

Chapter 2

Some Theoretical Background

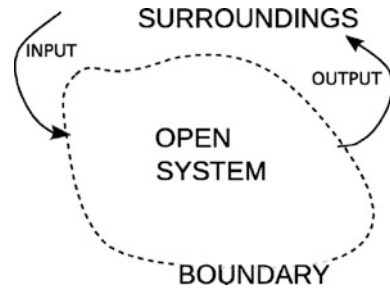
2.1 Introduction

The Chapter contains some theoretical background of the approach presented in the book including *General Systems Theory* inspired by biology and introducing open systems concept, *System Dynamics* with computer-simulated multi-loop network flow models, *Gestalt Psychology* with the phenomenon of grasping the whole first while treating parts in the context of the whole rather than vice versa, *Memetics* as an analogue to genetics but in social and information areas, and *Brain Waves and Consciousness* investigated on biological and psychological levels. Also analyzed are currently dominant *Interoperability* principles in organization of large civil and military systems, revealing their insufficiency and confirming necessity of introduction of higher-order organizational levels. The latter, symbolically called *Overoperability*, should orient on holistic, integral and global-goal-driven system organizations and applications which could withstand challenges emerging in large distributed dynamic systems.

2.2 General Systems Theory

This theory after Ludwig von Bertalanffy [1–6] is based on similar general conceptions and viewpoints which have emerged and evolved in various disciplines. In the past, science tried to explain observable phenomena by reducing them to communication and interplay of elementary units which are independent from each other. New approaches are based on what is termed “wholeness” where systems of various orders cannot be understood, even in principle, by investigation of their parts in isolation. Conceptions of this nature have appeared in all branches of science, regardless of which types of objects are being studied (i.e. inanimate things, living organisms, social phenomena, etc.).

Fig. 2.1 Open systems concept



General Systems Theory (GST) is an interdisciplinary field of science and the study of the nature of complex systems, a framework within which any group of objects that work together in concert can be analyzed and described. The theory attempted to provide alternatives to conventional models of organization, with applications to numerous areas of study, emphasizing *holism* over reductionism, *organism* over mechanism. There are many instances where identical principles were discovered in different fields, and these principles can be analyzed and classified regardless of the origin and nature of the systems.

One of central themes of Bertalanffy's work is discovery and analysis of *non-linear relationships* between system variables, where a small change in one variable may cause a significant change in another one. Another important contribution of GST is the theory of *open systems* (see Fig. 2.1) which, existing within certain boundaries, have input and output flows representing exchanges of matter, energy or information with their surroundings.

The open systems concept appeared to be particularly relevant to *living organisms*. Bertalanffy maintained that the conventional formulation of physics is, in principle, inapplicable to the living organisms, which keep themselves in a continuous inflow and outflow with the surroundings, also in building up and breaking down of components. They do not exist, so long as alive, in a state of chemical and thermodynamic equilibrium but maintain so-called *steady state* which is distinct from the latter.

In *social sciences*, Bertalanffy believed that general systems concepts were applicable too, criticizing classical atomistic conceptions of social systems. The GST encouraged for new developments from sociology, to anthropology, economics, political science, and psychology among other areas.

The holistic tune dominates the whole theory stating that the "progress is only possible by passing from a state of undifferentiated wholeness to differentiation of parts". Bertalanffy considered the entire world (symbolically in Fig. 2.2) as an *organization*, with biosphere as a whole, and this vision can drastically change traditional categories, our kind of thinking, also influence practical activity in different areas of life.

Fig. 2.2 The whole world as an organization



2.3 System Dynamics

Fundamental works have been carried out by Jay Forrester on analysis of complex systems (urban, industrial, world as a whole) and their detailed computer simulation [7–10]. It has become clear that complex systems are *counterintuitive*, where corrective actions are often ineffective or even adverse in the results. In complex systems the cause and the effect are often not closely related in either time or space, and their structure is not a simple feedback loop.

In reality, complex system has a *multiplicity of interacting feedback loops*, and its internal rates of flow are controlled by *nonlinear relationships*. Complex systems are usually of high order, with many system states or levels. They may contain positive feedback loops reflecting growth, and negative, goal seeking ones. In the complex system the cause may lie far back and away from symptoms, and the causes are usually found not in prior events but rather in the *structure and policies* of the system.

