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Data Storage and Statistical Data Processing Tools for Solving the Tasks of Managing Regional Innovation Systems

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Abstract

Digital platforms, as an example of digital tools for data handling, provide an entire cycle of working with data, from data acquisition, processing, and storage to visualisation and software simulation. The digital platform comprises a data storage and processing system that ensures compliance with data usage protocols by other modules of the digital application. Moreover, such data storage and processing systems should be adapted to multi-user work with large amounts of data, which are assumed to be part of the operation of the digital platform. The purpose of this article is to describe the design and software implementation of a data storage and processing system for a digital platform capable of analysing regional innovative development levels. The data storage and processing system was developed based on the data structure and features, as well as on the requirements for data operation. The development process is presented in the form of the implementation of sequential steps, starting with the analysis of the requirements for the data storage and processing system for the proposed digital platform, the development of an ER diagram, and an infological and logical data model. The description ends with a discussion of the software tools and the physical implementation of the system. This article discusses an approach to data storage system design based on the analysis of data features and structure, as well as the proposed algorithm for data handling. The approach offers the advantages of solution flexibility and scalability, as well as user convenience, which consists of a query structure adapted to the appropriate specifics.

Keywords: database; digital platform; data curation; data processing; design database; digital technologies

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Инструменты Хранения и Статической Обработки Данных для Решения Задач Управления Региональными Инновационными Системами

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Аннотация

Цифровые платформы, как частный пример цифровых инструментов для работы с данными, обеспечивают полный цикл работы с данными: от сбора, обработки и хранения до визуализации и программной симуляции на их основе. В основе цифровой платформы лежит система хранения и обработки данных, обеспечивающая соблюдение протоколов использования данных другими модулями цифрового приложения. Более того, подобные системы хранения и обработки информации должны быть адаптированы под многопользовательскую работу с большими объемами данных, предполагаемую в рамках эксплуатации цифровой платформы. Целью работы является проектирование и программная реализация системы хранения и обработки данных для цифровой платформы анализа инновационного развития регионов. В результате разработана система хранения и обработки данных с учетом особенностей и структуры данных, а также предполагаемого алгоритма работы с данными. Процесс разработки представлен в виде реализации последовательных шагов, начиная с анализа требований к системе хранения и обработки данных для разрабатываемой цифровой платформы, разработки ER-диаграммы, инфологической и логической модели данных, заканчивая обсуждением программных инструментов и физической реализации самой системы. В ходе исследование обсуждается подход к проектированию систем хранения данных, основанный на анализе особенностей и структуры данных, а также предполагаемого алгоритма работы с данными. Среди преимуществ выделяются: гибкость и масштабируемость решения, а также удобство для пользователя, выраженное в адаптированной под соответствующую специфику структуру запросов.

Ключевые слова: база данных; цифровая платформа; хранение данных; обработка данных; проектирование базы данных; цифровые технологии.

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1. Introduction

The rapid development of digital technologies has led to the emergence of new trends in analytical research, including those in the socioeconomic field (Popov et al., 2021; Baran et al., 2021). Official statistical centres have switched to acquiring and analysing big data on various regional systems, which can later be used in socioeconomic research (Belov et al., 2021; Hasell et al., 2020; Mathieu et al., 2021). Further, the data of official statistical offices are marked not only by large volumes but also by completeness and accuracy (Ricciato et al., 2019; Constantinides et al., 2018). Data from these sources does not require further data cleaning and verification. However, large volumes of data may require more complex technical means and tools for processing and analysis.

Within socioeconomic research, specialists are developing digital platforms covering the entire cycle of data analysis, from data acquisition to result visualisation (Liu et al., 2022). The data from the state statistical offices are applied in the calculation of economic indicators and are used in mathematical models to analyse the social and economic spheres of the region and/or country. The tasks that are solved with digital platforms include dynamic analysis of forming collaborations in the supply chain, regional cluster policy analysis, business environment dynamics analysis, dynamics of social security processes, or the support of scientific research (Jovanovic et al., 2022; Yanagisava et al., 2016; Winther et al., 2019; Mirziyoeva et al., 2020; Morozov et al., 2020; Turk, 2016; Tarasov et al., 2022). Thus, digital platforms allow for a timely analysis of regional development by means of complex work with data provided by state statistical offices (Rudskaya et al., 2022). As part of ensuring digital platform operation, there is a need to develop methods for acquiring and storing data from official statistics sources (Belov et al., 2021), including automated data processing methods (Kudryavtseva et al., 2021). Since the database is the main server-side element of the digital platform, providing access to data for calculation modules and data visualisation modules, its design and software implementation is the first task in digital platform creation.

