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METHOD FOR FORMING INFORMATION SERVICES BASED ON THE FUNCTIONAL COMPONENTS OF AN INFORMATION TECHNOLOGY PLATFORM

Modern information technology platforms support complex digital environments by integrating information resources, technological infrastructure, analytical components, information services, users, and intelligent agents. However, existing approaches to information service formation are primarily based on software component composition and insufficiently consider the functional structure of the platform, the relationships among its components, and the development patterns of the information technology ecosystem. The purpose of this study is to develop a method for forming information services based on the functional components of an information technology platform by defining methodological principles, formalizing the component composition process, and constructing a conceptual model for digital service formation. The research methodology is based on systemic, service-oriented, and ecosystem approaches, structural-functional analysis, conceptual modeling, and formalization of information service construction processes. Particular attention is paid to establishing relationships among functional requirements, technological and analytical components, interaction scenarios, and digital services. The results include the development of a method that provides a consistent transition from functional requirements to component composition, information service formation, and their integration into interaction scenarios involving users and intelligent agents. The methodological principles of functional completeness, requirement alignment, scenario orientation, composability, loose coupling, reusability, interoperability, adaptability and personalization, controlled autonomy, and security by design are formulated. The scientific novelty lies in the development of a method that establishes a cause-and-effect relationship between the functional components of an information technology platform, the principles of their composition, and the resulting digital services. The practical significance of the proposed method lies in its applicability to the design of information technology platforms for smart cities, digital twins, decision-support systems, research information systems, and multi-agent environments. Future research will focus on automating service composition, evaluating service quality, and integrating generative artificial intelligence into the information service formation process.

Keywords: information technology platform; information services; digital services; functional components; service composition; service-oriented architecture; conceptual model; intelligent agents; information technology ecosystem; formation method.

Introduction

Digital services should not be formed merely as external representations of existing software functions. Instead, their composition and purpose should be determined by functional requirements, available technological and analytical components, interaction scenarios, and the needs of target actors. In this context, users and intelligent agents act as active participants in information processes rather than merely as consumers of the generated results; they can formulate requests, invoke services, compose service outputs, and generate new data. This necessitates considering the principles of scenario orientation, composability, interoperability, personalization, controlled autonomy, and security by design when forming the platform's service subsystem.

Unlike existing approaches, the proposed method considers digital services not as derivatives of specific software implementations but as the result of composing functional requirements, technological and analytical components, and interaction scenarios. This approach provides a causally justified service configuration and ensures its independence from a particular technology stack.

Problem Statement

Modern information technology platforms provide the foundation for complex digital environments in which information resources, technological infrastructure, analytical components, information services, users, and intelligent agents are integrated. The effectiveness of such platforms is determined not only by the organization of their architectures but also by their ability to form information services that support functional processes, decision-making, and interaction among all participants of the information technology ecosystem.

In most existing approaches, information services are regarded as software modules or as outcomes of service-oriented architecture implementation, created through the integration of individual software components. Although this approach facilitates software reuse and improves software flexibility, it does not adequately consider the relationships among functional requirements, the structural components of an information technology platform, interaction scenarios, and the needs of users and intelligent agents. As a result, the process of information service formation often depends on the characteristics of specific software implementations, limiting their adaptability, scalability, and reusability across different application domains.

Therefore, an important scientific problem is the development of a method for forming information services that ensures a systematic transition from the functional requirements and structural components of an information technology platform to the composition of digital services, their interaction scenarios, and the collaboration of users and intelligent agents. Solving this problem is essential for improving the adaptability, scalability, and interoperability of modern information technology platforms while providing a methodological foundation for their further digital transformation and intelligent evolution.

Analysis of Recent Research and Publications

In recent years, one of the major research directions in the development of information technology platforms has been the formation of digital services capable of integrating heterogeneous information resources, analytical components, decision-support mechanisms, and intelligent interaction tools. The rapid advancement of cloud computing, service-oriented architectures, microservice technologies, artificial intelligence, and multi-agent systems has driven the transition from monolithic software applications to platforms whose functionality is implemented through the composition of digital services. However, the formal formation of information services based on functional requirements and the functional component configuration of an information technology platform remains insufficiently explored.

A significant contribution to the theory of digital platforms was made by Jovanovic, Sjödin, and Parida [1], who demonstrated that platform evolution results from the co-evolution of platform architecture, digital services, and governance mechanisms. Their study established the interdependence of these elements and identified different types of platform ecosystems. However, it does not address the formalized process of information service formation based on functional requirements and the functional component structure of an information technology platform.

Another important research stream is represented by studies on digital servitization and multi-platform ecosystems. Ahmed and Kowalkowski [2] investigated the role of digital platforms in enabling innovative digital services within multi-platform environments. Their findings indicate that digital services emerge through the interaction of ecosystem participants, platforms, and organizational coordination mechanisms. Nevertheless, service composition is considered primarily from an organizational perspective, without formalizing the transition from functional requirements to the composition of information services.

A separate line of research focuses on data-driven digital servitization. Smania, Ayala, Coreynen, and Mendes [3] presented the systematic literature review «Data-related Tensions in Digital Servitization Ecosystems», which summarizes the challenges associated with data integration, data governance, interoperability, security, and lifecycle management of information resources within service ecosystems. The authors demonstrate that the quality of digital services strongly depends on the organization of information flows and data management mechanisms. However, they do not propose a methodology for composing information services from technological and analytical components.

Goertler, Papert, Fischer, and Schmidt [4] investigated the evolution of digital platform ecosystems from a design perspective, demonstrating that platform development is driven by the interaction of architectural decisions, data-processing capabilities, user requirements, and service innovation. Their study identifies the principal design topics of platform ecosystems. However, it does not formalize the derivation of information services from functional requirements and interaction scenarios.