Figure 2.3 shows the simplest possible feedback system using just two symbols: a stock, and a flow.

The stock may be considered as an accumulation, integration or level, depending on the terminology from different fields, and the flow changes the amount in the stock. The flow is determined by a statement that tells how the flow is controlled by the value of the stock in comparison to a goal. All systems and everywhere consist of these two kinds of concepts, stocks and flows.

Another, a bit more complex, model introducing a second order loop is depicted in Fig. 2.4.

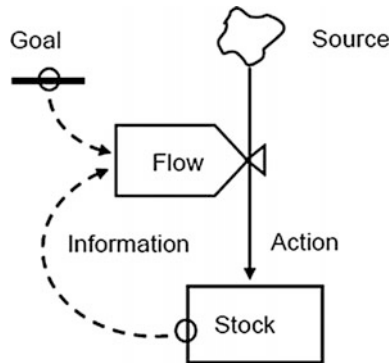


Fig. 2.3 Simplest feedback system

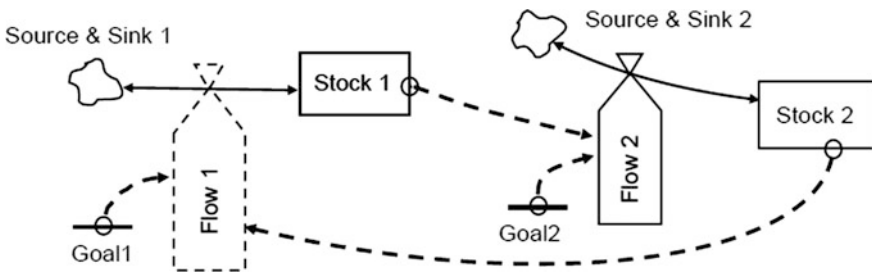


Fig. 2.4 Feedback system with second order loop

More complex network flow models (with hundreds of nodes and thousands of links in between) incorporated interrelations between such features as population, capital investment, natural resources, pollution, and agriculture at different system levels, etc. These levels took into account changes in the rates of flow in and out, such as birth and death rates which were causing the increase and decrease of population.

The detailed definition of the model states how each rate of flow is assumed to depend on the levels of population, natural resources, capital investment, capital devoted to agriculture, pollution, and so on. These models incorporated many nonlinear relationships.

The basic components of the network flow models with brief explanation of their meanings are shown in Fig. 2.5.

Using the system dynamics model, a computer simulation can show how a system, as described for each of its parts and links in between, would behave. Given a set of starting conditions, the simulation can calculate and plot the results that unfold through time.

The great uncertainty with mental models arises from their inability to anticipate the consequences of interactions between parts of a system, which may be in great

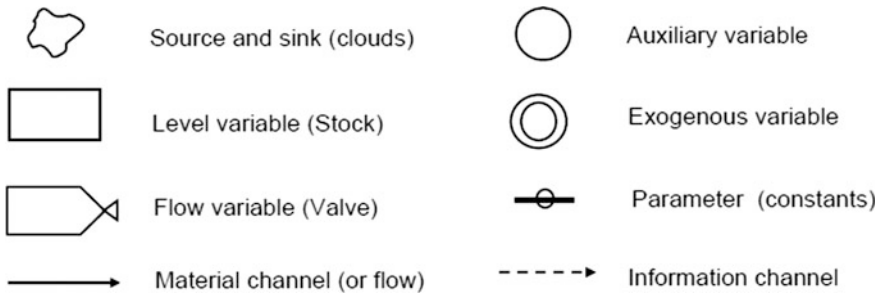


Fig. 2.5 Basic elements of network flow models

numbers and complex relationships. This uncertainty may be *totally eliminated* in computer simulation models. Forrester showed that the proper simulation is becoming a powerful procedure for clarifying many issues in large dynamic systems which are often counterintuitive for the human mind.

2.4 Gestalt Psychology

Gestalt is both philosophy and psychology term which means *unified whole* [11–14]. It refers to visual perception theories developed by German psychologists at the beginning of the past century. These theories tried to understand and describe how people can organize visual elements into groups or unified wholes under certain conditions and principles, maintaining our meaningful perceptions in an apparently chaotic world.