The purpose of the research is to develop functional requirements and software support of a digital platform's server side for the analysis of a regional innovation system that provides data storage, processing, and visualisation. Within the research, a digital platform data processing diagram, ER diagram, infological data model, and logical data model were developed. The developed database was implemented in the code. These solutions are the first steps in creating a digital platform for analysing regional innovation systems.

This paper is part of a project aimed at developing a digital modelling tool for a digital platform-based regional innovation system.

2. Literature review

Statistical offices are important data sources for socio-economic research. They collect and process (including aggregation) data (Gintciak et al., 2023). The Federal State Statistics Service website provides information on the activities of state bodies and local self-government bodies, placed in the form of data arrays in a format that ensures their automatic processing for reuse without prior modification by the users (machine-readable format) on the terms of its free use. Other sources of such statistical data include 5G, 4G, and LTE, social networks, and mobile operators.

Digital data sources close the gaps that statistics offices do not cover due to data aggregation (Gintciak et al., 2023). However, digital data require additional preprocessing (Yu et al., 2022). Given the heterogeneity of data sources in socioeconomic systems, the task of building a data warehouse becomes a class of complex tasks. Database formation is a complex task (Yanagisava et al., 2016; Liu et al., 2022; Cenamor et al., 2019), as the subsequent operability of software modules depends on the efficiency and correctness level of the created system. The database must meet the following characteristics: minimal redundancy, consistency, independence, and the possibility of adding/deleting and updating the data.

To meet these requirements, when designing databases, step-by-step-level modelling and database normalisation must be performed. As part of database development problem-solving, the content of the database, the way of arranging data, and data management tools should be outlined (Liu et al., 2022; Cenamor et al., 2019). The process of database development is marked by a transition from a natural human-understandable text to a formalised description and design of a data model. When developing a relational database model, several modelling levels are distinguished: domain model (conceptual scheme), infological data model, logical data model, physical data model, and database and applications.

Based on findings from relative worldwide projects, the most suitable instruments for database implementation are MySQL (Tarasov et al., 2022; Abd et al., 2021) and PostgreSQL (Belov et al., 2021).

3. Materials and methods

The development of innovation activity in regions is marked by the complex interaction of business entities with certain inputs and outputs. Regional innovation activity analysis requires consideration of key process components. For this task, specialists use the following methods: data envelope analysis (DEA) (Evtyanova, 2017), regional index of innovative and digital development calculation (Evtyanova, 2017), factor analysis of the influence of the index components on its formation (Evtyanova, 2017), and cluster distribution analysis (including calculation of the cluster localisation coefficient in the region) (Abd Rahman et al., 2021).

The initial data for the innovation activity analysis were the data from the state statistical offices. The data are provided as annual reports of official statistical offices. In this regard, the data have already been processed (cleaned, aggregated, etc.) and are in a template that can be machine-processed. These data can be entered into the system semi-automatically. The option of fully automating data uploading may be available if the source data are in one template. However, data from the official statistics offices of the Russian Federation are currently available in several template versions and cannot be automatically processed. Thus, the algorithm for semi-automatic data uploading can be described in two consecutive steps:

1. CSV source data from the portal of state statistical offices are processed by experts and brought to a certain template.

2. The tabular data are uploaded to the database by an authorised user with the appropriate “administrator”-level access rights through the integrated interface.

In addition to the data uploading module, it is necessary to consider the interaction with calculation and data visualisation modules. Calculation modules perform data processing and calculations in accordance with the selected methods for analysing the innovative development of regions. Thus, there is a need to record the results of the simulation experiments for subsequent analysis and comparison. Interactive work with indicators through the platform interface is also expected. Therefore, the user should be able to vary the parameter values, which will automatically recalculate a certain number of indicators. Figure 1 shows the entire cycle of working with the data.

