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**DEVELOPMENT OF A MODEL FOR COLORING RASTER ELEMENTS BASED ON DETERMINING THE CONTRAST OF COLORED RASTER POLYNOMIALLY TRANSFORMED DIGITAL IMAGES**

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The object of research is the technological process of pre-printing adjustment of image tone reproduction based on the determination of the contrast of colored raster polynomially transformed digital images.

One of the significant problems in the process of pre-printing image preparation is the absence of an automated zonal ink supply adjustment system in most offset machines. Accordingly, this makes it impossible to determine the optimal ink layer to ensure high-quality tone reproduction. Therefore, the urgent task of determining the contrast of colored raster polynomially transformed images over the entire tone reproduction interval arises.

The research process is based on the use of the method of mathematical transformation, the theory of digital image processing and object-oriented programming.

Rasterization algorithms have been developed based on the use of polynomial transformation of digital images of light tones. The result of raster transformation is the determination of the relative area of the coloring of raster elements, which is the main carrier of information about the tonality of the image.

A structural diagram of a contrast simulator of colored polynomially transformed images was constructed, with the help of which the characteristics of coloring of raster elements and the characteristics of the contrast of colored polynomially transformed images were constructed.

The proposed coloring model describes the dependence of coloring of raster elements on the change in the relative contrast of colored raster polynomially transformed images. It is proved that an increase in the thickness of the ink layer increases the initial contrast by +0.2 units. Therefore, changing the thickness of the ink layer can ensure optimal visual image quality due to a change in contrast, which is an advantage of the model.

The research results can be recommended for use in pre-printing processes of adjusting digital images.

**Keywords:** polynomial transformation, raster transformation, coloring, relative contrast, simulator, quantitative assessment.

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**DEVELOPMENT OF AN ONTOLOGY-BASED METHOD FOR SCALABLE GENERATION OF PARTIALLY OBSERVABLE MARKOV DECISION PROCESS (POMDP) MODELS**

pages 13–20

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The object of research is the automated construction of partially observable Markov decision process (POMDP) models from a semantic knowledge base, in which probabilistic parameters are formalized as an ontology or knowledge graph.

The problem addressed in this research is that the traditional approach requires manual construction of transition, observation, reward, and cost tables, which results in low data traceability. This significantly complicates model auditing and updating, and hinders reconciliation in cases of conflicting information sources or changes in domain knowledge.

A domain-independent schema has been developed that represents each numeric POMDP parameter as a provenance-aware claim, including the information source and timestamp.

A deterministic compilation method has been implemented that selects claims via SPARQL queries, resolves conflicts according to a policy, normalizes parameters, and forms the output tabular values for transition *T*, observation *O*, and reward *R* matrices.

A benchmark evaluation was conducted using a diagnostic task, confirming the model's high generation speed. In a series of 10 experiments, generation time did not exceed 3.6 s, even for a state space of  $|S| = 3957$ , and solution time by the SARSOP solver ranged from a few seconds to a set timeout of 600 s, depending on the scaling mode.

Treating parameters as graph entities allows transforming model updates into an explicit claim-editing procedure that is accessible to audit.

The method can be used when the domain knowledge is expressed as ontology with identifiable states/actions/observations, and when parameter provenance matters. It supports maintainable decision-support deployments with auditable parameter histories and handling of conflicting claims, generation of model variants for sensitivity analysis, and controlled extension of the model via ontology learning.

**Keywords:** ontology, knowledge graphs, automated model generation, probabilistic planning, POMDP.

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## IMPROVEMENT OF THE METHOD OF FUNCTIONAL REPRESENTATION OF THE SHAPE OF A THREE-DIMENSIONAL OBJECT

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The object of research is the process of creating a three-dimensional computer model of an aerodynamic product.

The research is devoted to solving the problem of combining a Transformer class model and a method of representing figures through a Fourier series. Such a combination is possible provided that a universal method of representing multidimensional data of different types is used. The results of the combination can improve the solution of the problem of creating a 3D model that meets the specified environmental requirements with sufficiently high accuracy. However, the issues of applying a universal method of representing multidimensional data remain largely unexplored.

