. In view of the distinctiveness of complex activity, it is taken into consideration here along with the implementing entity (as a rule, a Sociotechnical System (STS) [144]).

Consequently, the authors call the theory developed in this book—in the form of a series of assertions and an integrated system of models that constitutes a school of thought about the organization of complex activity—the *Methodology of Complex Activity* (MCA). In other words, the subject matter of this study is Complex Activity (CA), and the research topic is the general principles underlying its organization and management. MCA builds on a *general methodology* [97] as tailored to complex activity.

The proposed theory provides a systematic basis for solving such problems as follows:

- planning a new complex activity;
- considering alternative solutions in such a plan;
- developing procedural documentation;
- CA modeling, first and foremost computer modeling;
- creating CA management systems in the form of descriptions of management processes, specifications, knowledge and data used in corresponding information technology systems (both software and hardware), and, of course, trained employees;

and many others.

The models that make up the developed theory are diverse and quite numerous, which reflects the natural complexity of CA as a system, so modeling a large number of concrete elements of a CA is rather time-consuming and requires a great

[1] *Key terms in the text are shown in italics. If a well-known definition is used, the corresponding source is indicated.*

amount of effort. However, the system of models is constructed in such a way that it does not require an obligatory description of the "entire" complex activity each time. Such a system allows one to abstract and focus on the elements of interest and to model exactly these elements in detail, leaving the rest of the abstract as "black boxes" without losing the expressive properties of the models and without worsening the quality of the presentation.

Novelty. Due to "universality," activity of the kind that is the thrust of this book touches, to some extent, upon many areas of knowledge. Accordingly, the methodology of complex activity is associated with many scientific disciplines and many intellectual traditions, so it makes sense to immediately clarify the novel elements of the proposed approaches.

In this book, first, unified means are proposed to formally describe and analyze any complex activity, along with the players involved "in the entire range from 1a-1c to 2a-2c."

Second, the role of uncertainty is analyzed. It is shown that the complexity of an activity comprises manifestations of uncertainty (uncertainty in goals, uncertainty in results, uncertainty in external conditions, etc.) and how to deal with it. Uncertainty comes to be through the onset of a priori unpredictable events, and the reaction to this may be a new activity that was not present before their onset.

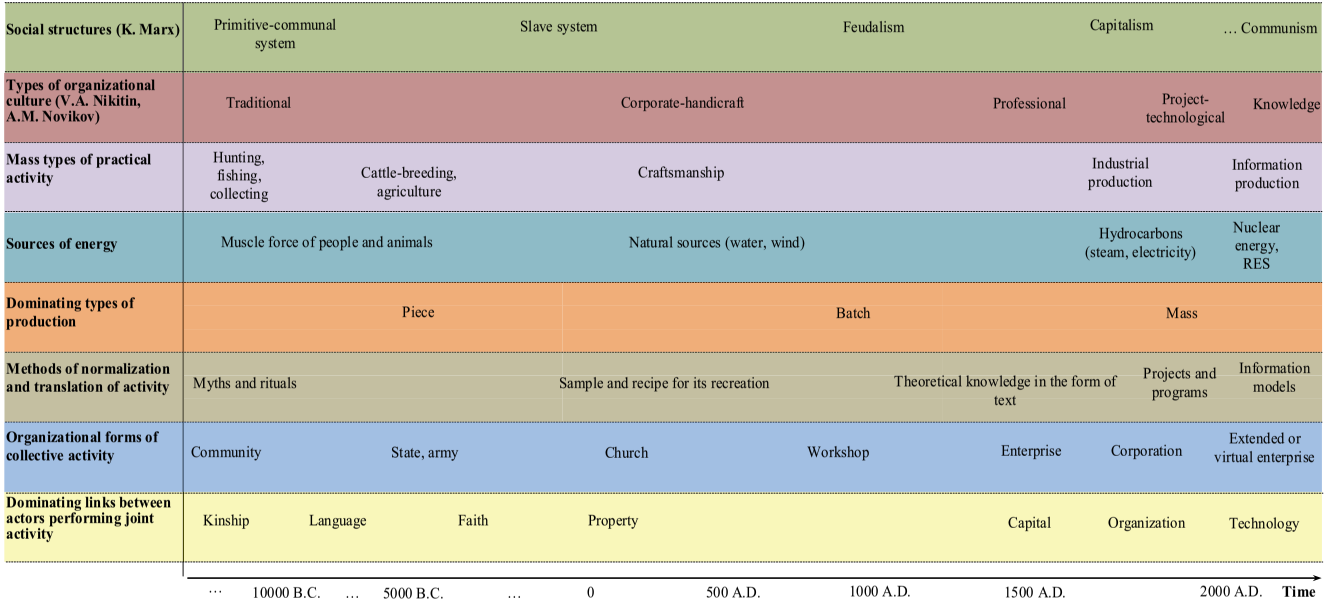
It is shown that complex activity, in spite of its intricacy, is basically "mechanistic"; it is "predetermined" a priori as determinate. In the overwhelming majority of examples of complex activity, uncertainty exerts an influence on them, but the reaction to uncertainty is formulated outside the activity: faced with a problem, the assembly worker at the aircraft manufacturing enterprise has no right to retool the work methods and procedures or to make changes. She is obliged to strictly comply with procedural norms and as a matter of course to refer problems to her superiors and then to the engineers. Thus, apparently "99%" of activity is "mechanistic," and the remaining "1%" is actually "complex"; it is shown below what this complexity is and how it is manifested.

