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Theoretical Aspects of Creating Multimodal Digital Twins with AGI Multilogic and Multisensory

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Abstract

AGI multilogic, multimodality and multisensors are the basis for the multidisciplinary development of intelligent digital twins. Multimodality is implemented in several formats: text, image, speech, formulas, etc. Multilogic is implemented according to several rules or methods or ways of working with knowledge and data, and the criterion for selecting the best result from all implementations. AGI multilogic carries out judgment, understanding, perception, comparison, analysis, choice, etc. Understanding is realized using the technology of unified objectification of the ontology of subject areas for the implementation of specific activities. Multisensor systems are combined groups of electro-optical, spectroscopic and holographic sensors, and combined series of sensors, such as a thermal imager, color camera, low-light camera, laser rangefinder, laser designator, laser, pointer-illuminator and others. Multisensory systems help monitor the psyche and performance of a person at the level of medical indicators of his physical condition in the process of joint activities with digital twins. Multimodal digital twin with AGI multilogic and multisensory is good human assistant in many areas of activity.

Keywords: multimodal digital twin, AGI multilogic, multisensor systems, technology of unified objectification

1. Introduction

The information basis of a multimodal digital twin with AGI multilogic is ontologies of subject areas. Many systems for constructing ontologies have been developed in the world for various fields of knowledge.

Protégé is based on the OKBC (Open Knowledge Base Connectivity) knowledge representation frame model and is equipped with a number of plugins, which allows it to be adapted for editing models stored in different formats (standard text, in a JDBC database, UML, XML, XOL, SHOE, RDF and RDFS, DAML+OIL, OWL).

OntoEdit was originally developed at the AIFB (Institute of Applied Informatics and Formal Description Methods) at the University of Karlsruhe. Currently commercialized by Ontoprise GmbH, it performs the verification, review, coding and modification of ontologies. Currently, OntoEdit supports representation languages: FLogic, including an inference engine, OIL, RDFS extension and internal, XML-based serialization of the ontology model using OXML — OntoEdit's XML-based Ontology representation Language. The advantages of the tool can be attributed to ease of use; development of ontology using the methodology and the process of logical inference; development of axioms; There are two versions of OntoEdit: the freely redistributable OntoEdit Free (limited to 50 concepts, 50 relationships and 50 instances) and the licensed OntoEdit Professional (no size limit). Naturally, OntoEdit Professional has a wider range of functions and capabilities (for example, an output engine, a graphical query tool, more export and import modules, a graphical rules editor, support for JDBC databases, etc.).

OilEd is an offline graphical ontology editor developed at the University of Manchester as part of the European IST On-To-Knowledge project. The tool is based on the OIL language (currently adapted for DAML+OIL, in the future — OWL), which combines the frame structure and expressiveness of Description Logics with reasoning services. This allowed for a clear and intuitive user interface style and the benefits of supporting reasoning (detection of logically inconsistent classes and hidden subclass relationships). Recently there has been an increase in the popularity of the OilEd editor. It is used for both teaching and research. The tool is freely distributed under the GPL public license.

WebOnto is designed for Tadzebao, an ontology exploration tool, and is designed to support collaborative browsing, creation and editing of ontologies. Its goals are ease of use, providing scalability for building large ontologies. WebOnto uses OCML (Operational Conceptual Modeling Language) to model ontologies. In WebOnto, the user can create structures, including classes with multiple inheritance, which can be done graphically. All slots are inherited correctly. The tool verifies newly entered data by checking the integrity of the OCML code. The tool has a number of useful features: saving structural diagrams, separate viewing of relationships, classes, rules, etc. Other features include collaboration between multiple users on the ontology, use of diagrams, send and receive functions, etc.

OntoSaurus is a Web browser for LOOM knowledge bases. It consists of two main modules: an ontology server and a Web browser for editing and viewing LOOM ontologies using HTML forms, providing a graphical interface for them. OntoSaurus also provides limited editing tools, but its main function is browsing ontologies. But to build complex ontologies you need to understand the LOOM language. Most users build an ontology in LOOM in another editor and then import it into OntoSaurus for viewing and editing. OntoSaurus implements all the features of the LOOM language. Automatic compatibility checking, deductive reasoning support, and several other functions are provided.

