Functional Programming of Intelligent Systems

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Abstract: An intelligent system is a system that uses intelligence to shape its behavior in its environment. This intelligence depends on the following main factors: the first is the ability of the system to model the environment with which the system interacts. The second factor: using this model to successfully plan and solve problems that determine the behavior of the system in the environment in order to achieve the goals set for the system.
Modeling of the environment is based on the use of knowledge about the environment and its components, which the system collects using its sensors and organs, as well as the knowledge base, which stores information previously collected or incorporated during the development of the system. This information in the form of knowledge uses various forms of mathematical structures that form the basis of the model, logic and ontology that are part of the knowledge representation. Problem solving applies either previous experience, or uses a logical conclusion, based on the logic embedded in the system during its development, or ontological description, included in the representation of knowledge and relationships between elements.
When developing an intelligent system, you can apply the methods and tools of functional programming as a way to represent the development of a particular system, and analyze its capabilities and efficiency at the computational level.

Key-Words: intelligence, subject area, modeling, knowledge representation, intelligent systems

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1 Introduction

Technological support for the process of development of social structures and their relations always occurs in leaps that separate one phase of development from another. In the individual elements of such a structure, factors are formed that accumulate over time and then in a relatively short time cause changes, a leap, a revolution - a transition from one form of structure to another. This position can be clearly traced by the example of consideration of industrial revolutions, which determined the natural historical transformation from an agrarian society to a modern society, in which, against the backdrop of the fourth industrial revolution, associated with the transition to the information society, a new transition, a new social transformation, has matured and begun. This transformation can be characterized as a transition in all areas related to the existence of society today, to the widespread use of technologies and systems that have intelligence (society 5.0), and the natural transformation of social relations.

Over time, the processes of spasmodic development accelerate. They are usually associated with new scientific results, engineering solutions and the formation of new technologies that actively change the conditions of human existence. Now a new period has begun, which has arisen in the depths of the information society and is determined by the widespread introduction of artificial intelligence methods and systems into life, the creation of various intelligent systems (IS) and the transformation of existing systems to a new form by adding an intellectual component to them. At the same time, IS is understood as a system that uses representations and methods determined by intelligence to form its actions and perform tasks for the solution of which such a system is created. Previously, insertion modeling was suggested as part of the general theory of interaction. In this models, basic concepts such as environment, agents, insertion function were introduced, [1], [2], [3]. Other models that can be viewed as agents interacting in the environment of distributed data structures based in macroconveyor parallel computations and insertion modelling are described in [4], [5] and [6] among others. A suitable mathematical structure is suggested in [7] to abstractly represent a subject area, where a number of such structures and various variants of logics are considered.

There are two main approaches to the creation and development of IS - internal and external. The first, internal approach, involves a focus on the human user. Therefore, such systems provide the possibility of contact and communication with a person on issues that interest him and which are formulated at the level of human perception and understanding.

The internal approach includes the directions:

- understanding and answers to the questions that the user puts before the IS in natural language
- search and selection of the necessary information

in the literature and on the Internet, which is related to the user's context

- creation of an individual information environment favorable to the user, meeting his interests and ideas
- solving standard tasks that arise for the user in the process of his interaction with the environment
- development of game programs for complex intellectual games (chess, go, poker), IP becomes a partner of a person
- creation of IS, which are trained in the process of its interaction with the user to the level of a human assistant

The external approach to creating IS includes the following directions:

- development of IS, the activity of which is comparable to human activity in similar conditions or exceeds human capabilities; this includes various "smart" systems (home, city, workshop, enterprise, car, rocket, unmanned device), as well as intelligent economic, management and production systems
- creation of systems that an expert assesses as intelligent under the given operating conditions of the system, including search, decision and analytical systems, big data processing, predictive systems
- development of IS that replace a person in appropriate conditions, for example, intelligent robotics, cars and vehicles without a driver
- creation of IS, which, after training, perform work at a level comparable to human activity in similar conditions
- creation of IS based on the definition of the concept of intelligence, which is associated with a given subject area and successfully solves the tasks assigned to it in it.

It should be noted that most of these areas are successfully developed in various forms, including the use of multilayer neural networks, which are trained using enormous amounts of information created and recorded by man in natural language. Then the collected information is used when it is necessary to answer a question or construct a text that would correspond to some task of the user and be considered as an answer to his questions.

Similarly, information presented in visual or musical form can be considered. Then the neural network, which is the basis for the collection and analysis of information, creates paintings painted in the style of the artist on whose work the network was trained, or musical works of a certain form and type. And even now it is doing it so successfully that it provokes protests from the experts on whose works this network was trained.

The method of creating and training multilayer neural networks to represent intellectual activity is undoubtedly promising and extremely successful, given the size of the network itself and the amount of information that such a network accumulates and uses, plus the capabilities of computers that form their conclusions and suggestions based on this information.

An excellent solution was to use for training networks millions of literary sources - books, articles, dictionaries, encyclopedias - which reflect the linguistic representation of various human intellectual activities, as well as various artistic and figurative representations of the outside world. The collected and interconnected knowledge reflects the common intellectual world of hundreds of thousands of different people. This allows us to organize such interaction between the network and a person at the level of linguistic and figurative representations, which corresponds to our ideas about intelligence and its capabilities.