For the gestaltists, “Gestalten” are not the sums of aggregated contents erected subjectively upon primarily given pieces. Instead, we are dealing with wholes and whole–processes possessed of inner intrinsic laws. Elements are determined as parts by the intrinsic conditions of their wholes and are to be understood as parts relative to such wholes.

Gestalt psychology was founded by German thinkers Max Wertheimer, Wolfgang Kohler and Kurt Koffka and focused on how people interpret the world. According to Gestalt psychology, *the whole is different from the sum of its parts*. Based upon this belief, Gestalt psychologists developed a set of principles to explain perceptual organization, or how smaller objects are grouped to form larger ones. These principles are often referred to as the “laws of perceptual organization.”

The school of gestalt practiced a series of theoretical and methodological principles that attempted to redefine the existing approach to psychological research. This was in contrast to investigations developed at the beginning of the 20th century, based on traditional scientific methodology, which divided the object of study into a set of elements that could be analyzed separately with the objective of reducing the complexity of this object.



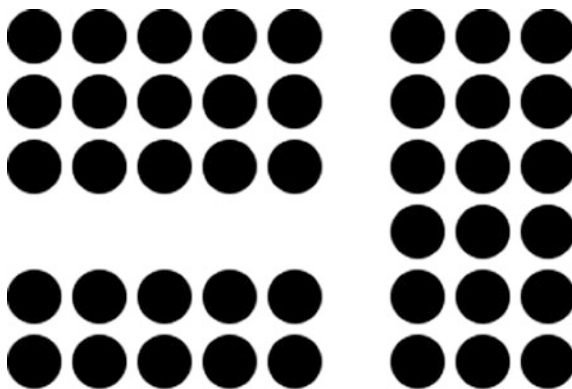
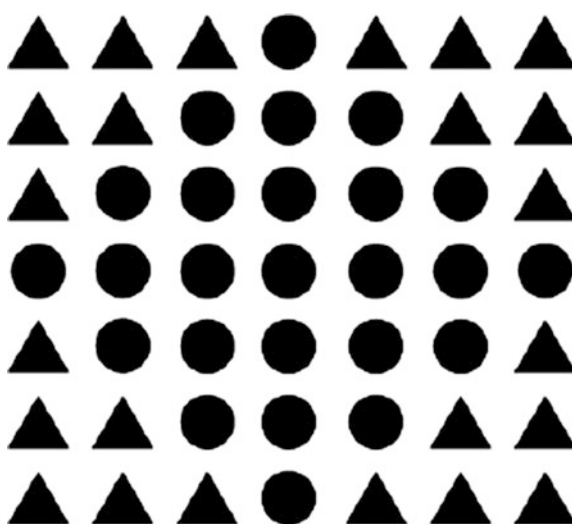
Fig. 2.6 Perceiving partial images as a whole

The word “Gestalt” is usually translated as form, although it might be better understood as *organized structure*, as opposed to heap, aggregate, or simple summation. A traditional perception example is shown in Fig. 2.6 depicting a Dalmatian dog sniffing the ground in the shade of overhanging trees.

The dog is not recognized by first identifying parts (like feet, ears, nose, tail, etc.) and then inferring the dog from those component parts. Instead, the dog is *perceived as a whole*, all at once.

By Gestalt psychology, the mind understands external stimuli as a whole rather than the sum of their parts. The wholes are structured and organized using grouping laws, which are called *laws* or *principles*. The most important laws with their names, meanings and simple explaining graphics are briefed below. (These laws deal with the sensory modality of vision but there are also analogous laws for other modalities including auditory, tactile, gustatory and olfactory.)

- **Law of Proximity** (Fig. 2.7) states that when individuals perceive an assortment of objects, they often first perceive objects that are close to each other as forming a group. According to the law of proximity, things that are near each other seem to be grouped together.
- **Law of Similarity** (Fig. 2.8) states that elements within an assortment of objects are perceptually grouped together if they are similar to each other. This similarity can occur in the form of shape, color, shading or other qualities.
- **Law of Closure** (Fig. 2.9) states that individuals perceive objects such as shapes, letters, pictures, etc., as being whole when they are not complete. Specifically, when parts of a whole picture are missing, our perception fills in the visual gap.
- **Law of Symmetry** (Fig. 2.10) states that the mind perceives objects as being symmetrical and forming around a center point. It is perceptually pleasing to

Fig. 2.7 Proximity example**Fig. 2.8** Similarity example**Fig. 2.9** Closure example

divide objects into an even number of symmetrical parts, and when two symmetrical elements are unconnected the mind perceptually connects them to form a coherent shape.