An ODE (Ontological Design Environment) ontology builder that communicates with users at a conceptual level, as opposed to tools like OntoSaurus that communicate at a symbolic level. The motivation for ODE was that it is easier for people to formulate ontologies at the conceptual level. ODE provides users with a set of tables to populate (concepts, attributes, relationships) and automatically generates code for them in LOOM, Ontolingua and FLogic. ODE forms part of the full life cycle methodology for ontology construction according to Methontology. The tool was further developed in WebODE, which integrates all ODE services into one architecture, stores its ontologies in a relational database, and provides additional services (inference engine, axiom construction, ontology collection, catalog generation).

KADS22 is a tool to support the design of knowledge models according to the CommonKADS methodology. Ontologies form part of such knowledge models (the other part is inference models). CommonKADS models are defined in CML (Conceptual Modeling Language). KADS22 is an interactive graphical interface for CML with the following functionality: CML file parsing, printing, hypertext browsing, searching, glossary generation and HTML generation.

Further development within the DWQ (Data Warehouse Quality) project leads to the i.com tool, a tool to support the conceptual stage of an integrated information systems project. i.com uses the Extended Entity-Relationship Model (EER) with the constraints of multidimensional aggregation and intermediate schemas. The i.com tool is fully integrated with a powerful DL-based reasoning server. i.com serves primarily for intelligent conceptual modeling. PROMPT is an addition to the Protégé system, implemented as a plugin, used to combine and group ontologies. When two ontologies are combined, PROMPT generates a list of suggested operations. An operation could consist, for example, of combining two terms or copying terms into a new ontology. The user can perform an operation by selecting one of the proposed ones or by directly defining the operation. PROMPT performs the selected operation, and any additional changes caused by that operation. Then the list of proposed operations is modified and a list of conflicts and possible solutions to these conflicts is created. This is repeated until the new ontology is ready.

Chimaera is an interactive federation tool based on the Ontolingua ontology editor. Chimaera allows the user to combine ontologies developed in different formalisms. The user can request analysis or guidance from Chimaera at any time during the merging process, and the tool will direct him to those places in the ontology where his intervention is required. In its proposals, Chimaera mainly relies on which ontology the concepts come from, based on their names. Chimaera leaves the decision of what to do to the user and does not make any suggestions on its own. The only taxonomic relationship that Chimaera considers is the subclass-superclass relationship. Chimaera is the closest to PROMPT. However, because it uses only the class hierarchy in its analysis, it misses many of the matches that PROMPT finds. These matches include proposals for merging slots with similar names that belong to the merged classes, merging the domains of slots that have been merged, etc.

In OntoMerge, a merged ontology is a union of two original ontologies and a set of join axioms. The first step in the OntoMerge merging process is to translate both ontologies to a common syntactic representation in the language developed by the authors. The ontology engineer then defines connection axioms containing terms from both ontologies. The process of translating instances is as follows: all instances in the source ontologies are considered to be in the combined ontology. Then, based on the instructions in the source ontologies and the join axioms, the inference engine will make an inference, thus creating new data in the join ontology. OntoMerge provides tools for translating instance data into a merged ontology.

OntoMorph defines a set of transformation operators that can be applied to an ontology. A human expert then uses an initial list of pairs and source ontologies to determine a set of operators that should be applied to the source ontologies to resolve differences between them, and OntoMorph applies these operators. In this way, a set of operations can be performed in one step. However, the human expert receives no guidance other than the initial list of pairs.

The OBSERVER system uses DL to answer queries using multiple ontologies and mapping information between them. First, users define a set of interontological relations. The system helps to cope with this task by finding synonyms in the source ontologies. Once mappings are defined, users can formulate queries in DL terms using their own ontology. OBSERVER then uses the mapping information to formulate queries against the source ontologies. OBSERVER relies heavily on the fact that the descriptions in ontologies and queries are meaningful.

FCA-Merge is a method for comparing ontologies that have a set of common instances, or a set of common documents annotated with concepts from the original ontologies. Based on this information, FCA-Merge uses mathematical methods from Formal Concept Analysis to produce a concept lattice linking the concepts of the source ontologies. The algorithm proposes equivalence relations and subclass-superclass. The ontology engineer can then analyze the result and use it as a guide to create a unified ontology. However, the assumption that the two ontologies being merged share a common set of instances or have a set of documents in which each document is annotated with terms from both sources is too rigid and in practice this situation rarely occurs. As an alternative, the authors propose using natural language processing techniques to annotate a set of documents with concepts from these two ontologies.