At the same time, there is another possibility of creating an IS, which is based on the definition of the concept of intelligence and the subsequent consideration of IS as a system that has this property. If such a definition includes only constructive components that can be constructed in computer form, then for the corresponding subject area it is possible to build an IS in which the intended intelligence is effectively implemented at the level of the components of the definition of intelligence. This definition is given in [7]. At the same time, various options and levels of intelligence are possible that correspond to this definition.

This allows you to build an IS in a subject area without being based on a linguistic representation that is associated with this area. By choosing the main components for a specific intelligence in a given area, we obtain different ISs that have different effectiveness in solving problems in the area under consideration. Moreover, such systems can act intelligently even in an area for which there is no preliminary description and which are studied by the IS during its interaction with the area. This approach is relevant, for example, for systems operating autonomously in subject areas that differ from each other. Let us also note that during its development, an IS may contain several different forms of intelligence at once, and the system simultaneously solves the same problem in different ways, comparing solutions with each other.

It is the approach based on the construction of an

IS based on a pre-selected form of intelligence that is considered in this work. Moreover, this form of intelligence is characteristic of a person who, for example, successfully plays certain games that he masters, or is engaged in certain areas of science, technology, or art. And it is precisely the focus on a separate subject area or several interconnected areas that makes it possible to create separate autonomous objects that have intelligence and apply it in the process of their behavior.

The work also discusses an approach to developing an IS of this type using functional programming methods.

This paper is organized as follows: section 2 introduces the basic conditions for intelligence settings, section 3 provides a definition for intelligence, section 4 introduces a definition for intelligence in functional programming and section 5 concludes with the implications of Functional programming of an intelligence system.

2 Basic conditions for setting intelligence

To define the concept of intelligence, it is necessary to first formulate some additional conditions that are necessary for a further understanding of what constitutes intelligence. There are three such conditions. The first condition: intelligence is always tied to a certain subject area (SbA), in which any system endowed with this intelligence operates. “A subject area is a part of the real, imaginary, or in some other way given world, environment, environment within a certain context. The SbA is considered as an integral part that determines the application of the intelligence possessed by this system. In this sense, the intellect of a mathematician differs from that of a composer, and the intellect of a philosopher differs from that of a poet. Although sometimes different SbA are combined. Thus, a philosopher may use mathematical theory to express philosophical views and propositions [8] or use linguistic representation to describe philosophical problems [9],[10].

For example, for an algebraic mathematician, SbA is a set of algebraic concepts and representations organized in a certain space and satisfying certain rules and axioms. In separate subdomains, these concepts and representations, together with the results obtained in the form of lemmas and theorems, get their name, for example, the theory of rings, algebras, groups, modules. Moreover, any of these subdomains includes, in particular, such an area as set theory in some of its representations.

For the intelligence associated with the processing of texts in natural language, SbA is, firstly, a set of words, sentences that can be built and are built by a person from these words, including the final texts that are made up of these sentences. And secondly, the set of rules (or possible use cases) that apply when combining words into sentences, and sentences into texts.

For the intellect of an artist who paints pictures, SbA is, on the one hand, the materials, paints and their combinations that the artist uses when drawing, and on the other hand, those artistic techniques and methods by which the artist transfers his idea of the world to the canvas, cardboard, paper (and, sometimes, wood, brick, glass, porcelain), on which he creates a drawing or picture. In addition, an essential role is played by the artist’s emotional state, which he also conveys in his work, his inner reflection of the world he represents. These individual, own ideas of the artist should also be attributed to the SbA. Therefore, very often different artists actually have different ideas about SbA even when they paint the same woman or the same landscape. And these differences allow the specialist to understand that the work belongs to a particular artist.

It should be noted that along with the natural material world, considered as a certain set of SbA (home, study, work, leisure (theaters, clubs, concerts)), it is possible to explore the worlds of ideas, ideas, fantasies, beliefs, hopes, virtual constructions. SbA includes the fields of science, art, management, and production. Each of them has its own characteristics and characteristics - literature, theater, painting, sculpture, architecture, cinema, those laws and forms, in each person can realize himself in artistic, scientific, industrial, technological and other areas characteristic of modern civilization.

The SbA may include an information base in which the experience of studying other areas is presented and accumulated, the knowledge and ideas of other subjects who have already encountered similar areas. This information is an additional component of any SbA and should be taken into account when a specific SbA is being considered (see Fig. 1). The information base for each SbA may expand and change over time, but the general tendency to include possible variants of information representation in the SbA remains.