Third, such activity as *management* and *organization* (as processes) is formalized and investigated. The components of organization—*analysis*, *synthesis*, and *concretization*—are ascertained and studied, as are the components of *management*: *organization*, *regulation*, and *evaluation*. It is shown that the focus of organization and management in relation to complex activity is the amalgamation (system of systems) of complex activity and the entity that implements it (the sociotechnical system).

Fourth, the role of *technology* in an activity is identified: activity connected with the development of technology is indeed "complicated," while all other activities, including organization and management, are routine! Management and organization become "complex" when, due to uncertainty, in the course of their implementation it is necessary to develop methods and tools (technology) for a new activity, because the existing ones are insufficient to adequately respond to uncertainty.

Back in History. The table below describes the organizational specifics of activity during different periods of human development, from the Stone Age to the present day. The main conclusions that can be drawn from such a periodization are as follows:

1. Starting from the appearance of man, human activity is characterized by multiple and changing goals and other attributes of the definition of CA. In other words, human activity has always been complex and MCA provides a uniform description for CA in all periods. Unlike other living creatures acting jointly (a swarm of bees, a colony of ants, a pack of wolves, etc.), man organizes all types of CA (labor, learning, play, creativity, communication), i.e., performs structuring of the subject matter, in accordance with the goals of CA not instinctively but consciously, as a form of management. The second distinctive feature of human CA is the use of artificial means of activity.
2. Besides the monotonously growing complexity of CA (the depth and width of its hierarchical logical structure), technologies have been the only evolving factor of CA. But even for technologies, it is difficult to identify certain "historically specific" forms and methods of activity. The means of activity have been evolving! That is, in the course of human development, the means of CA and methods for performing "industry-specific" elementary operations (industry-specific technologies) have been created and further developed. At the system-wide level of generalization, the technology of CA has been remaining invariant: the target (logical) structure and the cause-effect structure, as well as the process model of CA as a universal algorithm for managing and/or implementing the life cycle of CA.


Social structures (K. Marx)
Primitive-communal system
Slave system
Feudalism
Capitalism
… Communism
Types of organizational culture (V.A. Nikitin, A.M. Novikov)
Traditional
Corporate-handicraft
Professional
Project-technological
Knowledge
Mass types of practical activity
Hunting, fishing, collecting
Cattle-breeding, agriculture
Craftsmanship
Industrial production
Information production
Sources of energy
Muscle force of people and animals
Natural sources (water, wind)
Hydrocarbons (steam, electricity)
Nuclear energy, RES
Dominating types of production
Piece
Batch
Mass
Methods of normalization and translation of activity
Myths and rituals
Sample and recipe for its recreation
Theoretical knowledge in the form of text
Projects and programs
Information models
Organizational forms of collective activity
Community
State, army
Church
Workshop
Enterprise
Corporation
Extended or virtual enterprise
Dominating links between actors performing joint activity
Kinship
Language
Faith
Property
Capital
Organization
Technology
…
10000 B.C.
…
5000 B.C.
…
0
500 A.D.
1000 A.D.
1500 A.D.
2000 A.D.
Time

3. The maximum complexity of the projects implemented in different historical periods (which can be described, e.g., by the spatial dimensions of objects created and the number of their "elements," the duration of projects and the number of their participants) has been demonstrating a moderate growth over time.
4. The gradually accelerating development of technologies has led to the mass creation of more and more complex artificial systems, which allows achieving results with fewer resources (time, energy, etc.). In fact, "the set of achievable results" over the entire history of mankind has not changed much (a few exceptions are hydronautics, astronautics, etc.).