Gill and Hansnata [5], together with de Reuver, Ofe, Agahari, Abbas, and Zuiderwijk [6], investigated adaptive digital ecosystems and data platforms, while recent studies on intelligent digital platforms increasingly consider intelligent agents as active participants in service interactions. These studies demonstrate the growing importance of autonomous service orchestration and platform intelligence. Nevertheless, they focus primarily on architectural and implementation aspects rather than on the formal relationships among functional requirements, platform components, and information services.

Therefore, the analysis of recent studies indicates that the majority of existing research focuses on platform ecosystems, digital servitization, digital platform architectures, and service innovation. Considerably less attention has been paid to the methodological aspects of forming information services based on functional requirements, technological and analytical components, and interaction scenarios involving users and intelligent agents. Moreover,

virtually no studies describe this process as a formal methodological framework consisting of mapping operators, traceability relationships, and service composition principles that consistently transform functional requirements into information services. Addressing this methodological gap constitutes the primary objective of the present study.

Kolagar, Reim, Parida, and Sjödin [7] investigated digital servitization strategies for SME internationalization, demonstrating that the successful development of digital services depends on the interplay between digital service maturity and ecosystem involvement. However, the proposed approach focuses on strategic aspects of digital servitization rather than on the formal formation of information services from functional requirements and platform components.

Costabile [8] together with Nerbel and Kreutzer [9] analyzed the evolution of digital platform ecosystems, governance mechanisms, and digital servitization. Their studies identify the principal technological drivers of digital platforms and emphasize the growing importance of digital services as mechanisms for value creation. However, they do not propose a formal methodology describing how information services should be systematically derived from functional requirements and component configurations.

Sklyar, Kowalkowski, Tronvoll, and Sörhammar [10] analyzed organizational changes required for digital servitization from a service ecosystem perspective. Their work demonstrates that successful digital services depend on coordinated interactions among multiple ecosystem actors and organizational capabilities. However, the proposed perspective primarily addresses organizational transformation rather than the formal composition of information services from functional components.

Another emerging research direction focuses on the systematic analysis of digital servitization. Davies, Liu, Cooper, and Xing [11] investigated the relationships between supply chains, ecosystems, and digital servitization, showing that ecosystem collaboration, value co-creation, and inter-organizational coordination are essential for the successful deployment of digital services. Their systematic review advances the understanding of service ecosystems and identifies future research directions in ecosystem design and governance. However, the proposed approach remains focused on organizational interactions and does not provide a formal methodology for deriving information services from functional requirements, platform components, and interaction scenarios. Recent systematic literature reviews summarize the evolution of digital servitization research, identify the principal technological drivers, and analyze their impact on organizational performance and innovation. These studies confirm the increasing importance of digital services as mechanisms for creating value but also highlight the lack of formal methodologies describing how information services should be systematically derived from functional requirements and component configurations.

Finally, recent studies have increasingly focused on digital service innovation in multi-platform ecosystems. Duan, Eva, Andrews, and Liu [12] demonstrated that the performance of digital platform ecosystems depends on their configuration, coordination mechanisms, and service innovation. Their study extends the understanding of platform-enabled digital services but still considers them primarily as organizational capabilities rather than formally composed functional entities derived from platform requirements and component configurations. Ofe and de Reuver [13] investigated the impact of data artifact characteristics on data platform openness, demonstrating that it is jointly shaped by governance mechanisms and the intrinsic properties of data artifacts; however, their study does not address the formal derivation of information services from functional requirements and platform components. Adreani, Bellini, Fanfani, Nesi, and Pantaleo [14] proposed a digital twin framework for smart cities that enables real-time integration of heterogeneous data sources and digital services, demonstrating the importance of scalable service integration and interoperability; however, the proposed framework focuses on architectural implementation rather than on a formal methodology for forming information services from functional requirements and component configurations.

Therefore, the analysis of recent studies indicates that contemporary research primarily addresses digital platform ecosystems, digital servitization, ecosystem governance, service innovation, organizational transformation, and intelligent digital platforms. Considerably less attention has been devoted to the methodological foundations of information service formation based on functional requirements, technological and analytical components, interaction scenarios, and traceability relationships. Virtually no studies present this process as a unified formal methodology employing mapping operators, traceability relations, and composition principles that consistently transform data-driven functional requirements into executable information services. Addressing this methodological gap constitutes the primary objective of the present study.

Research objectives

The objective of this study is to develop a method for forming digital services through the composition of technological and analytical components derived from the functional requirements and functional component configuration of an information technology platform.

To achieve this objective, the following research tasks are addressed:

1. To improve the formalization of a digital service as a functionally complete form of implementing the capabilities of an information technology platform, to define its structure, design principles, and the role of interaction scenarios involving users and intelligent agents.
2. To develop a method for digital service composition based on functional requirements, technological and analytical components using mapping operators, traceability relationships, and scenario integration mechanisms.

3. To formulate the conditions of functional completeness and the evaluation criteria for digital services, ensuring the verification of their structural validity, compliance with functional requirements, consistency with interaction scenarios, and their potential for reuse.

Information service as a functional form of implementing the capabilities of an information technology platform

The technological and analytical components formed at the preceding stage of the study constitute the internal functional basis of the information technology platform; however, by themselves, they do not yet ensure the practical use of its capabilities. Users and intelligent agents access data, analytical processing results, forecasts, recommendations, and decision-support mechanisms through digital services. Therefore, the next stage of the proposed methodology is the formation of the service subsystem through the composition of functional requirements, technological and analytical components, and interaction scenarios.

Unlike approaches in which digital services are defined primarily according to the capabilities of existing software, the proposed method provides for their causally justified formation. Each service must have a traceable relationship with data properties, the functional requirements derived from them, the components that implement these requirements, and the scenarios for the practical use of the results.

A digital service of an information technology platform is understood as a functionally complete form of providing users or intelligent agents with the outputs of one or more technological and analytical components in accordance with defined functional requirements and interaction scenarios. In the present study, an information service is considered not as a separate software module or network service, but as a functional form of implementing the capabilities of an information technology platform. Its purpose is to support the execution of functional processes by integrating technological and analytical components in accordance with functional requirements, interaction scenarios, and the needs of the actors within the Information Technology Ecosystem.