Finally, when considered in relation to a certain system (subject), an SbA necessarily includes this system (subject), and possibly other subjects, as its necessary component. In turn, this addition to the general SbA, in addition to general knowledge about the part of space under consideration, contains personal ideas about this knowledge, its goals, character traits, individual properties that allow the system to additionally create its own entities - structures, images, associations, based on existing general ideas that are considered in the SbA. At the same time, the system can influence and change the components of

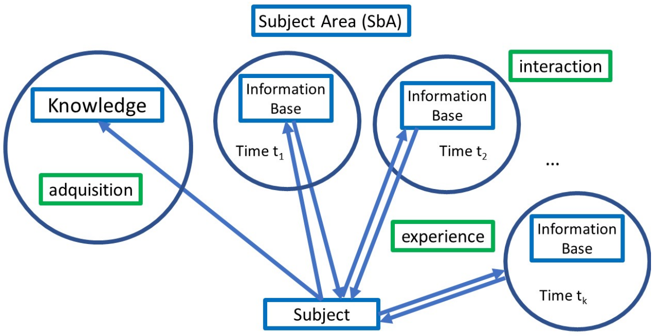

Figure 1: Subject Area Representation.

the SbA in order to create new entities in the SbA. The sequence of actions of the system in the SbA determines its behavior, the result of which should be a new or modified form of the SbA.

At the same time, the system (subject) has the ability to perceive both this entity and its individual parts after each action in order to compare changes in the SbA with the desired result for this system of individual actions and all behavior.

It is the possibility of changing the SbA that is desirable for the system that determines the effectiveness and level of development of the system operating in this area. And these properties are provided primarily by the intelligence of the system, which determines what needs to be done or what are the next goals of the system in the SbA, and what tasks and in what sequence it is desirable to solve in order to achieve these goals?

Therefore, the scope of the use of intelligence is connected with the need to determine the desired behavior of the subject (system) that has this intelligence in the considered SbA. This behavior, in turn, is built through the composition of the results of solving problems that are defined or that arise in this area in front of an intellectual subject. Therefore, the second condition associated with intellect is the determination of methods for planning and solving problems in the SbA in which this subject acts, relying on his intellect, to achieve the set goal. What and how should the subject use to solve the next task?

If we assume that both the task and the solution of the problem are formulated in the language associated with the SbA under consideration, then one of the possible options for a general approach to solving emerging problems can be the use of the language of logic chosen for this SbA. Logic is the science of the laws of representation of information about the environment, operations on this information and compositions of operations that provide means of formalizing reasoning about some environment based on their information about it. The conclusion in logic is considered as a sequence of statements about a given area, consistent with the laws and rules that determine the structure of the SbA, which links the initial conditions and the expected result. In this case, both the conditions and the result are elements of the SbA.

In other words, in such a language or its extension, first the condition of the problem is presented, then the transformations that already exist in the SbA, then the possible result or conditions that this result must satisfy. Then the solution of the problem consists in finding a suitable sequence of actions (each of which is admissible in the SbA), the composition of which gives the expected solution. From a logical point of view, it is necessary to build the conclusion of the solution of the problem, based on its condition and the rules for the conclusion of this logic.

At present, along with classical logic, there are various non-classical logics, which, in their form and meaning, are quite suitable for their use in IS. Examples of such logics, in addition to the logic of predicates, are modal logics, fuzzy, probabilistic, nonmonotonic, descriptive logics, the logic of defaults and a large number of other logics that are currently developed in order to bring logical reasoning closer to the forms and methods used by a person when solving tasks.

Therefore, the choice of the logic that will be applied when setting intelligence is considered as the second condition, which is associated with the possible solution of tasks that can be put before the IS.

Finally, the third condition associated with the process of modeling the SbA will be discussed below in the section on modeling.

3 Definition of intelligence

There are various definitions of intelligence [6], [11], [12], [13]. But one way or another, all these definitions are related to the ability to solve problems or determine the behavior of a system, most often at the human level. This means that there are certain restrictions on the perception, memorization and storage of information about the environment in which a subject or system endowed with intelligence can solve problems. In [7], the following definition of intelligence was given. Intelligence, considered as a property of a subject or system operating in some SbA, is determined by the ability, firstly, to model this area, and, secondly, on the basis of this model, using logic known to the system to effectively set and solve problems, the result of which allows the subject (system) to achieve its goals.

Thus, it is assumed that intelligence allows the system to build an SbA model that is adequate to this environment, based on its perception of this environment or the extension of this perception due to information received earlier and stored in the system's memory. This model serves as the basis for the intellect, in which it represents and solves the tasks set in the SbA for the system and aimed at achieving its goals in the SbA. Then this solution is transferred to the SbA, in which it is checked whether the solution obtained in the model coincides with the expected result of solving the problem already in the SbA. It is assumed that the property of intelligence is such that the model is adequate to the SbA and the solution of the problem obtained in this way is indeed the desired solution for the SbA. In the future, a subject or system with intelligence will be called an intellectual subject (system).

3.1 Subject area modeling

The process of SbA modeling is an essential part of the whole concept of intelligence. First of all, because at the model level all the main processes of solving problems that are associated with intelligence are performed. And the adequacy of the obtained IS solution in a real SbA depends significantly on how accurately the model is built.

There are various methods and ways of modeling [14], [15], [16], [17]. For example, when a large language model (LLM) is considered, the SbA consists of a set of words that are interconnected by semantic relationships determined by some contexts. In ordinary language, these relations appear in the form of sentences. In the case of using a multilayer neural network, it is trained on a large number of examples of various sentences that are found in books and articles written by people. Connections between words and groups of words are transformed into numerical characteristics in the form of neuron weights. Thus, a model of the language environment is obtained, which is then used, for example, to answer a question posed by an IS, which is implemented as a neural network, or to perform certain tasks (write an abstract, build a forecast, establish a connection between events). But this is just a specific example.