A universal method of representing mathematical descriptions of a 3D object and the physical environment that affects the characteristics of this object has been improved. A new method of calibrating the action orbit of the similarity group of figures by displacement has been developed. A method of applying the Fourier transform for figures that form multiple-valued functions after the second phase of the transformation has been improved. A quantitative quality assessment of the functional representation of a figure based on the Hausdorff

distance has been developed. A method for eliminating the existing shortcomings of this distance has also been developed.

An experimental verification of the obtained research results has been carried out. It has been established that the use of the proposed improvements ensures the invariance of the functional representation with respect to spatial characteristics of 99.9%. The largest root mean square deviation is 0.000008 absolute units of the Hausdorff distance.

The obtained results provide a universal method for representing any three-dimensional objects. Unlike most existing methods, the improved method allows to operate on 3D models as points in the Hilbert functional space. This possibility allows to significantly simplify the use of modern machine learning models of the Transformer class for solving scientific and applied problems of mathematical physics.

**Keywords:** 3D modeling, functional representation, Transformer, Fourier transform, calibration of the action orbit of the similarity group, quality assessment of the functional representation.

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### DEVELOPMENT AND VERIFICATION OF AN ORCHESTRATION ARCHITECTURE OF AI AGENTS FOR AUTOMATED API TESTING WITH A UNIFIED REPRESENTATION OF REQUIREMENTS

pages 31–40

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The object of this research is the process of automated testing of application programming interfaces (API) in systems developed following Agile and DevOps approaches, where requirements are heterogeneous, frequently changing, and represented in various formats: from formal OpenAPI specifications to textual documentation (Confluence). The problem addressed is the absence of an architectural mechanism for systematic integration of heterogeneous requirements sources and for decoupling requirements interpretation from test generation. Specification-oriented approaches fail to incorporate business rules from textual sources, covering only 70–80% of specification content. LLM-based approaches are unstable: repeated runs with identical prompts yield test sets differing by 20–40%, with coverage standard deviation reaching  $\pm 12\%$ .

AI-driven orchestration architecture is proposed, comprising a coordination layer  $O$ , requirements-processing agents  $A$ , and a protocol-independent unified requirements representation  $R$ . The test generation process is formalized as  $T = G(O(A(S)))$ , where  $S$  denotes the set of requirements sources and  $G$  the deterministic test generation algorithm. The key property of the architecture is isolation of the stochastic LLM component at the agent level, guaranteeing reproducibility of the test set  $T$  for any fixed  $R$ .

Verification was conducted through a comparative experiment on a REST API service with 5 endpoints and 12 business rules. API coverage: 88–92% vs. 72–78% (specification-based) and 55–82% (LLM-based). Standard deviation:  $\pm 2\%$  vs.  $\pm 3\%$  and  $\pm 12\%$ . Reproducibility: 0.97 vs. 0.95 and 0.62. Maintenance: 15–20% modified tests vs. 60–70% and 40–55%.

The proposed architecture targets software development teams practising API-First Development and Documentation-Driven Development. Results are applicable to Agile/DevOps environments with frequently changing requirements.

**Keywords:** API, testing, orchestration, API requirements, LLM, DevOps, CI/CD, architecture, automation, determinism.

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**DEVELOPMENT OF INFORMATION TECHNOLOGY OF OPERATOR-ORIENTED DIGITAL SPECTRAL TWIN WITH TWO-CIRCUIT LEARNING FOR SELECTIVE SPECTRAL IDENTIFICATION**

pages 41–52

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The object of research is spectral processes in plasma and multilayer optical structures.

The problem solved in the work is the insufficient accuracy of identification of physical parameters and the low resistance of classical spectral models to noise disturbances, model errors and technological uncertainties, which complicates the selective isolation of informative spectral components in real spectroscopic measurements.