Fig. 2.10 Symmetry example

- **Law of Common Fate** (Fig. 2.11) states that objects are perceived as lines that move along the smoothest path. Experiments using the visual sensory modality found that movement of elements of an object produce paths that individuals perceive that the objects are on.
- **Law of Continuity** (Fig. 2.12) states that elements of objects tend to be grouped together and integrated into perceptual wholes if they are aligned within an object. In cases where there is an intersection between objects, individuals tend to perceive the two objects as two single uninterrupted entities.
- **Law of Good Gestalt** (Fig. 2.13) explains that elements of objects tend to be perceptually grouped together if they form a pattern that is regular, simple, and orderly. This law implies that as individuals perceive the world, they eliminate complexity and unfamiliarity so they can observe a reality in its most simplistic form.

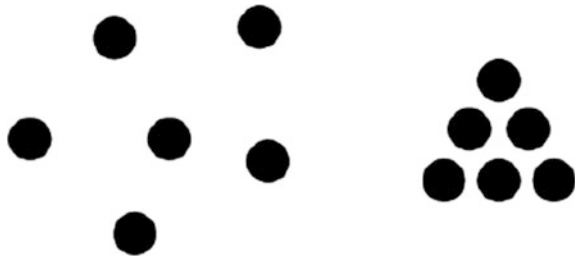


Fig. 2.11 Common fate example



Fig. 2.12 Continuity example

Fig. 2.13 Good gestalt example



- **Law of Past Experience** (Fig. 2.14) implies that under some circumstances visual stimuli are categorized according to past experience. If two objects tend to be observed within close proximity, or small temporal intervals, the objects are more likely to be perceived together.
- **Figure/Ground** (Fig. 2.15) refers to the relationship between positive elements and negative space. The idea is that the eye will separate whole figures from their background in order to understand what's being seen. It's one of the first things people will do when looking at any composition.

Although Gestalt psychology and theory was a very general approach with great potentials, most of the work on gestalt has been carried out in the area of perception (the laws and examples mentioned above just confirming this).

In our true belief, the theory and practice of gestalt can be effectively used in much broader sense and scale too, and especially for holistic global vision,

Fig. 2.14 Past experience example

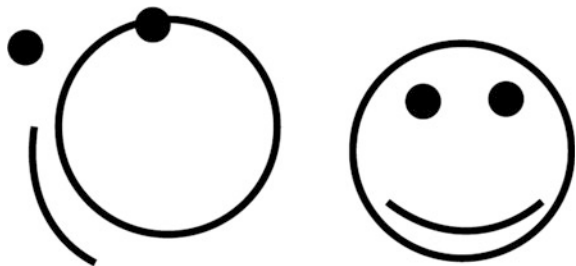


Fig. 2.15 Figure/ground example



comprehension and proper management of large distributed dynamic systems of most different natures, which is so important nowadays and which is the main theme of this book. Establishment of broader and more universal gestalt laws oriented on complex situations in large dynamic systems with proper technological support would be particularly important too.

2.5 Memetics Versus Genetics

Memetics [15–17] is the theory of mental content based on an analogy with Darwinian evolution. Being an emerging subfield of psychology, memetics is considered as an approach to evolutionary models of cultural information transfer. The *meme*, analogous to a *gene*, was conceived as a “unit of culture” (like idea, belief, pattern of behaviour, etc.) which is “hosted” in the minds of one or more individuals, and which can reproduce itself, jumping from mind to mind (as symbolically shown in Fig. 2.16).

Memes consist of information which persists, propagates, and influences human behaviour; they have an independent existence, self-replicate, and are subject to selective evolution through environmental forces. They spread through the social body similar to how genes spread through the biological body, forming the invisible DNA of human society. And like a virus moves from body to body, memes move from mind to mind.

Potentially, memetics can be effectively used to identify and target specific root causes of challenging social problems in different areas. It may also be useful for understanding the origin and evolution of modern humans, and to provide insight into science, industry, and technology.