On the other hand, an IS may collide with various objects (OBs), including those for which there is no large amount of training information. Therefore, an IS should be able to model any OB that the system encounters.

"In order to build a model of SbA, first of all, IS must abstract from reality and create its own idea of this area, its structure, elements and connections. Such a representation of the environment is often built as a set of points, objects (regions) of some space, in which these points are interconnected by dependencies and relationships defined in this space", [7].

At the same time, it is assumed that the IS has special organs for perceiving information coming from external objects of the environment. For example, a person has five senses that allow him to perceive the environment and adapt to it. But these sense organs are oriented mainly to the immediate environment in which a person exists from the moment of birth. In order to expand his understanding of the environment, a person creates various devices that allow him to obtain new information about the micro- and macrocosm, uses electron microscopes that make it possible to see viruses, and various types of telescopes to have an idea of galaxies that are distant from Earth is millions of light years away.

Therefore, the IS must also have sense organs and the ability to receive information about the elements of the SbA, the connections between them, changes in the area in time and space. Based on these data, it forms its own idea of the SbA, first dividing it into parts (structurization of the SbA), then studying each part, and finally combining such ideas about each part into a single representation - the synthesis of the SbA model. In order to perform such a combination, IS can use some mathematical representation as a basis, which we will call the supporting structure of the model. Moreover, for the same SbA, in the process of its study and use, models can be built that use different carrier structures that represent this area from a different angle of view (see Fig. 2). For example, in physics, light can be considered as a wave or as a particle-photon.

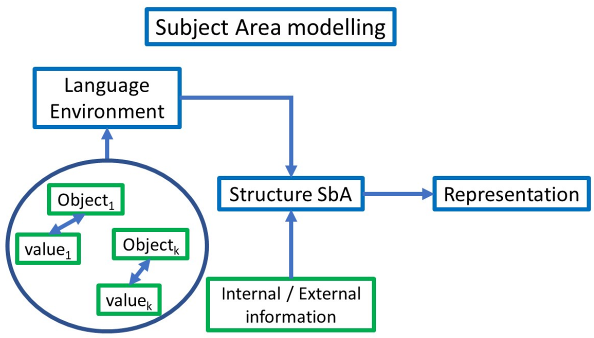

Figure 2: Subject Area (SbA) modelling representation.

Algebraic, categorical, probabilistic, topological, fuzzy, computational schemes and representations can be used as supporting structures for modeling, [7]. Depending on which carrier structure is used, we obtain various forms of intelligence, for example, probabilistic or topological intelligence. Thus, in the case of probabilistic intelligence, for modeling SbA, probabilistic representations are used, which make it possible to describe the properties of objects of SbA and the interaction (connection) between them using probabilistic concepts.

Note that the choice of one or another mathematical representation for setting intelligence is the third condition for setting intelligence (the first two were considered in Section 2).

The process of SbA modeling, which is associated with the actions necessary to determine intelligence, will be further called intelligent modeling (IM). This modeling is closely related to the knowledge that the IS accumulates in the process of studying and interacting with the SbA. In other words, at first the IS accumulates information about individual elements of the SbA, about the connections between these elements, and about the actions of some elements on others, about the structures generated by the elements in the SbA and stores this information in the form of a knowledge base about the SbA. In addition, the IS searches for suitable information about similar SbA in its knowledge base. For this purpose, knowledge about the general characteristics of those SbAs in which the given IS operates is stored in the knowledge base.

Then, having accumulated knowledge about what an SbA consists of, the IS begins the process of IM in order to ultimately combine and formalize its knowledge in a single subject - a model of a specific SbA.

3.2 Subject area knowledge

The process of SbA modeling, which is associated with the actions necessary to determine intelligence, will be further called intelligent modeling (IM). The general scheme is that the subject represents an SbA in the form of a knowledge system, which can be organized as a component of a knowledge base, defined by a knowledge network or some mathematical structure, the elements of which are individual knowledge. Various methods of specifying knowledge are known in the literature [11]. But, taking into account the orientation towards information systems, in [15] a new scheme for assigning knowledge, focused on systems related to intelligence, was presented.

In this case, knowledge about each element or structure of the X from SbA is specified in the form of a multicomponent set ζ_X, which includes a tuple of features that characterize X and are formed on the sensory organs of the IS or perceptual means that the IS possesses. The tuple of features is the first component of the set ζ_X. The second component is a logical formula that describes element X in the language of logic, a logical representation of element X. The third component of the set ζ_X is a set of connections between element X and other elements from the SbA. These three components determine the protoknowledge of the element X. Finally, the fourth component is an ontology that characterizes the element X already in linguistic form. The ontological characteristics of the elements of an SbA make it possible to operate with an SbA at the level of linguistic representations analyzed by a neural network, if necessary. Another component of knowledge is possible, reflecting the dynamics of element X, if such knowledge is needed when solving problems of an intelligent system.