Thus, the typical architecture of CA put forward by MCA is universal for any types of activity, throughout the entire past history of mankind. Hence, it can be hypothesized that such universality will hold in the future (at least, until the set of subject matters of activity that is accessible to mankind changes).

Main Results. The results obtained are formulated as a unified theory that provides a description and examination of complex activity, organization, and its management (as processes). The theory consists of a series of assertions and an integrated set of common models. Based on a fundamental understanding of the methodology [97, 98, 99], practical observations of how complex activity is implemented, and logical approaches, a number of conclusions reflecting the logic of the development of the theory and the components that make it up are subsequently formulated. The model system plays the role of a *framework* constituting a tool for solving practical and theoretical management challenges. This system of models allows modeling the "system of interest" and describing in an aggregated way the external environment for it with the necessary detail.

This allows not only structuring complex activity, but also reasonably breaking down the elements of an activity by the degree of complexity and uncertainty, singling out the most critical ones, respectively, in practice—allocating resources and managerial and organizational efforts. By the same token, such capabilities of the proposed system of models provide an opportunity for optimization, i.e., solving management problems in relation to CAs—a synthesis of effective processes of organization and management of complex activity and its players—via complex systems.

Structure of the Presentation. Chapter 1 is devoted to laying out the task of developing a methodology of complex activity. The relevance of the issue is analyzed, a general logical research plan is outlined, and the research topic is defined: complex activity as the primary one and the sociotechnical system as a secondary research topic.

In Chap. 2, definitions of elementary and complex activity are introduced and the defining features of CA are analyzed. The requirements for a methodology of complex activity are laid out, and a comparative analysis of the related branches of knowledge on the question of satisfying the requirements for MCA is carried out, that is, the necessity of developing MCA as a new theory is substantiated.

In Chap. 3, an analysis of the structural features of CAs is performed, and a unified formalism is proposed for describing the *Structural Element of Activity* (SEA) as an integrated subject, which describes the elements of CA and defines the rules for operating SEAs. The logical and cause-and-effect structures of CA are introduced as a set of links between SEAs.

Chapter 4 is devoted to questions on the origin of various kinds of activity; it introduces the classification of CAs and SEAs, and a generic model is proposed for the realization of activity (behavior of SEAs and CAs as a whole).

Process models of complex activity, its execution, and the fulfillment of the life cycles of its various elements are given in Chap. 5.

Chapter 6 introduces the metrics of complex activity: indicators and criteria for its effectiveness and performance. The system-wide factors on which the effectiveness and performance of CAs depend are discussed.

Chapter 7 is devoted to such types of CAs as organization and management, including CA optimization questions.

The appendices comprise the following: main abbreviations (Appendix 1), main definitions (Appendix 2), main assertions (Appendix 3), and results of analyses of the interrelationship between MCA and its requirements (Appendix 4). The assertions in the text are featured in light gray boxes, with a line separating the title in bold type from the description.

Several typical examples of CA are used to illustrate the implementation of common approaches throughout the text, referring to spheres of human activity that differ significantly from each other: the functioning of work groups, organizational units, projects, and organizations in general:

- a retail bank,
- an aircraft manufacturer,
- a fire department, and
- a nuclear power plant.

We would like to suggest several options for becoming familiar with this book. The first—and the most superficial—is to read the Introduction, Sect. 1.1, the conclusions in Chaps. 1–7, Sects. 7.1 and 7.2, and the Conclusion. A more detailed level of understanding will require additional familiarization with the material of Chaps. 2–5. Finally, for a complete picture, it is best to read the entire book in order.

The authors are grateful to V. N. Burkov, A. A. Voronin, A. O. Kalashnikov, G. N. Kalyanov, V. V. Kondratiev, N. A. Korgin, R. M. Nizhegorodtsev, V. V. Novochadov, A. N. Raikov, S. A. Saltykov, A. G. Teslinov, and G. L. Tsipes for their discussions, criticism, and valuable comments.[2]

[2] *The authors are also grateful to the Russian Science Foundation (grant no. 16-19-10609) for partially supporting this research.*

Contents