Critics of memetics, however, contend that some of its assertions are still untested, unsupported or incorrect, even considering it as pseudoscientific dogma and threat to the study of consciousness and cultural evolution. Some also say that culture cannot be best understood by examining its smallest parts like memes, but rather is pattern-like, comparable to an ocean current.

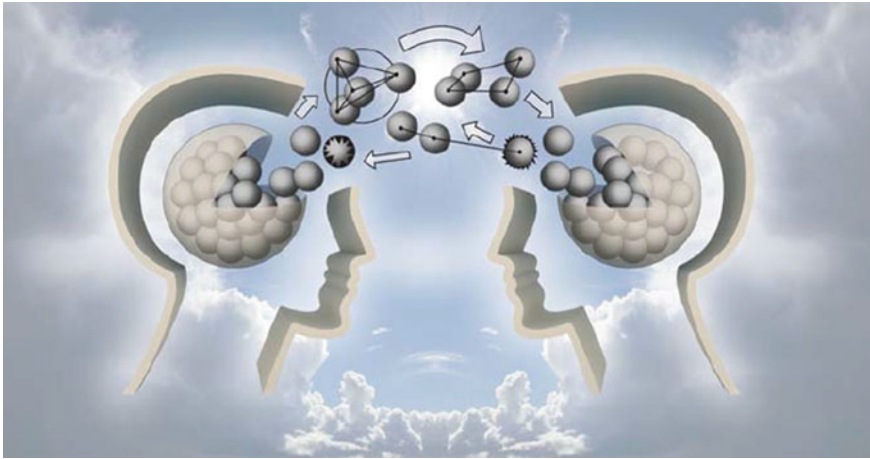


Fig. 2.16 Symbolic memes exchange

2.6 Brain Waves and Consciousness

Many things and activities in the world and universe are existing and proceeding, also considered as such, in the form of waves from, say, electromagnetic, radiation, gravitation, heat, sound, seismic and ocean waves to the waves of economic development [18], spiritual waves [19], democracy's waves [20], waves in linguistics [21], social waves [22], crime waves [23], immigrant waves [24] and many others like, for example, brain waves [25–27]—the latter to be discussed below in some details.

The human brain is a complex entity which is constantly at work, sending electrical signals, communicating, building new neural connections and so on. This electrical activity generated by the brain, also known as *brainwaves*, reflects our state of mind (as symbolically in Fig. 2.17). If we deepen our understanding of these brainwave frequencies, we can control our reality.

There are different kinds of brainwaves occurring at a specific frequency or pattern. Each brainwave has its own set of characteristics representing a unique state of consciousness. The different brain waves and the resultant states are usually classified as follows.

- **Beta** (12–30 Hz) are the brainwaves of our *normal waking consciousness*. It is associated with a heightened state of alertness, logical thinking, problem-solving ability, concentration, when the mind is actively engaged in mental activities. Most people spend their waking lives in a beta state.
- **Alpha** (8–12 Hz) brainwaves are slower in frequency as compared to Beta, which translates to a *highly relaxed state of awareness*. It is a normal brainwave pattern in people who are naturally relaxed and creative. Children tend to have much higher levels of alpha brainwaves than adults.



Fig. 2.17 Brain waves

- **Theta** (4–7 Hz) brainwaves occur during *deep relaxation and meditation*, light sleep or lucid dreaming. It is the realm of your sub-consciousness, where the mind is capable of profound insight, advanced intuition, and healing. Most children and teenagers have dominant theta brainwave patterns.
- **Delta** (0.5–4 Hz) waves are the slowest in frequency but are the highest in amplitude. Observed in *deep, dreamless sleep*, this frequency is the gateway to the universal mind and the collective unconscious, where information received is otherwise unavailable at the conscious level. It is a dominant brainwave of infants and even adults in deep sleep.
- **Gamma** (25–100 Hz) brainwave is the fastest frequency at which the brain functions, where an individual can experience *bursts of insight or high-level information processing*. It is the state of feeling that you can do anything.

People can alter their brainwave pattern in order to reach a desired level of consciousness. For example, if you can't get sleep at night when you feel stressed, you can synchronize your brainwave into the frequency that corresponds to sleep using sound. During meditation you reach a calm and relaxed state, corresponding to the alpha state of consciousness.