This modeling is closely related to the knowledge that the IS accumulates in the process of studying and interacting with the SbA. In other words, the IS first accumulates information about the individual elements of the SbA and about the relationships between these elements, the actions of some elements on others, stores this information in the form of knowledge about the SbA, and searches for appropriate information in the knowledge base. Then, having accumulated knowledge about what the ObA consists of, it starts the process of IM in order to ultimately combine and formalize its knowledge in a single subject - the SbA model.

3.3 Knowledge about the subject area

There are various options for constructing an SbA model in the course of IM, [7]. The general scheme is that the subject represents the SbA in the form of a knowledge system, which can be organized as a knowledge base about the SbA, defined by a knowledge network or some mathematical structure. Knowledge about each element X from the SbA is specified as a multicomponent set and consists of attributes, a logical formula that describes the element X in the language of logic, links between the element X and other elements from the SbA, and an ontology that characterizes the element X already in the language form. The first three components define protoknowledge, and the last one determines the interpretation of the element X in the ontology associated with the SbA. Although one more component of knowledge is possible, reflecting the dynamics of element X, if such knowledge is necessary.

The IM process itself is built as follows:

First, in the SbA, on the basis of the collected information and data from the knowledge base about similar areas, the entities of this SbA are distinguished, and the corresponding knowledge is associated with each entity.

Entities in the SbA include:

- objects perceived at a given level of perception as a certain integrity
- instances of objects
- classes of objects
- structures built from various objects, classes

- sets of objects considered and interacting in the field as a single entity, called an image
- connections and relations between objects, classes, structures, images
- processes considered as a successive change of entities as a result of their interaction or due to their dynamic characteristics

Then, some subdomains are identified in the SbA which consist of interrelated entities and have specific features and features that are characteristic of this particular SbA and distinguish one subdomain from another. At the same time, it is assumed that the IS has enough information in the subdomain that can be used to form the behavior of the system. In other words, a subdomain is a part of the SbA, analyzed and used by the IS for planning and determining the behavior of the system in it.

For example, if a robot is considered as an IS that can act in various natural conditions and accordingly orients its behavior to the conditions in which it acts, then the robot first represents this SbA in the form of a set of subdomains, and then builds its behavior, taking into account the detailed features each area.

Each SbA entity is further represented in the form of knowledge associated SbA with such an entity. Knowledge about an entity is its representation of IS, oriented to use when creating an model. In the future, information will be understood as new information about the entities of the SbA, received by the IS from the SbA from the knowledge base or with the help of the sense organs, appropriate devices, by means of logical conclusions or hypotheses about the content, state, and changes of these entities. When constructing an IS model of the SbA, information about the area must be described, structured, associated with the constituent elements of the external environment known to the subject (understand the information) and save this description. Information about the SbA, which is stored by the IS for further intended or specific use, is used later in the formation of knowledge about the SbA, [15].

Knowledge is a representation and a semantic description of the individual entities of the SbA. Knowledge is used to create an SbA model. Note that in the absence of knowledge, when modeling an SbA, assumptions, hypotheses about certain entities can be used. For example, in mathematics, results are sometimes proved under the assumption of the validity of certain hypotheses that have not yet been proven, but previously formulated.

There are different forms of knowledge assignment. Next, consider a representation method based on a multicomponent representation of knowledge. This representation includes several components introduced and considered in [15]. This variant of knowledge representation is focused on their use in the process of SbA modeling, which is necessary for setting intelligence. This representation uses information about the characteristics of the ObA elements perceived by the subject, the links between them, the logical representation of each element, and its ontological description. This representation can be expanded by adding a fifth component to the knowledge, which characterizes the dynamic change in the parameters of an element, for example, its movement or the change over time of individual links between elements.

It is assumed that, in addition to the sense organs, the subject also has a knowledge base (KB), which reflects his previous experience, or information about similar SbA, which are already known to the subject or which he can receive from other subjects. This is necessary so that the intellectual subject can immediately begin to act, without a preliminary complex process of mastering an unfamiliar world.

Formally, knowledge Θ_A is represented by a three-component structure of the form $\Theta_A = (kn(A), \Omega_A, D_A)$, where $kn(A)$ is proto-knowledge directly related to the internal representation of the element and consisting of three components: a set of features of the object A, a set of links from the object A to other objects from the SbA, and a logical formula that describes the object A in the logic that is used by the IS. The set of features of an object is a set of its characteristics that the IS can receive from its sense organs, from the tools with which the IS is armed, and finally from the knowledge base, in which the experience of both the IS itself and other subjects who have studied this or similar areas has been accumulated. Descriptions obtained from other information sources or relevant literature can be introduced into the knowledge base. The second component of proto-knowledge is those relations and connections that represent the conditions for the interaction of a given entity A with other entities of the SbA under consideration. Finally, the third component of proto-knowledge $kn(A)$ is a logical description of the entity A within the framework of those conditions and representations that can be set in the logic used by the IS.

The Ω_A component is an ontological description of the object A, focused on a person who controls the behavior, or on an additional opportunity to obtain the characteristics of an entity by analyzing its ontological description. Finally, the component D_A is a set of operators that characterize the dynamic properties of the considered object in the considered SbA. For example, a robot can move in the SbA while receiving additional information about its current position and state, including possible changes. Or the robot gradually changes its state, for example, consuming energy or ammunition.