The peculiarity of the obtained results is the introduction of a composite operator of a digital spectral twin, which combines a physical model, a spectral filter and a neurooperator, in a single mathematical structure. A two-loop hybrid model training algorithm has been developed, which provides consistent adaptation of both physical parameters and neurooperator parameters. The effectiveness of the developed training algorithm has been assessed and the adaptive properties of the model to external conditions have been investigated. The time dynamics of the model and the dependence of the parameter identification error on the noise level have been estimated. The model was tested on two typical synthetic films, for which the Root Mean Square Error (RMSE) was reduced by almost 6–7 times compared to the purely physical model (Transfer Matrix Method, TMM), and the parametric error was reduced by almost 3 times.

The testing of experimental data demonstrated selective identification of the dominant spectral lines of the electrode material against the background of contributions from impurity components. It was shown that the physical component of the model provides the correct localization and shape of the spectral lines of the electrodes, while the neurooperator compensates for residual spectral deviations. The practical significance of the results obtained lies in increasing the accuracy of spectral identification, automation of parametric synthesis, calibration of spectroscopic systems, and creation of adaptive digital twins in the tasks of diagnostics and design of optical and plasma systems.

**Keywords:** information technology, digital twin, operator model, spectroscopy, parameter synthesis, regularization, spectral information content, multilayer structures.

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**ADVANTAGES OF THE END-TO-END HYBRID AWRED ARCHITECTURE IN TERMS OF THE EFFICIENCY OF VISUAL ANOMALY DETECTION UNDER CONDITIONS OF TRAINING DATA DEFICIENCY COMPARED WITH THE CLASSICAL CNN + ONE-CLASS SVM ENSEMBLE**

pages 53–59

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The object of research is the process of detecting visual anomalies in images under conditions of reduction of the training sample and class imbalance, relevant for visual monitoring systems of IT infrastructure and telecommunication equipment, including recognition of microcracks on printed circuit boards, corrosion on antennas, and damages of fiber-optic lines. The problem lies in the fact that with a small volume of training data two-stage approaches lose stability, reducing defect recognition accuracy. This concerns schemes in which a convolutional autoencoder is combined with an external classifier One-Class SVM. Under such conditions, the latent representation is formed with lower quality, and the ranking of anomalies becomes less reliable.

As an alternative, the Hybrid AWRED v4 architecture was used, in which anomaly detection is performed directly in the space of reconstruction errors without an external classifier. The approach is based on an objective function that combines dynamic weighting and an adaptive cutoff threshold.

The verification was carried out on three datasets of 800, 107, and 54 images. For each dataset, eight runs were performed. On the sample  $N = 800$ , the CNN + AWRED architecture showed better *Precision*, *F1-Score*, and *MCC* than the CNN + SVM ensemble. At  $N = 107$ , the advantage of the proposed approach was manifested in AUC-ROC and AP.

For the micro-sample  $N = 54$ , the threshold metrics of both approaches were close, while AUC-ROC and AP remained higher in the baseline model. This indicates that with such a data volume both approaches approach the limit of their effectiveness without additional expansion of the sample. It was established that Hybrid AWRED reaches the early stopping criterion earlier, and its heat maps form clearer zones in defect areas. The approach is promising for automation of visual control under deficit of training data.

**Keywords:** end-to-end architecture, Hybrid AWRED, One-Class SVM, dynamic weighting, class imbalance, visual control.

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## DEVELOPMENT OF AN ADAPTIVE DATA PROVENANCE CONTROL METHOD FOR RESOURCE-AWARE REAL-TIME STREAM PROCESSING

pages 60–65

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The object of research is the process of managing data provenance in real-time stream processing systems. The subject of research is an adaptive data provenance method for resource-aware stream processing in Apache Flink, which changes provenance granularity at runtime without affecting business results.

The problem addressed is how to maintain explainable provenance for anomaly detection or auditing while avoiding system resource overload from always-on, fine-grained data provenance.