The concept of waves is also used in a study of higher levels of mental activity like, for example, *integral psychology* [28, 29], which is determined to embrace and unite all aspects of human consciousness under one concept, integrating ideas and models of consciousness, psychology, and therapy. The resultant psychological model includes *waves of development*, *streams of development*, *states of consciousness*, and the *self*. Under existing general consensus, neither mind nor brain can be reduced without each other, which means that both mind and brain need to be included in a *non-reductionistic way* in any integral theory of consciousness.

The idea of brainwaves on both biological and psychological levels can be exploited in a much broader sense and scale, covering such conceptions as self-awareness, self-analysis, self-organization, self-control, self-recovery, and many others. If supported by proper information technologies, it can also be effective for integral, holistic management of complex systems, not only localized but arbitrarily distributed in virtual and physical spaces too, converting them into a sort of holistic brain having a sort of spatial consciousness and pursuing global goals. These ideas and thoughts will be influencing the remaining material of the current book.

2.7 Interoperability Organizations and Their Weakness

Another system concept, widely used at present for organization and management of large distributed systems, especially military and international, is called *interoperability* [30–33], as a quality of a system with understood and clear interfaces to work with other systems without restrictions.

There may be different kinds of interoperability. *Syntactic interoperability* means that two or more systems are just capable to communicate with each other. *Semantic interoperability* supposes that beyond the ability to exchange information, different systems are capable of interpreting the exchanged information. *Cross-domain interoperability* occurs when different kinds of entities (which may be multiple social, organizational, political, legal, etc.) can work together for a common purpose.

Interoperability is currently the key principle for joint operations in both civil (Fig. 2.18) and military (Fig. 2.19) areas.

For example, NATO has been based on interoperability since 1949 when it was founded. Interoperability allows organisations of different nationalities and armed services to conduct joint peacekeeping operations. Interoperability is also dominant in any international relief missions acting after natural or manmade disasters.

Over the last several decades, the military has greatly benefited from the increased knowledge and capabilities provided by using computerized command and control systems. As this use has expanded exponentially, so has the need to integrate these systems. The breadth of computing technology at the component, functional, and mission level has complicated the issue of interoperability. By their nature, these disparate systems have varying levels of fidelity, granularity, quality and availability. The cost of establishing collaboration between these systems is typically high, and is complicated by differing organizational readiness levels, willingness, and technical ability to affect collaboration.

The need for translation of information and data to forms that are readable and interpretable by every unit has continuously challenged users of computer systems. Over time, the technologies employed to accomplish interoperability have evolved. Initially, and still prevalent today, one-to-one interfaces explicitly define how two systems interact. This type of approach works but does not scale. Other approaches,