A digital service may provide access to information resources, perform an analytical operation, monitor the state of objects, generate a forecast, recommendation, or alert, compare alternatives, initiate a management action, or coordinate interaction among platform actors. At the same time, the service conceals the internal complexity of the technological implementation and provides a standardized means of using the platform's functional capabilities through application programming interfaces, web applications, mobile applications, analytical dashboards, conversational interfaces, or machine-readable protocols. Let the set of digital services be denoted as $S = \{s_1, s_2, \dots, s_p\}$. The mapping operator responsible for the formation of digital services is defined as

$$\Gamma_S: (Q, TI, AN, SC) \rightarrow 2^S \quad (1)$$

where Q - is the set of functional requirements; TI - is the set of technological components; AN - is the set of analytical components; SC - is the set of interaction scenarios; 2^S - is the power set of S , representing all possible subsets of digital services.

The operator Γ_S formally represents the service formation process by establishing a mapping from functional requirements, technological and analytical components, and interaction scenarios to the corresponding set of digital services. Consequently, each digital service is interpreted as the result of a formally defined composition process rather than as an independent software implementation.

The use of the power set 2^S as the codomain of the mapping operator reflects the fact that a particular configuration of functional requirements, components, and interaction scenarios may give rise to not a single digital service but to a set of mutually related digital services. For an individual digital service $s_k \in S$, the service formation process can be specified as

$$s_k \in \Gamma_S(Q_k, TI_k, AN_k, SC_k)$$

where $Q_k \subseteq Q$ - is the subset of functional requirements satisfied by the service; $TI_k \subseteq TI$ - subseteq is the subset of technological components required for its implementation; $AN_k \subseteq AN$ - is the subset of analytical components whose outputs are utilized or provided by the service; $SC_k \subseteq SC$ - is the subset of interaction scenarios in which the service is employed.

According to the proposed method, a digital service is interpreted not as the result of an individual software component but as the outcome of the functional composition of functional requirements, technological components, analytical components, and interaction scenarios.

The composition and functional purpose of digital services are determined not only by data properties and the resulting functional components but also by the requirements of the platform actors. Let the set of interaction scenarios be denoted as $SC = \{sc_1, sc_2, \dots, sc_r\}$.

An interaction scenario is defined as a formalized description of a goal-oriented sequence of actions performed by a user or an intelligent agent. It specifies the actor, the objective, the execution context, the required input data, the sequence of operations, the expected outcome, time constraints, security requirements, and the form in which the result is presented.

An individual interaction scenario is represented as $sc_l = \langle a_l, g_l, x_l, op_l, y_l, \tau_l, sec_l \rangle$, where a_l - is the interaction actor; g_l - is the goal; x_l - is the input data; op_l - is the sequence of operations; y_l - is the expected outcome; τ_l - is the maximum allowable execution time; sec_l - denotes the security and access constraints. Interaction scenarios transform the general capabilities of technological and analytical components into functionally complete

digital services. For example, the existence of a forecasting component alone does not constitute an independent service. A digital service emerges only when it is specified who uses the forecast, for what purpose, which input data are required, in what form the result should be delivered, and within what time constraints it must be provided. For each interaction scenario $sc_l \in SC$, the set of digital services required for its execution can be defined as

$$\Omega_S(sc_l) = \{s_k \in S \mid (sc_l, s_k) \in R_{SC}\},$$

where $R_{SC} \subseteq SC \times S$ – is the traceability relationship between interaction scenarios and digital services.

An individual interaction scenario may require the composition of multiple digital services, while a single digital service may be utilized in multiple interaction scenarios. This many-to-many relationship provides the methodological basis for the modular and compositional organization of the platform's service subsystem, enabling service reuse, flexible service composition, and support for diverse interaction scenarios.

The formation of a digital service is based on the composition of technological and analytical components into a functionally complete configuration. Let the set of components constituting the digital service s_k be defined as $C_k = TI_k \cup AN_k$, where the technological components provide data acquisition, transmission, storage, routing, security, and availability, while the analytical components perform data cleansing, interpretation, modeling, forecasting, and the generation of information-value-oriented results.

The component composition operator is defined as $\Gamma_{CS}: 2^{C_{TA}} \times 2^S \rightarrow 2^S$, where $C_{TA} = TI \cup AN$. For an individual digital service $s_k = \Gamma_{CS}(C_k, SC_k)$. For example, a real-time monitoring service may be formed through the composition of a message broker, a stream processing engine, a time-series database, an anomaly detection component, a notification mechanism, and a visualization interface. Each of these components performs a specific function; however, only their coordinated composition results in a functionally complete digital service.

An individual component may be reused by multiple digital services. For example, a forecasting component may be incorporated into a monitoring service, a recommendation service, and a decision-support service. Therefore, for a component $c_j \in C_{TA}$, it is useful to define the set of digital services in which it is utilized as:

$$\Lambda_S(c_j) = \{s_k \in S \mid (c_j, s_k) \in R_{CS}\},$$

where $R_{CS} \subseteq C_{TA} \times S$ – is the traceability relationship between functional components and digital services. Conversely, the projection of a digital service onto its constituent functional components is defined as $\Gamma_C(s_k) = \{c_j \in C_{TA} \mid (c_j, s_k) \in R_{CS}\}$. This bidirectional representation ensures the traceability of the service composition process. For each digital service, the set of constituent components can be identified, while for each functional component, the digital services whose operation it supports can be determined.

Principles and formal conditions for information service formation

The proposed method is founded on a system of formally defined methodological principles. Each principle establishes a necessary condition for the formation of digital services and is expressed both conceptually and mathematically.

The formation of the service subsystem should be based on a set of interrelated methodological principles.

The *principle of scenario justification* states that each digital service shall be created to support at least one interaction scenario involving users or intelligent agents within the information technology platform. The existence of such a scenario is a necessary prerequisite for including a service in the platform, as it prevents the creation of functionally unjustified services.