3.4 Tasks in SbA

The $\mathcal{M}$ SbA model is a certain part of the model representation space, in which a set of interrelated knowledge about entities (objects, structures, images) existing in this space is specified, and at the upper level of the interconnection of subdomains that are included in the SbA. The model can be associated with a multilevel map, where the map of each level is a set of identical, interconnected and interacting entities of a given area. At the bottom level are objects, at the next level there are structures, then images, and finally subdomains.

Problems in an SbA are considered either as an exact problem or in a generalized form. An exact problem in SbA is a pair of entities (A, B), the first of which A is the condition of the problem, and the second B is its result. The expression

$$(A, B)$$

itself also includes the formulation of what should be done as a result of solving this problem, what actions should be performed by the IS: transform A into B, find the essence of B in A, include, calculate, derive or prove the possibility of transition from it to entity B, and so on.

The generalized task is given as a set of entities $(A_1, \ldots, A_n)$, which should serve as the basis for achieving a given goal, defined as a part of interrelated entities obtained from the set $(B_1, \ldots, B_m)$. Such a task can be considered as the problem of achieving some goal determined by the initial entities from $(A_1, \ldots, A_n)$.

The complete solution of the exact IS problem is defined as a sequence of transformations from the SbA that allow one to pass from the entity A to the entity B. Sometimes one can consider an approximate solution in which the entity B' is considered as a solution to the problem

$$(A, B)$$

which in a given sense is close to exact result B and can therefore be considered as a solution. There may be cases when the desired solution does not exist at all or cannot be obtained by the means that the IS has.

Note that a variant is possible when the problem (A, B) is first modified by expanding or supplementing the condition A of the problem to A□ and this completion becomes part of the general problem, and then the new transformed problem (A', B) is already solved.

At the same time, we emphasize that, according to the assumption, those components from which the problem solution is built already exist in the SbA, they do not need to be further defined, but it is desirable to include them in the problem statement in order to obtain the necessary solution. For example, it happens that knowledge about SbA needs to be expanded through additional transformations that were not taken into account in order to obtain a solution to the problem. So, for example, in mathematics, various sub-fields of mathematics are often linked together in order to solve a problem from one area using the methods of another. Or you need to apply computer technology to analyze a large number of solutions.

In addition, we note that to solve problems in SbA methods of logic can be used, which is included in the representation of knowledge, as well as experience in solving similar problems, which is stored in the KB of IS. At the same time, it should be taken into account that individual entities of the SbA can change in the course of their existence: the task was set under the same conditions, and after a while not only the entity A changed, but also the expected result B, or some intermediate entities associated with the solution of the problem. Taking into account the dynamic nature of the SbA, we have to solve another problem. And this feature of IS is very significant. In fact, very often, instead of solving one IS problem, one has to solve several interconnected subtasks that take into account possible options for changing the situation in the process of solving the main initial problem.

The problem solving planning process consists in the initial representation of the SbA in the form of a certain structure, the elements of which are subdomains, and then the presentation of the existing task in the form of a set of subtasks, each of which is solved in its own subdomain. The plan for solving the problem is built as a plan for connecting the expected solutions of subtasks in a single solution.

4 Functional IC programming

The development of IS implies the possibility of software implementation of such a process as a way to represent at the program level the main functions and processes associated with the creation of such a system. In particular, such a programming approach can be effectively implemented at the functional level. The program representation allows you to model the behavior and explore the desired system at the level of its computer form, make the necessary changes and check the effectiveness of the system before its physical implementation. This is especially important for systems that assume rather complex behavior, especially for intelligent systems, who have intelligence, and therefore are capable of demonstrating quite complex behavior.

The creation of an IS assumes that since the constructed system has intelligence, it must, firstly, model the SbA that the system perceives and in which this system operates. And, secondly, using this model, the IS can plan and solve the tasks that are set for this system within the framework of a common goal and for which the system is being developed. Moreover, the solution process for complex problems may include a preliminary search for a certain sequence of intermediate, auxiliary tasks that need to be solved before moving on to solving the main problem - the goal of the system (this is the solution planning process), then solving auxiliary problems, and, finally, the transition to solve the main problem.

The modeling process is based on a preliminary perception of the properties of individual elements of this area, and the transformation of these perceptions into knowledge, which then form the basis of both the construction of the model and the processes of solving problems in this model. There are various options for the transition from perceptions to knowledge. Let's assume that the set of possible variants of knowledge is already contained in the knowledge base, to which the IS has access. In the knowledge base, knowledge is interconnected in the process of building the database itself through the use of information that is characteristic of objects and structures, but which cannot be obtained using data from observation bodies only. Not to mention that the time of possible observation and identification in real conditions can be very short.

When an IS enters the SbA, it first orients itself in it, highlighting individual elements and structures based on the collected features, and then turns to its knowledge base, which ensures the development of an IS for a given type of SbA, in order to find matches with the elements and structures identified in the environment. There is a process of recognition and comparison of these elements and structures, as a result of which the SbA modeling is performed, which combines the perception of IS and information from its knowledge base. These elements, images and structures are placed in the area of some space associated with the model, and the area itself is considered as the carrier of the model with which the IS operates.