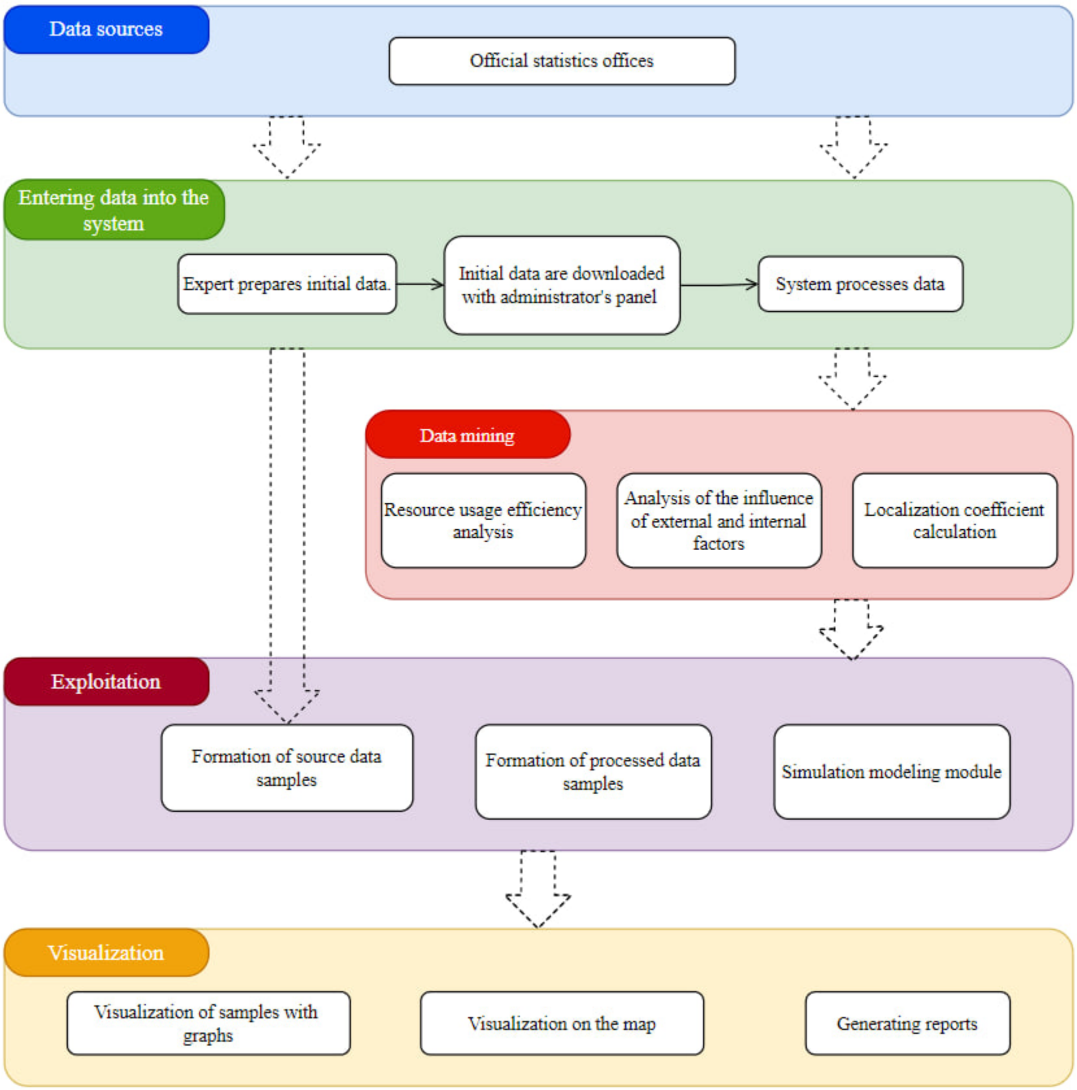

Figure 1. Cycle of working with data

4. Results

Conceptual framework development

The proposed digital platform can provide automated data uploading, processing of the data with consideration for the recording of query results, and storing the results of a given number of experiments in a simulator. The subject domain does not require storing all data about entities (as in the case of information retrieval systems). Thus, a set of data required for software processing and obtaining arrays of necessary indicators as a result should be determined.