Formally, this principle can be expressed as

$$\forall s_k \in S \exists sc_l \in SC: (sc_l, s_k) \in R_{SC},$$

where S – is the set of digital services; SC – is the set of interaction scenarios; $R_{SC} \subseteq SC \times S$ – is the traceability relationship between interaction scenarios and digital services.

The *principle of functional completeness* requires that a digital service implement either an entire interaction scenario or a complete functional capability whose outcome has independent practical value. The output of a digital service may include an information resource, an analytical indicator, a forecast, a recommendation, a notification, a risk assessment, or a management action.

$$Req(sc_l) \subseteq \Lambda_Q(s_k),$$

where $Req(sc_l)$ is the set of functional requirements associated with the execution of interaction scenario sc_l , whereas $\Lambda_Q(s_k)$, represents the set of functional requirements satisfied by digital service s_k .

This expression indicates that all functional requirements necessary for the execution of a given interaction scenario must be supported by the corresponding digital service.

The *principle of requirement alignment* states that the inclusion of every digital service in an information technology platform shall be justified by one or more functional requirements. A service that has no relationship with the set of functional requirements should not be included in the platform's functional configuration.

Accordingly, every digital service shall be formed to satisfy one or more functional requirements of the information technology platform. The inclusion of a service in the platform's functional configuration is justified only if its purpose is directly associated with the implementation of the corresponding functional requirements.

Formally, this principle is expressed as

$$\forall s_k \in S \exists q_i \in Q: (q_i, s_k) \in R_{QS},$$

where Q - is the set of functional requirements; S - is the set of digital services; $R_{QS} \subseteq Q \times S$ - is the traceability relationship between functional requirements and digital services. This expression indicates that every digital service must satisfy at least one functional requirement of the information technology platform.

The *principle of composability* ensures that complex digital services can be constructed through the composition of simpler functional components. A digital service shall therefore be formed by composing the technological and analytical components required to satisfy the specified functional requirements and interaction scenarios.

This approach enables the construction of complex digital services from reusable functional components, promotes the reuse of previously implemented modules, and facilitates the scalability of the platform's service subsystem. For example, a decision-support service may be formed through the composition of data acquisition, forecasting, risk assessment, alternative comparison, and visualization services.

Formally, this principle is defined as

$$\forall s_k \in S \exists C_k \in C_{TA}: s_k = \text{Comp}(C_k),$$

where S - is the set of digital services; $C_{TA} = TI \cup AN$ - is the set of technological and analytical components; C_k - is the subset of components used to form the digital service s_k ; $\text{Comp}(\cdot)$ - denotes the component composition operator. This expression indicates that every digital service is formed through the composition of one or more technological and analytical components required to realize its functional purpose.

The *principle of loose coupling* requires minimizing the dependence of a digital service on the internal implementation of its technological and analytical components. Replacing a data repository, an analytical algorithm, an integration mechanism, or any other component shall not require the reconstruction of the digital service, provided that the corresponding functional interfaces remain unchanged. This principle enables the independent evolution of individual components, simplifies platform modernization, and improves the adaptability of the information technology platform to changes in the technological stack.

Formally, this principle is expressed as

$$\forall c_i, c_j \in C_{TA} (\text{Interface}(c_i) = \text{Interface}(c_j)) \Rightarrow \text{Comp}(C_k \setminus \{c_i\} \cup \{c_j\}) \equiv \text{Comp}(C_k),$$

where $C_{TA} = TI \cup AN$ - is the set of technological and analytical components; $C_k \subseteq C_{TA}$ - is the subset of components composing the digital service; $\text{Interface}(c)$ - denotes the functional interface of component c ; $\text{Comp}(\cdot)$ - is the component composition operator; $\equiv$ denotes the functional equivalence of the resulting digital service. This expression indicates that replacing one component with another having the same functional interface does not alter the functional capabilities of the digital service.

The *principle of reusability* states that the functional capabilities of technological and analytical components, as well as the digital services formed from them, should be reusable across multiple interaction scenarios without duplicating software implementations.

This principle reduces software complexity, lowers maintenance costs, improves the consistency of the platform's functional capabilities, and facilitates the further evolution of the service subsystem.

Formally, this principle is defined as

$$\forall c_i \in C_{TA} \exists S_i \subseteq S, |S_i| \geq 1 : \forall s_k \in S_i, (c_i, s_k) \in R_{CS}$$

where C_{TA} - is the set of technological and analytical components; S - is the set of digital services; $R_{CS} \subseteq C_{TA} \times S$ - is the traceability relationship between functional components and digital services.

This expression indicates that a single technological or analytical component may be reused by multiple digital services, thereby supporting different interaction scenarios without requiring duplicate software implementations.

The principle of interoperability requires the use of standardized communication protocols, data formats, application programming interfaces, semantic descriptions, and metadata to ensure seamless interaction among digital services and with external information systems.

Accordingly, digital services shall support interoperable communication with one another and with external information systems through agreed communication protocols, data formats, application programming interfaces, semantic descriptions, and metadata. Compliance with this principle enables the exchange of data and analytical results among services without modifying their internal implementations and facilitates the integration of individual services into more complex service compositions.

Formally, the principle of interoperability is expressed as

$$\forall s_i, s_j \in S, i \neq j: \text{Compat}(s_i, s_j) = 1 \Rightarrow \text{Exchange}(s_i, s_j) \neq \emptyset$$

where S - is the set of digital services; $\text{Compat}(s_i, s_j)$ - is the compatibility function of digital services s_i and s_j ; $\text{Exchange}(s_i, s_j)$ — denotes the set of information exchanges that can be established between the two services. This expression indicates that whenever two digital services are compatible in terms of interfaces, communication protocols, data formats, semantic descriptions, and metadata, a correct information exchange between them shall be possible.