Note that in the KB, the basic structure S is first selected, for each element of which there is a correspondence $SbA \rightarrow KB$. Then this structure is expanded to the area S^0 by adding elements to S that are not directly observed by the IS, but whose existence is possible based on the experience embedded in the development knowledge base. In addition, those transformations and relations are entered into S^0, which are determined on the basis of knowledge about the constituent elements considered in S^0. The area S^0 also determines the restriction of the total KB to the area $S^0 = KB(S^0)$. This limited base, which is tied to the area under consideration, can be used by IS in solving problems, especially in conditions of limited time.

In addition, if individual features of an entity in an SbA can be determined by direct measurements, then the possible actions of individual structures and entities are related to the fact that these entities are and may not appear during direct observation. At the same time, these data are usually contained in the knowledge base as general information about the possible components of the SbA. Then they are introduced into the logical and ontological components of knowledge included in model $\mathcal{M}$ of SbA.

For example, for an IS robot, the model is specified as a multilayer system of maps, starting with maps that indicate the relative position of objects with varying degrees of detail in the considered representation, and ending with maps that show the possible dynamics of SbA objects reflected in the information of the robot. Note that the map can include both a graphical representation of the environment and sets of programs corresponding to the actions that the robot can perform in a particular environment.

This model can change dynamically. The changes themselves can be associated with the properties of the modeled entities of the SbA, or be determined by the interactions between the entities and the IS. Or be refined as a result of additional data that the IS receives in the course of its actions in the SbA. Dynamic changes are associated with a sequence of maps in which these changes are presented or predicted as possible or planned states.

For example, if an IS is a robot that operates in an SbA, then the area itself may change if aerial reconnaissance means appear in it, or objects that were absent in the area may appear, or changes may be introduced in the form of new knowledge about previously defined objects that were absent or disguised.

Considering further the problems of functional programming, we will focus on the use of Python language concepts for programming, [18], [19]. The constituent elements of the model, firstly, are the objects of the SbA, determined by knowledge about them. Secondly, the SbA structures, considered as a set of several interconnected objects, which are determined by knowledge about the structure as a whole and act on other entities as a whole. Thirdly, images are a composite object, in which its constituent objects set the characteristics of individual properties of the image, considered as a union of components and having an integral prototype in a real environment. Fourthly, subdomains are part of the SbA, including its individual entities, their dynamics and interaction.

Fifthly, the processes executed in the SbA.

To specify knowledge about the individual components of the SbA and its structures, the IS software uses data that is specified in the form of lists and named dictionaries. In this case, dictionaries may include names derived from the ontology, which is included in the knowledge associated with these components. And the corresponding function displays knowledge about individual entities, structures, images into the necessary lists and dictionaries. These lists and dictionaries are then linked into maps as part of the SbA model.

Note that the structure of knowledge is quite heterogeneous, since knowledge includes not only measurable features, but also various expressions - logical and verbal (ontological). Therefore, both the process of modeling an SbA and solving problems in this model are determined by parallel approaches that combine logic, language representation, and formal operations on attributes.

In addition, it should be taken into account that knowledge about the essence of the SbA may not be enough, it may turn out to be incomplete, inaccurate, probabilistic, and sometimes simply absent. In these cases, it is impossible to construct a unique unambiguous model of the SbA. Therefore, hypothetical variants of knowledge are considered, and for each variant and hypothesis, its own model is built. Then we have a multiple representation of the simulated environment in the form of a set of different variants of models with different possible entities for which there is no exact information, but there is an assumption about what this information can be.

Accordingly, for each version of the model, its own tasks are solved in parallel, but there is a constant refinement of the model parameters, the hypothetical values of those functions and quantities are checked for which there were no exact data.

If the model has already been built, then the tasks facing the IS are formulated within the framework of those entities and relationships between them that are specified in the built model. The solution of the problem in this case is considered as a sequence of transitions between the condition of the problem and the expected result. Each transition is specified by an existing transformation that is specified in the model, and the composition of transformations from the sequence of transitions is added to the solution of the problem. And the complexity of the solution is determined by the length of the sequence and the order in which the transformations are applied.

Note that for models that are based on knowledge, there is a general approach in which the search for the necessary solution has a number of basic capabilities. In knowledge, there are three different forms of describing the essences of the SbA and, accordingly, methods for searching for transformations based on these descriptions. These forms include:

- direct characteristics at the level of signs,
- logical description, which involves the use of inference methods to build a solution, and
- ontological description, for which the methods of choosing the necessary transformations are applicable based on methods that are currently widely used in language models and based on the application of problem solving learning methods.

And these forms must be consistent with each other, and the results obtained from one form are taken into account when looking for transformations needed in another form.

Accordingly, for a sufficiently universal IS, preliminary preparation and accumulation of information is necessary, followed by the creation of a knowledge base associated with the tasks to be solved, so that on its basis it would be possible to look for a way to solve each specific task that can be assigned to the IS in this particular SbA.

There is also a simpler way, when for a given SbA and possible tasks of the IS, the classes of tasks that the IS will have to solve are preliminarily studied and identified. For example, when the behavior of an intelligent robot is considered, it is possible to simultaneously consider the range of tasks for which this robot is created. In this case, the intelligence of the robot will manifest itself in the way the robot analyzes and models the environment in which it operates, and in the breadth of the area of tasks it solves. Since the robot can combine various tasks, their total number can be large and quite versatile.