In this work, innovation activity in the country's regions was analysed in terms of particular regions and years. The innovation activity of the region was marked by the presence of input and output parameters. The researchers distinguished the following parameters: the intrinsic value of R&D projects, the number of entities conducting R&D projects, the cost of technical innovations, the number of patents granted, and the volume of innovative goods and services. Moreover, regions were marked by the presence of the region's number and name attributes. The researchers used the input–output matrix analysis method to classify industries into clusters (Evtyanova, 2017; Abd Rahman et al., 2021). In total, the classification method revealed 98 industries, which, as a result of the analysis, were divided into 22 clusters. Industries are marked by the labour activities of a certain number of people. This indicator allows for the calculation of the localisation coefficient, which represents the region's industry concentration extent.

Innovation activity is supported by key actors in the environment. Researchers are developing methods for analysing such activities from the perspectives of the environment-provided key actors' and conditions' perspectives (Evtyanova, 2017; Abd Rahman et al., 2021). In this study, business, research entities, universities, and the state were singled out as actors of innovation activity. The region's conditions consist of economic and social factors, as well as its digitalisation level. Further, actors and the environment have attributes that make up indicators that allow the assessment of the region's development degree.

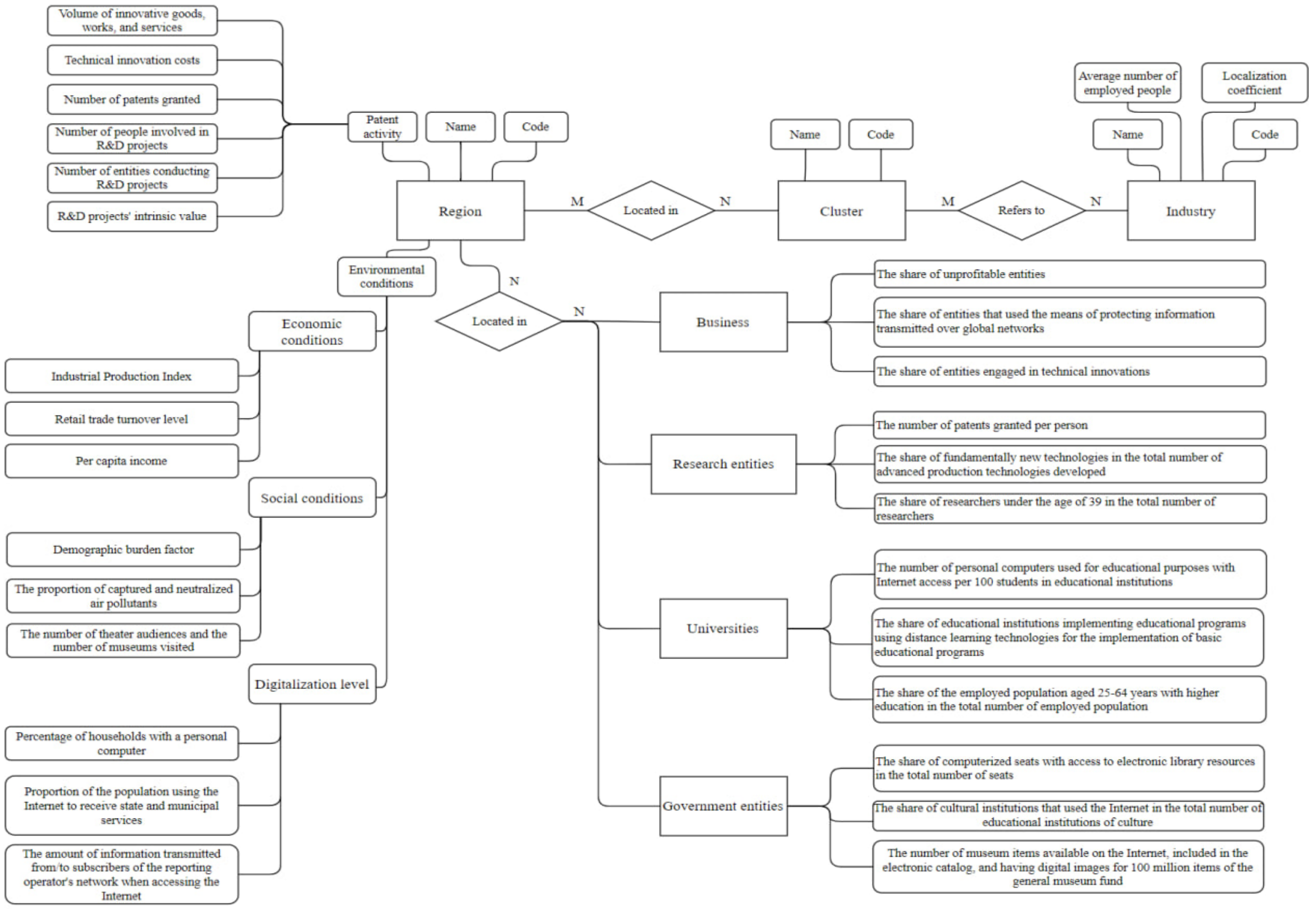

Figure 2. ER diagram

Infological model development

Based on the subject domain description, an ER diagram was compiled to reflect entities, their relationships, and attributes (see Fig. 2). The subject domain description and the ER diagram were used to create an infological model, which represents the entities of the future database, the data being stored, and the relationship between the data. To structure information and ease the access and data uploading, information about the region (name and code), its attributes were divided into separate entities: region, patent activity, and environmental conditions. It is noteworthy that the attributes of the environmental conditions were aggregated into groups for the convenience of the model. However, the database can store complete information about environmental conditions according to the classification shown in the ER diagram. The database can also store information about the regions in terms of years. Therefore, the relationship between the region entity and the patent activity and environmental conditions entities will be one-to-many (see Fig. 3).

In the model, clusters consist of several industries, while the industry is included only in a specific cluster. Thus, the relationship between entities is one-to-many (Fig. 4). Actors consist of businesses, research entities, universities, and the state. Each actor has its own properties, but they have not been mapped out for better visual representation. They will be stored in one actor entity. Each property is unique for a region; however, because the database contains information from 2009, the relationship between entities will be one-to-many (Fig. 5).

Based on the description of the entities and their attributes, an infological scheme was compiled (Fig. 6). The region entity is linked to the cluster entity by a many-to-many relationship since each region has a set of clusters, and each cluster is represented in a set of regions. This type of relationship requires further elimination.