The compatibility function can be further specified as:

$$\text{Compat}(s_i, s_j) = \text{Prot}_{ij} \wedge \text{Form}_{ij} \wedge \text{API}_{ij} \wedge \text{Sem}_{ij} \wedge \text{Meta}_{ij},$$

where $Prot_{ij}$ - denotes communication protocol compatibility; $Form_{ij}$ - denotes data format compatibility; API_{ij} - denotes application programming interface compatibility; Sem_{ij} - denotes semantic compatibility of exchanged information; $Meta_{ij}$ - denotes metadata compatibility.

Thus, interoperability can be achieved only when digital services are compatible at the technical, structural, and semantic levels. This prevents situations in which information can be transmitted successfully between services but is interpreted incorrectly because of differences in data structures, terminology, or domain models.

The *principle of adaptability and personalization* requires that the composition of information resources, the presentation format, the level of detail, the notification frequency, and the recommended actions be adapted to the role, operational context, and information needs of the interaction actor.

Accordingly, digital services shall adapt their behavior to the characteristics of interaction actors by providing personalized information, recommendations, and functional capabilities according to their roles, current contexts, and information needs. Adaptation may include the selection of information resources, presentation formats, levels of detail, notification frequency, available functions, and recommended actions. This approach improves the effectiveness of digital services, reduces information overload for both users and intelligent agents, and facilitates well-informed decision-making.

Formally, this principle is expressed as

$$A = U \cup AI, \forall a \in A, Conf(s_k, a) = f(Role(a), Context(a), Needs(a)),$$

where A - is the set of interaction actors; U - is the set of users; AI - is the set of intelligent agents; $Conf(s_k, a)$ - denotes the functional configuration of the digital service s_k , for the interaction actor a ; $Role(a)$ - is the role of the actor within the information technology platform; $Context(a)$ - denotes the actor's current operational context; $Needs(a)$ - is the set of the actor's information needs; $f(\cdot)$ - denotes the service adaptation function.

This expression indicates that the configuration of a digital service depends on both its internal structure and the characteristics of the specific interaction actor. Depending on the actor's role, current context, and information needs, the service may dynamically adjust the set of available functions, the information resources provided, the level of data detail, the presentation format, the notification frequency, and the recommended actions.

The *principle of controlled autonomy* defines the conditions under which digital services may be invoked by intelligent agents. Autonomous service invocation shall be accompanied by authorization verification, policy compliance checking, audit logging, result explainability, and human review of critical decisions.

Accordingly, intelligent agents shall be permitted to autonomously invoke digital services, formulate requests, compose functional capabilities, and utilize service outputs only in compliance with established security and governance policies. Every autonomous service invocation shall include agent authorization, verification of policy compliance, audit logging, result explainability, and the transfer of critical decisions for human review. This approach enables the safe utilization of intelligent agents while preserving the controllability of the information technology platform.

Formally, this principle is expressed as

$$\forall a \in AI, \forall s_k \in S: Invoke(a, s_k) \Rightarrow Auth(a) \wedge Policy(a, s_k) \wedge Audit(a, s_k) \wedge Explain(s_k) \wedge HumanReview(s_k),$$

where AI - is the set of intelligent agents; S - is the set of digital services; $Invoke(a, s_k)$ - denotes the invocation of digital service s_k by intelligent agent a ; $Auth(a)$ - denotes agent authorization; $Policy(a, s_k)$ - denotes verification of compliance with access and governance policies; $Audit(a, s_k)$ - denotes audit logging of the service invocation; $Explain(s_k)$ - denotes the explainability of the generated result; $HumanReview(s_k)$ - denotes the submission of critical results for human confirmation or review.

This expression indicates that autonomous invocation of a digital service by an intelligent agent is permitted only when all required control mechanisms ensuring security, traceability, and explainability are simultaneously satisfied.

The *principle of security by design* requires that authentication, authorization, data protection, access control, audit, and logging mechanisms be incorporated during the formation of a digital service rather than added after its implementation.

Accordingly, authentication, authorization, data protection, access control, audit, and logging mechanisms shall be incorporated into the digital service during its formation. This approach ensures that security requirements are considered when defining the technological and analytical components of the service, its interfaces, interaction scenarios, and access policies.

Formally, this principle is expressed as

$$\forall s_k \in S: Security(s_k) \subseteq Design(s_k),$$

where S - is the set of digital services; $Security(s_k)$ - denotes the set of security mechanisms associated with digital service s_k ; $Design(s_k)$ - denotes the set of design decisions defining the structure, components, interfaces, and operational rules of the service. This expression indicates that security mechanisms shall be integrated into the design decisions during the service formation stage.

The relationship between this principle and the platform's component configuration is further specified as:

$$Security(s_k) \subseteq C_k \subseteq CC,$$

where $C_k = TI_k \cup AN_k$ - is the set of technological and analytical components composing digital service s_k ; CC - denotes the component configuration of the information technology platform. This expression indicates that the required security mechanisms shall be included within the service components, while the corresponding security-related components shall be incorporated into the platform's component configuration.

The set of security mechanisms associated with a digital service is defined as

$$Security(s_k) = \{Auth_k, AuthZ_k, Access_k, Protect_k, Audit_k, Log_k\},$$

where $Auth_k$ - denotes authentication mechanisms; $AuthZ_k$ - denotes authorization mechanisms; $Access_k$ - denotes access control mechanisms; $Protect_k$ - denotes data protection mechanisms for storage and transmission; $Audit_k$ - denotes audit mechanisms; Log_k - denotes event and activity logging mechanisms.

$$Security(s_k) \subseteq C_k \subseteq C_{TA}, \quad C_{TA} = TI \cup AN,$$

where C_{TA} constitutes part of the platform's component configuration CC .

Thus, security is regarded as an integral part of digital service design, and the required protection mechanisms are incorporated into the component foundation of the service before implementation begins. This establishes a traceable relationship among security requirements, the platform's component configuration, and the digital services formed on its basis.