Fig. 2.18 Interoperability in a civil area

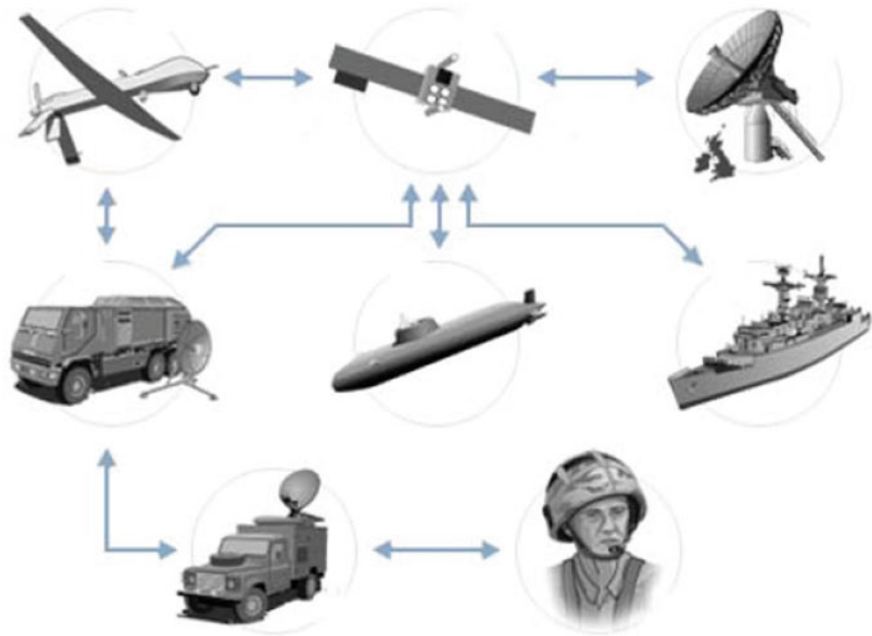


Fig. 2.19 Military interoperability

such as shared databases, common data repositories, and defined common standard messaging and interface formats, present solutions to some interoperability issues but are not panaceas. Each approach is appropriate in given circumstances only. Attempts to provide a single solution for all scenarios typically fall short due to technical challenges, adoption resistance, and funding availability.

Taking also into account the increased complexity of joint operations due to the growing world dynamics and emerging instability makes existing interoperability principles not sufficient to provide the needed overall awareness, integrity, and pursuit of global goals with runtime adjustment to new ones. The situations are often complicated by the necessity to operate in cyber-contested multi-dimensional spaces with high connectivity and inter-dependence, also with numerous actors having own, often quite different purposes and interconnections.

We are often witnessing failures of the currently dominant interoperability-based approaches and systems at national and international levels, especially where seemingly honest and noble intentions and actions of different players to improve complex situations in certain places on the globe lead to quite unexpected and even dangerous results. This mainly occurs by incapability of grasping the current and future whole of the problem properly, which is aggravated by the lack of appropriate scientific research, advanced system models and supporting technologies for its expression and management.

2.8 Over-Operability Versus Interoperability in System Organization

The current dominant interoperability organizations continue exercising *atomistic*, parts-to-whole philosophy of the system comprehension and implementation, criticized and rejected by holistic and gestalt approaches even a century ago. Interoperability is also very close to the atomistic vision of how human mind functions, like a “society of mind” [34], which proved its fundamental weakness and even incorrectness.

Let us briefly outline a possible alternative way to the design, formalization, implementation, and management of large distributed systems, which may help us overcome the weaknesses of interoperability organizations. Calling this *over-operability* [35, 36], also being gestalt-based [37, 38], the following ideas are the result of thorough investigation of how integral distributed systems should be planned, designed, and managed, also decades of practical experience in the field.

The usual sequence of design and implementation steps of large distributed systems may look like what is shown in Fig. 2.20.

Originally, the system idea and its expected functionality and capability emerge in a very general, holistic, indivisible and non-verbal form in a single human mind or close collective of such minds.

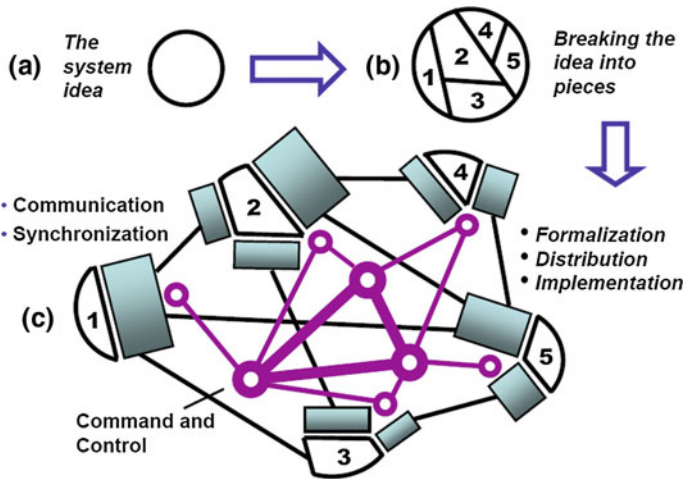


Fig. 2.20 Traditional steps in system design and implementation

Then this initial and “shapeless” idea, symbolically shown Fig. 2.20a just as a circle, is tried to be partitioned into individual chunks (shapeless too, but representing certain potential functionalities, still inseparable from the whole and from each other and having no individual meaning), each trying to be understood, detailed, redefined, and mentally studied further under the context of the whole, Fig. 2.20b.

This logical partitioning inevitably causes “swelling” of the problem’s complexity, because each chunk needs autonomous definition, discussion, and investigation of its potential relations with the other chunks, which were not present and even imagined at the initial stage of Fig. 2.20a.