The significance of the results obtained is a provenance level controller driven by live CPU and heap memory usage metrics. Its scientific novelty lies in a three-level logic (detailed, summary, none) that dynamically adjusts the provenance level without interrupting the pipeline. Performance was evaluated on 5000 simulated IoT sensor workloads with 60-second processing windows and a target of 15000 records per second under 3-, 15-, and 30-minute runs.

These results indicate that the suggested method maintains throughput close to the no-provenance baseline while significantly reducing CPU cost compared to full provenance. For equal workloads, adaptive runs consume roughly 3–4 times the baseline CPU, whereas full provenance requires about 6–9 times the baseline CPU, because the controller demotes provenance under pressure and restores detailed mode only when resources are recovered. Heap usage is a weaker control signal because it reflects only part of the total memory and can change when the runtime periodically frees unused memory.

The proposed method is most useful during anomalies, incidents, or audits where selective, on-demand provenance is needed. This adaptability makes it highly suitable for IoT gateways, edge devices, and regulated industries operating under strict resource constraints.

**Keywords:** stream processing, data provenance, Apache Flink, distributed systems.

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## SYSTEMS AND CONTROL PROCESSES

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### DEVELOPMENT OF PROJECT MANAGEMENT MECHANISMS FOR THE CONSTRUCTION AND OPERATION OF TRANSPORT SHIPS ON INLAND WATERWAYS OF UKRAINE IN POST-WAR RECONSTRUCTION

pages 66–74

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The object of research is the process of project management of transport ships on the inland waterways of Ukraine. The subject of the research is a set of theoretical, methodological and applied aspects of the formation of project management mechanisms in the shipbuilding cluster system. The article solves the problem of restoring the competitiveness of inland waterway transport in Ukraine. The essence and features of cluster systems are revealed. Mechanisms for organizing a shipbuilding cluster for the construction of transport ships on the inland waterways of Ukraine are proposed. A feature of cluster systems is the participation of business structures, government bodies and scientific centers in them. It is proposed to organize in the cluster structure: a logistics center that will ensure the implementation of logistics tools; a dual form of training that will facilitate the transition to a qualitatively new level of training of workers and specialists for the industry; a project office that implements project management functions within a single information system and provides communication between projects. The results obtained are a tool for ensuring the competitiveness of enterprises in the shipbuilding industry. The cluster system is a functionally distributed logistics network that will develop both in the domestic and international transport markets. Modern logistics tools allow to build an effective system of material support for enterprises that are part of the cluster. The range of functions that the logistics center implements requires constant analysis at all stages of the life cycle of building a cluster. The proposed structure of cluster integration of enterprises in the shipbuilding industry will allow to link the project structure and the organizational structure of project portfolio management into a single comprehensive information tool in specialized project management software.

**Keywords:** project management, cluster system, shipbuilding cluster, water transport, dual education, logistics providers.

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## DEVELOPMENT OF A SIMULATION MODEL AND TESTING METHODOLOGY FOR FREQUENCY CONTROL SYSTEMS OF AN INDUCTION DRIVES USING SINAMICS G220 AND DIGITAL TWIN TECHNOLOGY

pages 75–90

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The object of research is information processes of control in Sinamics G220 frequency converters with an induction drive. The research problem lies in the need to develop simulation models of components of control systems for technological objects, as well as to design methodology and implement procedures for their testing based on Digital Twin technology.

A functional scheme of a Sinamics G220 simulation model with an integrated induction drive has been developed in the TIA Portal environment. A project of a frequency control system for a 5.5 kW induction drive has been developed through parameterization, and setup of the communication environment based on Simatic S7 tools. Procedures for parameterization and Digital Twin generation were applied to create a virtual Sinamics G220 with an integrated induction drive.

The functionality of the operating modes of the Digital Twin has been defined and implemented, involving the application of the following variable parameters of rotational speed and mechanical load:

- Speed setpoint (1000 rpm and 2950 rpm with a period of 20 s);
- Ramp Function Generator (1.0 s "Up" and 1.0 s "Down");
- Constant load torque (0.95 and 0.75 p. u.).