The above principles constitute the methodological foundation for the formation of the service subsystem of an information technology platform. Their combined application ensures consistency among functional requirements, the component configuration, and digital services, regardless of the application domain. Unlike traditional descriptive presentations of digital service design principles, the proposed methodology represents each principle using a unified three-level structure verbal definition $\rightarrow$ formal mathematical expression $\rightarrow$ interpretation. This approach ensures an unambiguous interpretation of the principles, increases the rigor of their application, and establishes a coherent mathematical framework for the proposed methodology. Consequently, the principles serve not merely as design recommendations but as formal methodological provisions that define the conditions for the formation, interaction, and evaluation of digital services.

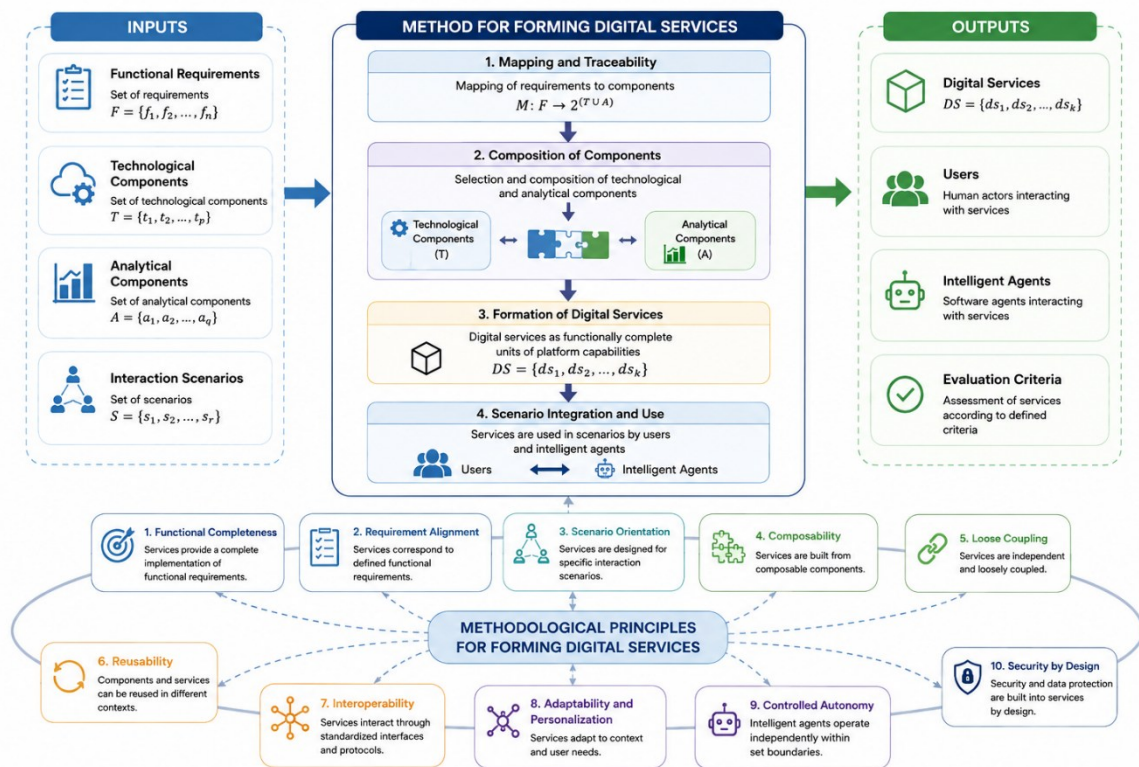


Fig. 1. Conceptual framework for forming digital services of an information technology platform

Classes of information services

Depending on their functional purpose, the following classes of information services can be distinguished within the set S .

Information Access Services provide search, retrieval, browsing, filtering, aggregation, and access to information resources, data, and metadata. This class includes electronic catalogs, information retrieval systems, open data services, and services for obtaining the current state of monitored objects.

Integration services support interaction between internal and external information systems, including data format transformation, synchronization, message routing, application programming interface management, and message exchange.

Analytical services perform statistical analysis, classification, clustering, forecasting, pattern recognition, optimization, semantic analysis, and behavioral analysis. Their outputs include analytical indicators, patterns, models, assessments, and forecasts.

Monitoring services continuously observe the state of monitored objects, information flows, technological components, or domain-specific indicators, generating notifications about anomalies, critical events, and threshold violations.

Recommendation services generate personalized recommendations, ranked alternatives, information content, or action scenarios based on the goals, operational context, and profile of the interaction actor.

Decision-support services integrate analytical results, evaluation criteria, domain-specific rules, and scenario models to support alternative comparison, risk assessment, recommendation generation, and explanation of proposed decisions.

Management services support the initiation and execution control of actions, as well as the management of processes, parameters, resources, and platform configurations.

Intelligent agent interaction services provide machine-readable interfaces that enable intelligent agents to obtain contextual information, invoke tools, execute analytical operations, coordinate interactions with other agents, and exchange results among automated actors.

The set of digital services can be represented as

$$S = S^{\text{inf}} \cup S^{\text{int}} \cup S^{\text{an}} \cup S^{\text{mon}} \cup S^{\text{rec}} \cup S^{\text{dss}} \cup S^{\text{man}} \cup S^{\text{agent}}$$

This classification is functional in nature and does not preclude a complex digital service from belonging to multiple classes simultaneously.

Users and intelligent agents as interaction actors

Users (UUU) and intelligent agents (AIAIAI) are active participants in digital service provision: they determine service functionality, formulate requests, provide input data, evaluate service outputs, and initiate new information processes.

For users, a digital service shall take into account their role, access privileges, professional context, information needs, level of expertise, and the preferred form of presenting results. The same analytical result may therefore be presented to an operator as an alert, to an analyst as a detailed set of analytical indicators, and to a manager as a high-level recommendation.

Intelligent agents interact with digital services through formalized machine-readable interfaces. They are capable of autonomously retrieving data, constructing sequences of service invocations, combining the outputs of multiple services, generating recommendations, and initiating subsequent actions. Consequently, digital services intended for intelligent agents shall provide formal descriptions of input and output parameters, operational constraints, available operations, confidence levels associated with generated results, and escalation rules for transferring critical decisions to human users.

