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Models of Technologies

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Introduction

Without any doubt, the history of mankind development can be called the history of technological progress. Really, technologies are demanded by economy and society; have accelerated growth; are the systemically important (backbone) elements of any production; and finally, maintain the existence and further development of mankind [1–3]. All of these factors determine the conceptual meaning of the above statement. In addition, it seems somewhat populistic: fashionable expressions like "technological revolution," "converging technologies," "neural technologies," "digital technologies," etc. are alternating each other rapidly, causing a gracious smile of professionals and a muddle of men in the street.

In accordance with the definition of the Merriam-Webster Dictionary, technology[1] is (1a) the practical application of knowledge especially in a particular area; (1b): a capability given by the practical application of knowledge; (2) a manner of accomplishing a task especially using technical processes, methods, or knowledge; and (3) the specialized aspects of a particular field of endeavor. This term originates from Greek *technologia* (technē art, skill + -o- + -logia –logy), meaning "systematic treatment of an art."

In [1, 4], a *technology* was defined as a system of conditions, criteria, forms, methods, and means for achieving the desired goal. The models of technology design, adoption, and use described below will rest on this definition.

The models of technologies can be classified in the following general way, in the descending order of their scale:

(1) "*civilization models*," which reflect the general "macro" laws of technology design and interaction with society over characteristic periods of century or decades (technological structures, Kondratiev cycles, etc. [5–7]);
(2) "*innovations models*," which study the general laws of innovations initiation, implementation and deployment/diffusion at the micro-level, including the scale of economic sectors and organizations [8] (innovation is a new technology);

[1]The term "technology" was introduced in 1772 by German scientist Johann Beckmann to mean the science of trade.

(3) "*activity models*," which study the general organization laws of any activity, including those of the design and use of different activity technologies [1];
(4) "*models–standards*," which are being intensively developed in Systems Engineering and contain the well-systematized extensions of best practices from practical or industrial activity [9, 10].
(5) "*subject-matter models*," which describe specific technologies in different sectors.

This book[2] is focused on the third (activity-related) level of the classification and further develops the original results of the authors presented in [1, 11–13]; also see Chap. 1. A systematic overview of the first two classes of the models seems unreasonable due to their extreme richness and fast evolution; moreover, it would be beyond the scope of this research. The fourth class of the models is fixed, while the fifth one consists of concrete (and specific) elements, and hence, they should not be overviewed too.

Technologies may have different translation forms such as flowcharts and process regulations in industrial production, construction documents in building, network diagrams in project management, and business processes descriptions in the activity of organizations. The general form is an *information model* that describes the actor's states and also the actions (together with the corresponding methods and means) to transform it. Much attention below will be therefore paid to the information models of technologies. At the same time, the computerized design and management tools for the information models of products and technologies known as Continuous Acquisition and Lifecycle Support (CALS) systems—Computer Aided Design, Manufacturing and Engineering (CAD, CAM, CAE) systems and Product Data Management (PDM) systems—will be not considered in this book because they are merely a particular (albeit modern) case of technology translation means.

On the one hand, the design of each technology includes the *general-system* and also *specific* components. We will adopt the general-system approaches only, which neglect any sectoral specifics. On the other hand, the design of each technology includes routine and also *creative* components. This book does not pretend to model creation.

From a mathematical viewpoint, technology is an *algorithm* that describes a multivariant scenario of activity in which multiplicity is caused by external and internal conditions. However, the automatic design and optimization problems of nontrivial algorithms with given properties[3] either cannot be solved in general form or have a very high computational intensiveness. As a result, technology is often designed using its *decomposition* into interconnected simple parts or some *heuristics*.

[2]The research was partially supported by the Russian Scientific Foundation, project no. 16-19-10609.

[3]As a rule, the results obtained within the framework of mathematical logic and automata theory are very concrete and can be included in the fifth class of the models (somewhat conventionally).

A technology can be interpreted as a *mapping* of the set of *situations* (current states and, perhaps, the history of system, requirements to result, constraints, etc.) into the set of *actions* and utilized *resources*. In other words, "what, how, and by which means" should be done in a certain situation. As a matter of fact, technology design and adoption consist in proper search and operation of these mappings; see Chap. 2 for details.

A technology is often represented as a *graph*—a finite set of states and transitions between them (perhaps, the latter functionally depend on available resources).

For a technology defined by a *function*, optimization problems can be formulated as follows: Find an optimal value of an efficiency criterion subject to given constraints and properties of the "controlled" system.[4] Such optimization problems will be studied in Chap. 3.

Control mechanisms (the sets of rules and procedures—"mappings") can be treated as a "technology" of managerial decision-making: They describe the desired behavior of a controlled element (agent) and the corresponding decisions of a control element (principal) in different situations. Technologies need to be *optimized*, in many cases using exhaustive and heuristic search methods. The design and adoption of technologies often involve so-called *typical solutions*. Thus, the corresponding analytical complexity and errors have to be analyzed; see Chap. 4 below.

This book is organized[5] as follows. The technology of complex activity and its general models are considered in Chap. 1. The models of technology design and adoption are introduced in Chap. 2. The models of technology management are presented in Chap. 3. Finally, the analytical complexity and errors in solving technology design/optimization problems are estimated in Chap. 4.

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[4]In accordance with this approach, optimal positional control design is the design and further optimization of control technology.

[5]Chapters consist of sections. Formulas are numbered independently within each chapter, while the figures, tables, examples, and propositions continuously throughout the book.

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