A procedure for setting the "Speed setpoint" via virtual digital inputs has been implemented for the operating modes "Setpoint channel", "Fixed setpoint", and "Binary", providing 16 predefined "Speed setpoints".

Testing of the Digital Twin was carried out using the built-in WEB server for two parameter sets with switched "Speed setpoints" and variable mechanical load "Constant load torque". The testing results confirmed the adequacy of the simulation model's response to changes in input parameters and operating modes of the Digital Twin of the Sinamics G220.

The obtained results are of practical significance for the commissioning of frequency control systems for induction drives using Sinamics G220.

**Keywords:** control system, Sinamics G220 frequency converter, induction drive, simulation model, Digital Twin.

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## DEVELOPMENT OF A METHOD FOR DETERMINING THE WEAR OF AN ARTILLERY MOUNT BARREL UNDER CONDITIONS OF UNCERTAIN DISTURBANCES BASED ON FUZZY LOGIC AND STOCHASTIC MODELING

pages 91–100

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The object of research is the processes of determining the wear of gun barrels and controlling the firing of artillery mounts under conditions of uncertain disturbances. This work addresses the problem of ensuring the adequacy of determining the current wear of the barrel and adaptive adjustment of the settings of the artillery mount when firing in short series from different positions. At the same time, the research considered the effect of random disturbing influences on the mount, including the failure of the projectile leading belt and the low quality of the powder charge.

The research used fuzzy logic methods to calculate the current value of barrel wear based on the parameters of the ballistic wave of the shot and taking into account the total gun firing. Also, stochastic modeling methods, in particular, Markov chains, were used to simulate the processes of firing under conditions of random disturbances.

A method for determining the current barrel wear based on fuzzy logic has been developed and investigated, which allows for adaptive adjustment of artillery mount settings when firing in short bursts under conditions of uncertain disturbances. To correctly determine wear, the proposed method uses three information channels, including the dominant frequency and depth of frequency modulation of the ballistic wave, as well as the total gun firing rate.

The results of computational experiments were obtained, confirming the high efficiency of the developed method in comparison with other known methods. In particular, an increase in firing efficiency by 14.5% and a reduction in the time spent at firing positions by 3 min. were achieved when compared with the most effective method using measurements of the dominant frequency of the ballistic wave.

The developed method can be used for diagnostics and control of modern artillery systems to increase firing efficiency and reduce the time spent at firing positions.

**Keywords:** artillery firing, barrel wear determination, fuzzy logic, rule base, stochastic modeling.

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**EXPERIMENTAL IDENTIFICATION OF UNMANNED AERIAL VEHICLE MODEL PARAMETERS BASED ON THE OPERATOR CONTROL SIGNAL AND THE OBJECT RESPONSE**

pages 101–112

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The object of research is the process of identifying the parameters of the model of a separate channel of motion of an unmanned aerial vehicle (UAV). The paper addresses the problem of obtaining an accurate and simple computational procedure for estimating the time constant and damping coefficient of a UAV model represented as a second-order dynamic element, suitable for implementation in programmable controllers without the use of matrix libraries. The method is designed for implementation in programmable controllers without the use of matrix libraries. The identification procedure was developed using a dataset that includes 500 experimental UAV motion trials performed by operators in a computer-based simulator. The model parameters cover damping ratios in the range from 0.25 to 1.25 with a fixed time constant of 0.5 s. The obtained results provide an analytical calculation of the model parameters. Based on the theory of linear dynamic systems and the least squares method, the differential equation of the second-order system is transformed into a linear regression form. This is done using central finite differences to compute the first and second derivatives of the output signal. The parameter estimation is performed analytically, without using specialized software functions. This ensures compatibility with programmable logic controllers. To reduce sensitivity to noise during numerical differentiation, the experimental data are pre-smoothed. The analysis interval is limited to the dominant part of the transient response. The identified parameters show good agreement with the true model values. The relative error does not exceed 0.8% for the time constant and 1.2% for the damping ratio. The results can be used for PID controller autotuning and for the synthesis of adaptive control laws for UAVs. The identification procedure can be extended to online parameter estimation during flight, as well as to higher-order and nonlinear dynamic models.