The set of actors authorized to use the digital service s_k is defined as

$$A_k = U_k \cup AI_k,$$

where $U_k \subseteq U$ is the set of users of the digital service; $AI_k \subseteq AI$ is the set of intelligent agents authorized to invoke the service.

Traceability of digital service formation

A methodologically justified digital service shall possess a complete traceability chain linking data properties to its practical use within an interaction scenario:

$$v_i \rightarrow q_j \rightarrow c_l \rightarrow s_k \rightarrow sc_r.$$

This chain indicates that a data property $v_i \in V_D$ gives rise to a functional requirement $q_j \in Q$; the functional requirement is implemented by a functional component $c_l \in C_{TA}$; the component is incorporated into the digital service $s_k \in S$; and the digital service supports the execution of the interaction scenario $sc_r \in SC$.

The overall logic of the proposed methodology can therefore be represented as

$$V_D \xrightarrow{f_Q} Q \xrightarrow{(f_{TI}, f_{AN})} (TI, AN) \xrightarrow{f_S} S.$$

Thus, the service subsystem is not formed independently but results from a successive mapping process in which data properties are transformed into functional requirements, functional requirements into technological and analytical components, and these components, together with interaction scenarios, into digital services. Consequently, digital services are interpreted not as isolated software artifacts but as the final outcome of a traceable methodological process that successively transforms data properties into functional requirements, functional components, and ultimately into executable service capabilities.

Not all functional requirements need to be exposed directly to users or intelligent agents as independent digital services. Internal infrastructure requirements, such as redundancy, logging, or load balancing, may be implemented as intrinsic properties of the platform's internal components. Therefore, let

$$Q_{\text{app}} \subseteq Q$$

denote the set of application-level functional requirements whose functionality shall be made available to interaction actors in the form of digital services.

A necessary condition for the functional completeness of the service subsystem is

$$\forall q_i \in Q_{app} \exists s_k \in S: (q_i, s_k) \in R_{QS}$$

where

$$R_{QS} \subseteq Q_{app} \times S$$

is the traceability relationship between application-level functional requirements and digital services.

Conversely, every digital service shall be functionally justified:

$$\forall s_k \in S \exists q_i \in Q_{app}: (q_i, s_k) \in R_{QS}$$

Furthermore, every functionally complete digital service shall support at least one meaningful interaction scenario:

$$\forall s_k \in S \exists sc_i \in SC: (s_k, sc_i) \in R_{SC}$$

Consequently, a digital service is considered valid within the proposed methodology only if it simultaneously satisfies an application-level functional requirement, is realized through a defined configuration of technological and analytical components, and supports at least one interaction scenario.

After a digital service has been formed, its compliance with functional, technological, and operational requirements shall be evaluated. For the digital service s_k , let the evaluation criteria vector be defined as

$$E(s_k) = (e_k^{\text{fun}}, e_k^{\text{acc}}, e_k^{\text{time}}, e_k^{\text{avail}}, e_k^{\text{scal}}, e_k^{\text{int}}, e_k^{\text{sec}}, e_k^{\text{exp}}, e_k^{\text{usab}}, e_k^{\text{reuse}}),$$

where e_k^{fun} - denotes functional completeness; e_k^{acc} - denotes accuracy and correctness of results; e_k^{time} - denotes timeliness and response time; e_k^{avail} - denotes availability and reliability; e_k^{scal} - denotes scalability; e_k^{int} - denotes interoperability; e_k^{sec} - denotes security; e_k^{exp} - denotes explainability of results; e_k^{usab} - denotes usability for both users and intelligent agents; e_k^{reuse} - denotes reusability and composability.

A digital service is considered acceptable if $\forall e_{kh} \in E(s_k): e_{kh} \geq \theta_{kh}$, where θ_{kh} - denotes the minimum acceptable value of the corresponding evaluation criterion.

For mission-critical digital services, additional requirements may be imposed, including fault tolerance, redundancy, auditing, control of autonomous actions performed by intelligent agents, and mandatory human confirmation of critical decisions. Accordingly, the proposed evaluation model provides a unified framework for assessing both the functional quality of digital services and their operational readiness for deployment within an information technology platform.

Method summary

The outcome of the third stage of the proposed methodology is the set of digital services S , formed through the composition of functional requirements, technological and analytical components, and interaction scenarios. Each digital service possesses a traceable origin, a well-defined component configuration, identified target actors, a clearly specified functional purpose, and formally defined evaluation criteria.

In general, the proposed method for forming digital services can be represented as

$$(Q, \mathcal{T}, AN, SC) \xrightarrow{\Gamma_S} S.$$

Thus, the service layer provides the transition from the internal functional configuration of the Information Technology Platform to the practical capabilities made available to users and intelligent agents.

The distinguishing feature of the proposed method is that digital services are neither defined arbitrarily nor derived solely from the available technological infrastructure. Instead, each digital service is determined by the underlying data properties, justified by functional requirements, implemented through the composition of technological and analytical components, and designed to support specific interaction scenarios.

The proposed methodology integrates all previous stages into a single formal transformation chain:

$$CT \rightarrow V_D \xrightarrow{\Gamma_Q} Q \xrightarrow{(\Gamma_{\mathcal{T}}, \Gamma_{AN})} (\mathcal{T}, AN) \xrightarrow{\Gamma_S} S \rightarrow FC \rightarrow EV, \quad (2)$$

where CT - domain context; V_D - fundamental data properties; Q - functional requirements; $\mathcal{T}$ - technological components; AN - analytical components; S - set of digital services; FC - functional configuration of the information technology platform; EV - evaluation of the resulting service subsystem.

The mapping operators perform the following transformations Γ_Q derives functional requirements from the fundamental properties of data; $(\Gamma_{\mathcal{T}}, \Gamma_{AN})$ transform functional requirements into technological and analytical components; Γ_S composes digital services from platform components and interaction scenarios.