The ONION (Ontology Composition) system is based on ontology algebra. Therefore, it provides tools for defining rules of articulation (connection) between ontologies. Articulation rules usually take into account only the relevant parts of the source ontologies. To propose a join, ONION uses both lexical and graph-based methods. The method of finding lexical similarity between concept names uses dictionaries and semantic indexing methods based on the location of a group of words in the text.

Currently, the automatic construction of ontology is recognized as the most effective means of formalizing and systematizing knowledge and data in subject areas (Amita Arora, Manjeet Singh & Naresh Chauhan, 2017; Shishenkov M. A., 2024). The comprehensive combination of existing methodologies for automated construction of ontologies makes it possible to determine the meaning of the processed information from the subject area of knowledge and the intentions of users, and present them in a machine-processable form. Automation of determining the meaning of processed information and user intentions expands the scope of use of a multimodal digital twin with AGI multilogic.

2. Functional Aspects of Multimodal Digital Twins with AGI Multilogic

A multimodal digital twin with AGI multilogic consists of multimodal self-organizing ensembles of software and hardware agents with artificial intelligence (Evgeny Bryndin, 2024a; Evgeny Bryndin, 2024b). Logic, as a sequence of associative acts, is determined by the specifics of information. The sequence of associative acts of formula implementation is determined by algorithmic rules. The logic of justifying events by sentences of the language is implemented according to grammatical rules. The sequence of associative acts of implementing combinatorial problems is determined by design methods. Management logic is aimed at developing various solutions. To solve complex problems of everyday life, AGI multilogic is activated, relying on various techniques.

A multimodal digital twin with AGI multilogic explores subject areas of knowledge using different methods, methods and approaches. For this purpose, AGI multilogic selects information processing options (Evgeniy Bryndin, 2020; Alexey SP, Vitaly B., 2021; Selmer B, Naveen SG, John S, James TO, Mike G, et al., 2022; Evgeny Bryndin, 2022; Anton GK, Alexey G, Arseniy F, Mari M, Mario C, et al., 2023; Boris B. Slavin, 2023; Proceedings of AGI-24, 2024). The choice of method, method or approach is based on the correlation of the data of the current task with existing standards, rules and facts proven by science and practice. In practice, there are many methods, methods or approaches, each of which solves the current problem. Techniques for solving a problem involve performing many actions and revealing the features of the problem being solved.

Choosing a method, method or approach for solving a current problem requires an analysis of the ontology of the subject area within the framework of the selected topic. Analysis of the ontology of the subject area within the chosen topic is carried out using a unified objectification. It is aimed at determining the semantic meanings, data and patterns of the subject area of knowledge that are relevant to solving a specific problem. Automated analysis of the domain ontology is carried out according to the methodology.

Methodology is the study of methods, methods and strategies for studying a subject. She uses system of criteria for organizing and constructing theoretical and practical activities. The methodology includes characteristics of the study; reflects the logical structure of the problem being solved; shows the planned scheme for solving the problem (stages, stages, sections and solution methods). Decision techniques are your guide throughout the analysis. They serve as a ready-made scheme, following which the current task is implemented step by step. Decision methods represent a set of actions, certain algorithms or a set of specific steps aimed at solving a specific problem at a particular stage.

An objectified methodology based on the ontology of the subject area and the base of skills of a certain field of activity of multimodal self-organizing ensemble of software and hardware agents with artificial intelligence allows you to automatically find techniques for developing a solution. The set of multimodal parameters suitable specifically for the solution that will be used in this methodology is determined by the solution techniques. The processes of analyzing a subject area and objectifying its ontology can use several methodologies simultaneously, which will then be used to solve the problem at different stages, separately or jointly.

AGI multilogic with objectified methodologies harmonizes multimodal ontologies of subject areas for interdisciplinary work with them.