**Keywords:** identification, second-order dynamic model, UAV, model parameters, programmable controller.

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- DOI: 10.15587/2706-5448.2026.363099
- DEVELOPMENT OF REGRESSION TECHNOLOGY FOR ASSESSING THE STATE OF SEMI-MARKOV SYSTEMS UNDER CONDITIONS OF A SMALL SAMPLE OF INITIAL DATA**
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The object of research is to assess the state of semi-Markov systems in conditions of a small sample of initial data.

This paper addresses the problem of assessing the state of a multi-element multifactorial stochastic object under conditions of a small sample of fuzzy initial data. Known methods for solving similar problems are ineffective in practical conditions of a small sample of initial data. A real possibility for identifying the relationship between explanatory and explained variables lies in the use of artificial orthogonalization of the results of a passive experiment. In this case, a full factorial experiment design is constructed, the most important property of which is orthogonality. This makes it possible to independently evaluate all the coefficients of the regression equation, which determine the degree of influence of factors and all their interactions on the value of the explained variable. This is achieved through the development of a technology for artificial orthogonalization of a passive experiment and a method for processing the resulting full factorial experiment design. The resulting heterogeneity of the full design is mitigated by finding a truncated representative orthogonal subdesign. The research resulted in a method that enables the calculation of all coefficients of the full regression equation with a small sample of initial data. This method provides a more accurate solution to the problem compared to known methods. The universality of the method lies in the fact that it is implemented in the same way for any set of objective functions. The ability of this method to overcome the computational complexity arising from the large dimensionality of relevant problems allows it to be applied in a wide range of practical areas. The proposed methodology is illustrated step by step by solving an example.

**Keywords:** semi-Markov systems, regression polynomial, small sample, artificial orthogonalization, representative subdesign.

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### DEVELOPING AN ONTOLOGY-MEDIATED SEMANTIC CONTROL METHOD FOR IMPROVING THE RELIABILITY OF LLM-GENERATED INFRASTRUCTURE-AS-CODE

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The object of research is an LLM-assisted process of Infrastructure-as-Code (IaC) generation for cloud deployment. The problem is that large language models can convert user requests into syntactically valid IaC, but such generated IaC fails deployment. This occurs because such artefacts often omit required cloud relations or violate policy constraints, inaccurately interpret user intent, or lack rollback logic. As a result, the research proposes a Semantic Infrastructure-as-Code (SIaC) pipeline, where instead of a final IaC, the LLM first generates a candidate infrastructure graph. Further, this graph is completed and validated using ontology reasoning, SHACL/SPARQL validation, and other formal procedures before the generation of the final backend artifact. According to the 60 AWS ECS/Fargate-oriented scenarios that were tested in a LocalStack-based AWS emulation environment, Full SIaC achieved 74.4% sandbox deployment success, compared with 43.6% for direct LLM-to-IaC and 59.0% for LLM + RAG-to-IaC. Compared with the baselines, SIaC improved semantic intent coverage, dependency completeness, and policy compliance. It also reduced invalid dependencies and the need for manual corrections. This improvement is achieved because reliability is checked through an inspectable knowledge graph, not only through prompts and generated text. This graph supports the detection and correction of dependencies, placements, policies, and safety issues before deployment. In addition to higher deployment success, SIaC also provides a more controllable and manageable transformation path from natural-language intent to executable infrastructure.

This method is suitable if the user's requirements can be mapped to the maintained provider ontologies and if the additional time spent on analysis is considered an acceptable trade-off for improved reliability, auditability, and reduced maintenance.

**Keywords:** Semantic Infrastructure-as-Code, infrastructure graph, semantic control, SHACL/SPARQL validation, dependency completeness.

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