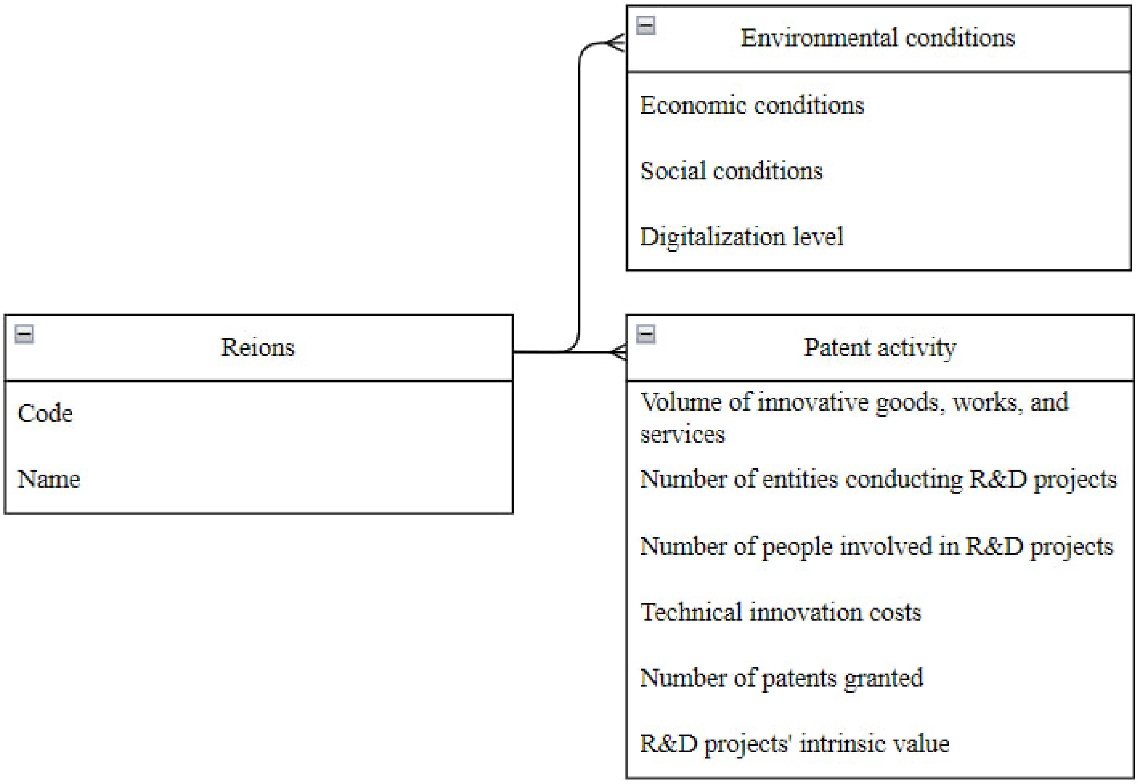

Figure 3. Infological scheme of regions, environmental conditions, patent activity