2.1 Objectification of the Domain Ontology

Ontologies are a formal description of knowledge from a subject area, taking into account thematic rules and connections between elements, allowing automatic knowledge extraction. Ontologies serve for the systematic organization of knowledge, allowing one to discover new facts and identify the necessary relationships between elements. Ontology-based knowledge organization systems are already very common and used in many industries.

The ontology of the subject area consists of an ontology of knowledge and an ontology of reality. The ontology of reality reproduces those structural connections and relationships that are inherent in reality. The connections between the ontology of knowledge and the ontology of reality are objectified by semantic identity. Ontologies can be multi-level. When constructing an ontology, the following sequence of actions is distinguished: classification of basic concepts, selection of basic concepts, definition of relationships, a conceptual scheme of the ontology is formed as a connected complex of concepts, the ontology is supplemented with subject-specific implementations of classes (Individuals) and data that have a physical meaning, a linguistic component is formed.

The mathematical basis of ontology is the so-called descriptive logic (a branch of mathematics), which assumes that any information expressed in natural language can be represented as a chain of triplets. The ontology is represented as a graph, the vertices of which are entities, and the edges are relationships between entities. It is believed that any statement in natural language can be represented in the form of simple sentences from which entities and relationships between them can be extracted. There are two main tools: RDF (Resource Description Framework) or OWL (Ontology Web Language). OWL allows you to further describe logical rules over data. Ontologies (unlike conventional databases) allow you to find hidden data. Conventional ones are well suited for searching for specific information, and knowledge bases are needed where it is necessary to identify new knowledge, for example, in decision support systems.

The power of ontology is manifested if the relationships between its elements are described in detail and qualitatively, using the mathematical apparatus of descriptive logic. For example, for relations you can set their properties (functional, transitive, reflexive). And then you can automatically extract facts from the ontology, this process is called reasoning, there are standard reasoning algorithms based on graphs. Possible applications: clarifying the characteristics of an object and identifying a unique one from a set of similar objects, searching for similar objects, "understanding text" and assigning text to a specific class, assistance in NLP tasks (NER, Relation Extraction), root cause analysis, identifying patterns in data. The most popular ontology editor that supports reasoning is Protégé. There are other tools, for example: IBM Watson, Wolfram Alpha.

Automated creation of ontologies is carried out based on existing knowledge bases. The tools used contain various methods for working with ontologies. Each ontology has a unique IRI (Internationalized Resource Identifier). The mathematical support of a multimodal self-organizing ensemble of agents with artificial intelligence makes it possible to write triplets, that is, triplets of the "subject-predicate-object" type. The Entities section allows you to describe subjects and objects. An ontology is constructed as a hierarchical structure of classes related by concepts. In ontology, properties have an independent nature; a property is separable from a class. For predicates, you can set different properties, for example: functional; back; transitive. Based on the described ontology, you can use a reasoner that produces solutions based on the found properties and connections.

2.2 Functional and Structural Aspects of the Multisensory System

Various modern multi-sensor monitoring systems operate with spectroscopic, holographic, optical, sound and electronic sensors and use a variety of segmentation and tracking algorithms. The functional and structural aspects of a multi-sensor system for monitoring and interpreting heterogeneous data are considered, which will help in the development and design for creating a wide range of applications for monitoring and interpreting data that allow interaction with multi-modules.

It is now common to work with distributed systems in which multiple sensors interact to track objects of interest (23 Examples of Multi-Sensory Technology, 2014; Cornelio, P., Velasco, C., & Obrist, M., 2021; Gail Bednar II., 2022; Stacey Aston, Marko Nardini & Ulrik Beierholm, 2023; P. Shanmugavadivu, Hsin-Hsi Tsai, Bharathi Raja Chakravarthi, 2024). It is clear that any new approach to intelligent monitoring and interpretation must be adaptive when considering the implementation of an ever-increasing and wider range of sensors. Therefore, modern monitoring systems must combine several heterogeneous distributed structures and use universal segmentation and tracking algorithms.

The multisensor system is designed as a distributed multi-layer architecture. In this way, the synergy between the user and the environment is increased. Monitoring systems consist of multiple sensors covering wide areas, grouped in processing nodes that provide high scalability and reliability. The nodes perform real-time monitoring to alert the operator to pre-detected specific events.

A distributed multi-tier system consists of a central node and a set of remote nodes. Remote nodes are responsible for data collection and lower-level processing (such as segmentation and tracking), while the central node collects dynamic information and performs higher-level processing tasks.