In cases where the classes of tasks to be solved for IS have already been previously identified, possible solutions can be prepared for them even at the stage of IS development. Then the IS, instead of developing a new algorithm, simply selects the appropriate solution from the array of existing solutions. Accordingly, at the functional level, a function is built that maps the condition of the problem and the expected result into one of the solutions that are developed in advance and stored in the knowledge base. In addition, methods are needed to combine the selected sequence of solutions, which is determined by the selected tasks and methods for solving them, into a single path from the task condition to its result, which determines the behavior of the IS.

5 Conclusion

An intelligent system is a system that uses intelligence to shape its behavior in its environment. This intelligence is determined by two main factors: the first is the ability to model the environment, and the second is the ability to successfully plan and solve problems that determine the actual behavior of the system in the SbA using this model. Modeling of the environment is based on the use of knowledge about the environment and its components, which the system collects using its sensors and organs, as well as the knowledge base, which stores information previously collected or incorporated during the development of the system, related to possible SbA. In particular, this information can use various forms of mathematical structures that form the basis of the model. Problem solving is based on the use of either previous experience stored in the IS knowledge base, or is performed using logical inference or other methods, based on the logic embedded in the system during its development, or uses an ontological description of the problem. Finally, the IS may try to apply solution methods that have been used in similar problems, information about which exists in the system's knowledge base.

In the future, future research in this direction is primarily related to the development of certain types of intelligence associated with various mathematical structures - topology, probability, fuzzy methods, algebraic structures. In addition, it is assumed that various types of logic are used as the basis for IS reasoning. The ability to communicate with the SbA implies the development and widespread use of specific research and production systems endowed with intelligence, which should radically change the modern economy.

If there is a need to quickly create such systems, then software implementations of their main elements and associated processes will be required. At the modern level of presentation, such programs can be based on functional programming, which assumes the possibility of a functional representation of the main processes associated with the actions of an IS and the use of intelligence when performing operations that determine the actions of such a system, including its modeling and the ability to operate with knowledge that describes the SbA, development of a knowledge base, logic and methods for planning and solving problems in the model.

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References:

[1] Gilbert D. R., Letichevsky A. A., *A universal interpreter for nondeterministic concurrent programming languages*. In M. Gabbrielli (Ed.), Fifth Compulog network area meeting on language design and semantic analysis methods. 1996.

[2] Letichevsky A.A., Gilbert D., A general theory of action languages, *Kibernetika and System Analysis*, 1, 1998, pp. 16-36.

[3] Letichevsky A., Gilbert D., Interaction of agents and environments D. Bert, C. Choppy (Eds.), Resent trends in algebraic development technique, LNCS 1827, Springer-Verlag. 1999.

[4] Kapitonova J., Letichevsky A. Mathematical theory of computing systems design, Moscau Science. 1988. - 295 p.

[5] Letichevsky A., Letychevsky Jr. A., Peschanenko V., Insertion modeling system, PSI lecture notes in computer science, Springer. 2011, pp. 262-274.

[6] Letichevsky A., Theory of interaction, insertion modeling, and cognitive architectures, *Biologically Inspired Cognitive Architectures*, Vol. 8, April 2014, pp. 19-32.

[7] Meitus V.Yu., Problems of Building Intelligent Systems, *Intelligent Modeling. Cybernetics and System Analysis*, No. 4, 2021, pp.3-19.

[8] Russell B.,Principles of Mathematics, 1903.

[9] Wittgenstein L., Wittgenstein's Lectures on the Foundations of Mathematics, Cambridge 1939, ed. C. Diamond. Ithaca: Cornell University Press, 1976.

[10] Wittgenstein L., Tractatus Logico-Philosophicus, 1922, translation on facing pages by C. K. Ogden. Routledge and Kegan Paul, London. 2nd ed., 1933.

[11] Russell S., Norvig P., Artificial Intelligence: A Modern Approach. Pearson. 2016. – 1132 p.

[12] Bostrom N., Superintelligence: Paths, Dangers, Strategies. – Oxford University Press. 2014. – 345 p.

[13] Laurier J. L., Systems of artificial intelligence. - Moscow: "Mir", 1991. - 568 p. (in Russian)

[14] Khaikin S., Neural networks: full course. Moscow: "Williams", 2006.- 1104 p. (in Russian)

[15] Meitus V.Yu., Problems of Building Intelligent Systems. Representation of knowledge. *Cybernetics and System Analysis*, No. 4, 2019. pp.3-14.

[16] Meitus V.Yu., Problems of Building Intelligent Systems. Levels of Intelligence, *Cybernetics and System Analysis*, No. 4, 2018. pp. 32-44.

[17] Glibovets M.M., Gulaeva N.M., Evolutionary algorithms: assistant. – K.: NaUKMA, 2013.- 828 p.

[18] Summerfield M., Python in Practice: Create Better Programs Using Concurrency, Libraries, and Patterns. Addison-Wesley, 2013. - 336 p.

[19] Lutz M., Programming Python. – O'Reilly Media, Inc., 2010. – 1628 p.

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