The next step is materialization of the defined parts and their relations with each other, using existing formal models, programming and simulation languages and technologies, as well as methods and capabilities of distribution in physical and virtual spaces. To make these parts working together as the whole system and believably within the original idea of Fig. 2.20a, we may need a good deal of their communication (with both physical matter and information) and synchronization, also a sophisticated command and control infrastructure generally distributed rather than concentrated (which may need introduction of additional physical and virtual entities or “chunks” too), as depicted in Fig. 2.20c.

The overhead with such distribution, communication, synchronization and control may be essential, even in some sense outweighing the original (considered “useful” and “pure”) project functionality and complexity of Fig. 2.20a. But this overhead may need to be tolerated in any way, as parts of the distributed system may have to be located in particular physical and virtual points in order to serve local dynamic data there and other systems directly associated with these locations.

As can be seen, the real system formalization, description, and implementation (using existing philosophies, models, languages and technologies) can start only from the already developed distributed, interlinked, and synchronized stage of Fig. 2.20c (directly relating to what we called above as *interoperability*). And this can cause (and really does) numerous problems, some of which are as follows.

- It is often difficult to put the resultant distributed system with many interlinked parts *into compliance* with the initial idea representing the system as a whole, as in Fig. 2.20a, partially Fig. 2.20b too.
- The hopefully correctly assembled whole for the separate parts may have *quite different features* than expected, including unwanted and even dangerous ones.
- The resultant solution of Fig. 2.20c is *predominantly static*. If the initial idea of Fig. 2.20a changes, the whole system may have to be redesigned and reassembled, partially or even completely.
- Adjusting the already existing multi-component system to a new idea and new goals may be with high price and considerable loss of performance.

In this book, we will be introducing a special holistic or *over-operability* layer G shown in Fig. 2.21, which can help us to substantially reduce or even eliminate the problems mentioned above.

The establishment of such a layer, supported by special formal model and high-level universal language as opposite to informal one of Fig. 2.20b, may allow us to keep top system definition, description, and modification in a semantic, integral, compact, and very flexible form. The latter also allowing numerous traditional details of system partitioning, implementation, load distribution, and restructuring, especially at runtime, to be shifted partially or even completely to

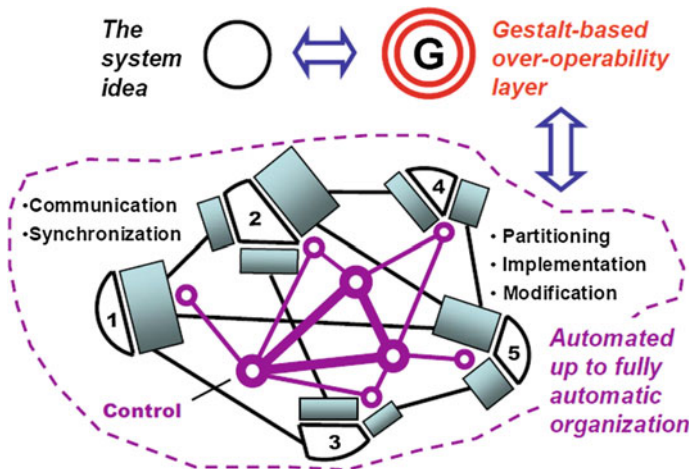


Fig. 2.21 Establishing over-operability layer for system creation and management

effective automatic level (which can massively use manned, unmanned and mixed components).

This over-operability layer will be the main theme of this book. Allowing us to effectively grasp large distributed systems on topmost level, it will be creatively using the described above ideas of *general system theory*, *system dynamics*, *gestalt psychology*, *memetics*, *brain waves*, and *interoperability*, among others. It will also be further investigating and developing the integral vision of large distributed dynamic systems originally expressed in the European patent [39] and previous books and book chapters [40–46].

2.9 Conclusion

Considered were some fundamental theories and novel approaches shedding the light on how large distributed systems of different natures, from technical to biological to social, are organized, behave and how they should be managed to fulfill complex objectives. The real shift should be done, first of all, from still dominating atomistic parts-to-whole philosophies and approaches, which were in doubt even a century ago, towards integral and holistic vision and management of large dynamic systems in order to provide increased power, overall awareness, and pursuit of global goals. And this over-operability needs to be supported by advanced system models and information and control technologies to move forward in reality and practice, which is the main goal and content of this book.

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