A multi-logic, multi-modal ensemble of intelligent agents is isolated from the user interface to provide independent monitoring and control. To provide greater flexibility. This is necessary not only to meet the needs of monitoring and interpretation systems, but also to incorporate existing algorithms or newly developed ones. Functionality is provided by various modules that make up the layers of the multisensory system structure. This way, new or existing functionality can be easily incorporated into the framework, not only for developers but also for users.

Each layer is implemented as advanced modules, operating from a lower level — data collection or communication with nodes — to higher levels such as tracking, classification, or dynamic detection. The extension views the structure as a combination of extended modules of a multisensory system. Each module focuses on one level of the proposed data monitoring and interpretation framework. Before describing each level of the structure in detail, it is necessary to describe the execution model. The execution model follows a hybrid distributed design, where remote nodes perform process-level processing, and a central node is responsible for collecting and merging data and performing high-level processing.

The acquisition layer directly interfaces with digital analog devices through measurements from the physical world. In this case, we mean data from sensors, as well as data from other sources of information (database, knowledge base, etc.). The data acquisition layer also performs information preprocessing.

The data fusion layer combines data from sensors to improve the quality of information (more complete and accurate). Data fusion algorithms also work with a variety of spectral, holographic and optical images.

The object classification level is particularly important for good dynamics analysis because it provides knowledge about what the object is. In addition, object classification provides information about the orientation of objects.

The object tracking layer is responsible for matching the coordinates of image objects to the real picture. Thus, it computes the trajectories followed by moving objects within a scenario, regardless of the specific sensor that detected them. It also makes predictions about the future positions of objects based on previously detected trajectories. Information from the general model, sensor situations and their coverage ranges are used.

The event detection layer generates semantic information related to the behavior of objects in a scenario. This is the last layer of the structure stored in remote nodes. The remaining layers are implemented in the central node. In a multi-sensor monitoring and interpretation system, multiple sensors monitor a common scenario, events generated from different sources. This is why the event fusion layer is needed to unify the information coming from the various sensory data generated in the previous layer.

The final layer of the framework, activity detection, is responsible for analyzing and detecting activities already associated with temporal features. After merging the events, the current layer has a better idea of what is happening in the scenario according to the detected events. Therefore, actions detected at this level can be translated into scripted actions, providing a higher level.

A multi-level multi-sensor helps to coordinate the meanings of the ontology of the subject area of the multimodal digital double and its Agi multi-mental intentions and motives of the user, interlocutor or team. Improving multi-sensing systems will allow you to develop and create multimodal digital doubles with AGI multi-unit for scientific applied studies in various subject fields, for researching the safety of industrial processes, for researching the intentions and motives of various groups during mass events, for the study of disasters and various natural processes.

3. Conclusion

Multimodal digital twins with AGI multi-logic and multi-sensory capabilities can be safely used in many areas of activity as human assistants, especially in harmful and dangerous jobs, for example, those related to radiation, chemistry, etc. This requires standardization of the security of knowledge of domain ontologies and the mental intentions and motivations of the skill base (Bryndin E. G., 2024c). This allows a multimodal digital twin with AGI multilogic and multisensory capabilities to work confidently with subject knowledge ontologies by analogy, similarity, deduction and induction.

Japanese private companies have created several multimodal multisensory systems with artificial intelligence for Japanese schools and universities. The Konica Minolta system is capable of analyzing the mental reaction of students to the material presented and can collect data on the level of concentration of students and active participation in the lesson. The system from Techno Horizon is designed to analyze the emotional state of each student. The artificial system helps determine which students are excited, which students are stressed or bored, and which students are focused on the lecture. Intelligent systems monitor the progress and effectiveness of schoolchildren and students' learning and provide recommendations to teachers during the learning process.

Multimodal digital twins with AGI multi-logic and multi-sensory capabilities make it possible to model adaptive skills and imitate the human psyche by imitation at the model, virtual, information and program levels. They will be able to possess a fundamental human ability — to understand the intentions of other people. Cognitive imitation of the human psyche contributes to social learning and the accumulation of psychological experience. The cognitive imitation, developed according to cognitive rules, will then move to learning by observation.

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