Consequently, the proposed methodology establishes a complete and traceable transformation from the domain context and data properties to the evaluation of the resulting service subsystem.

Conclusions

A method for forming information services has been developed based on the composition of functional requirements, technological components, analytical components, and interaction scenarios (1).

A digital service has been defined as a functionally complete means of delivering the outputs of information technology platform components to users or intelligent agents in accordance with specified functional requirements and interaction scenarios. The methodological principles of functional completeness, requirement alignment, scenario justification, composability, loose coupling, reusability, interoperability, adaptability, controlled autonomy, and security by design have been formulated.

The following classes of digital services have been identified: information access services, integration services, analytical services, monitoring services, recommendation services, management services, decision-support services, and intelligent agent interaction services. The results demonstrate that users and intelligent agents are active participants in digital service processes, contributing to the definition of interaction scenarios, the generation of new requests, data provision, and the evaluation of service outcomes. For services accessible to intelligent agents, the necessity of formal descriptions of operations, authorization control, audit logging, explainability, and mechanisms for transferring critical decisions to human users has been substantiated.

The conditions for the functional completeness of the service subsystem have been formulated. According to these conditions, every application-level functional requirement shall be represented by at least one digital service, every digital service shall possess a justified component configuration, and every service shall support at least one practically meaningful interaction scenario. A set of evaluation criteria has been proposed, covering functional completeness, accuracy, timeliness, availability, scalability, interoperability, security, explainability, usability, and reusability.

The methodological foundations for forming digital services within information technology platforms have been further developed through the formalization of the principles governing their construction. Unlike existing approaches, these principles are represented by a unified three-level structure consisting of verbal definition → formal mathematical expression → interpretation, thereby ensuring their unambiguous interpretation, internal consistency, and integration into a coherent mathematical framework.

The integral result of the study is the generalized transformation procedure (2), which provides a consistent transition from the domain context and data properties to functional requirements, platform components, digital services, functional configuration, and its evaluation.

The principal contribution of the proposed method lies in interpreting digital services not as isolated software implementations but as the traceable outcome of the successive composition of functional requirements, technological and analytical components, and interaction scenarios. This approach provides a methodologically justified foundation for constructing the service subsystem, preserves the traceability of design decisions, and enables the reuse of digital services across different information technology platforms.

ADDITIONAL INFORMATION

AUTHOR CONTRIBUTIONS

Conceptualization, N.K.; methodology, O.H.; validation, V.K.; formal analysis, O.H.; investigation, O.H.; data curation, O.H.; writing-original draft preparation, O.H.; writing-review and editing, N.K.; visualization, O.H.; supervision, N.K.; project administration, V.K. All authors have read and agreed to the published version of the manuscript.

DECLARATION ON THE USE OF GENERATIVE ARTIFICIAL INTELLIGENCE TOOLS

In preparing this work, the author used DeepL Translate and Grammarly for: grammar and spelling checks, paraphrasing, and rephrasing. After using these tools/services, the author reviewed and edited the content and takes full responsibility for the content of this publication.

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МЕТОД ФОРМУВАННЯ ІНФОРМАЦІЙНИХ СЕРВІСІВ НА ОСНОВІ ФУНКЦІОНАЛЬНИХ КОМПОНЕНТІВ ІНФОРМАЦІЙНО-ТЕХНОЛОГІЧНОЇ ПЛАТФОРМИ

Сучасні інформаційно-технологічні платформи забезпечують функціонування цифрових середовищ шляхом інтеграції інформаційних ресурсів, технологічної інфраструктури, аналітичних компонентів, інформаційних сервісів, користувачів та інтелектуальних агентів. Водночас існуючі підходи до формування інформаційних сервісів переважно ґрунтуються на композиції програмних компонентів і недостатньо враховують функціональну структуру платформи, взаємозв'язки між її компонентами та закономірності функціонування інформаційно-технологічної екосистеми. Метою роботи є розроблення методу формування інформаційних сервісів на основі функціональних компонентів інформаційно-технологічної платформи шляхом визначення методологічних принципів, формалізації процесу композиції компонентів і побудови концептуальної моделі формування цифрових сервісів. Методологія дослідження ґрунтується на системному, сервісно-орієнтованому та екосистемному підходах, структурно-функціональному аналізі, концептуальному моделюванні та формалізації процесів побудови інформаційних сервісів. Особливу увагу приділено встановленню взаємозв'язків між функціональними вимогами, технологічними й аналітичними компонентами, сценаріями взаємодії та цифровими сервісами. Результати дослідження полягають у формуванні методу, який охоплює послідовність переходу від функціональних вимог до композиції компонентів, побудови інформаційних сервісів та їх інтеграції у сценарії взаємодії користувачів та інтелектуальних агентів. Сформульовано методологічні принципи функціональної завершеності, відповідності вимогам, сценарної орієнтації, композиційності, слабкого зв'язування, повторного використання, інтероперабельності, адаптивності й персоналізації, контрольованої автономності та безпеки за проектом. Наукова новизна полягає у розробленні методу формування інформаційних сервісів, який встановлює причинно-наслідковий зв'язок між функціональними компонентами інформаційно-технологічної платформи, принципами їх композиції та цифровими сервісами. Практичне значення результатів полягає у можливості використання запропонованого методу під час проектування інформаційно-технологічних платформ різного призначення, зокрема платформ Smart City, цифрових двійників, систем підтримки прийняття рішень, науково-дослідницьких інформаційних систем та багатоагентних середовищ. Подальші дослідження доцільно спрямувати на автоматизацію композиції сервісів, оцінювання їх якості та інтеграцію генеративного штучного інтелекту в процес формування інформаційних сервісів.

Ключові слова: інформаційно-технологічна платформа; інформаційні сервіси; цифрові сервіси; функціональні компоненти; композиція сервісів; сервісно-орієнтована архітектура; концептуальна модель; інтелектуальні агенти; інформаційно-технологічна екосистема; метод формування.