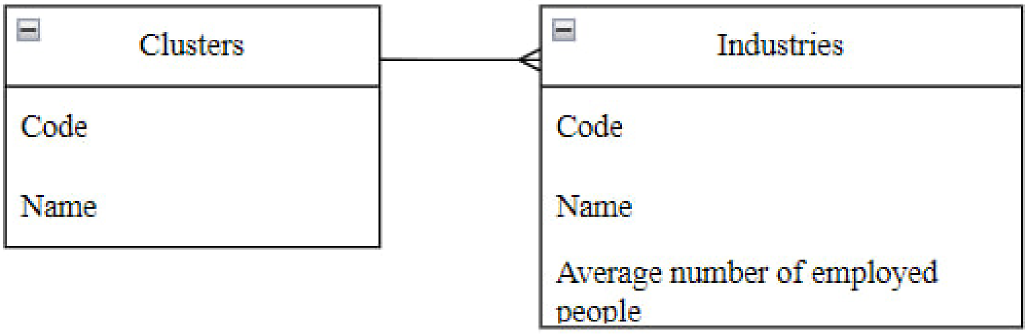

Figure 4. Infological scheme of clusters and industries

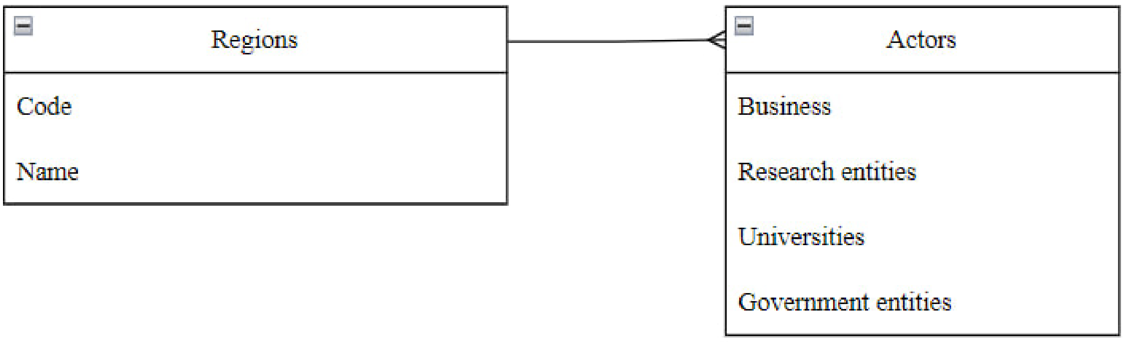

Figure 5. Infological scheme of regions and actors

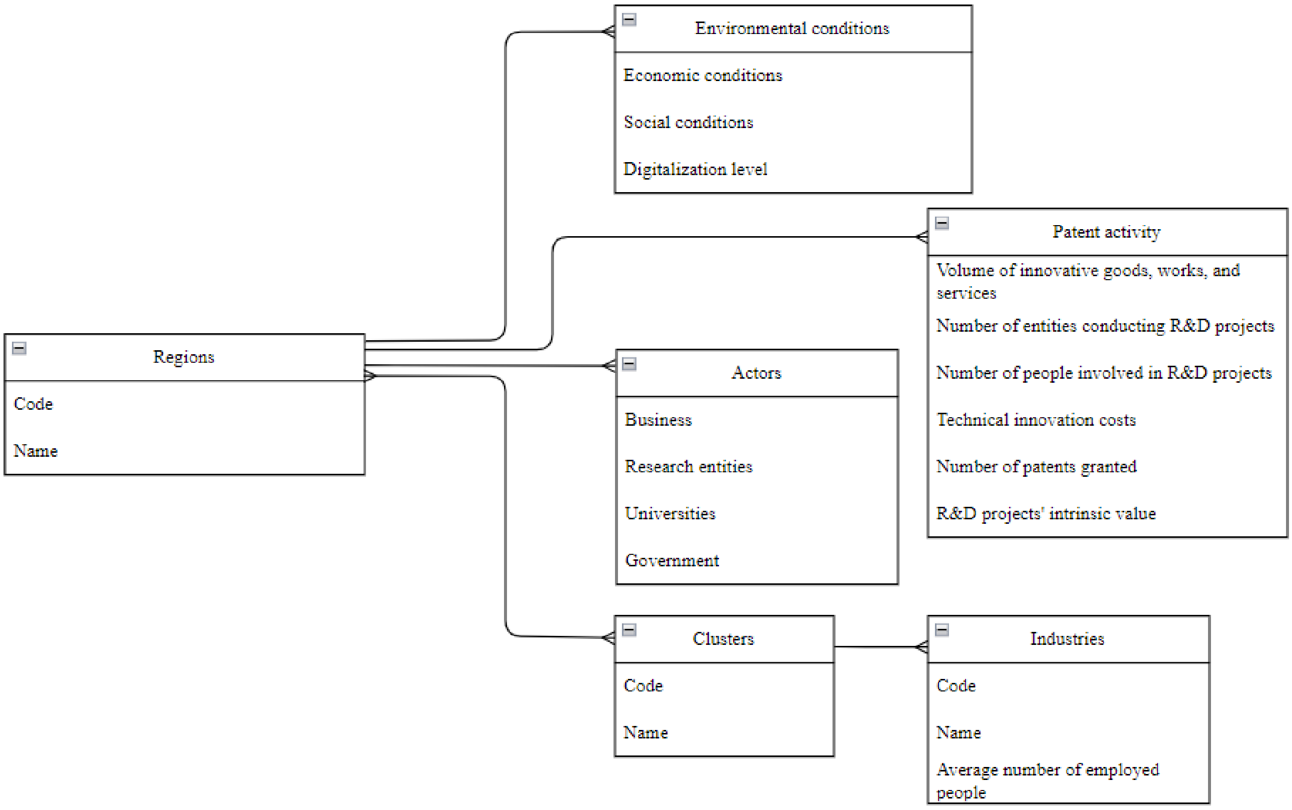

Figure 6. Infological scheme

Logical data model

Since innovation activity is analysed over time for different regions, all indicators by region are stored by year. Thus, a table with a list of regions and years (ID relation) was selected as the pivotal relation. The key field of this relationship is id_regions, which connects two non-key fields. Information about regions is stored in the region directory. The key field in the directory is id_region, which is the area code. This relationship also contains the name (the region name) and slug (the region name to address in the code) attributes.

The industries directory contains the attributes id_industry (industry code according to the OKVED classification), which is the key field, and industry_name (the name of the industry according to the OKVED classification). The cluster relationship contains their OKVED classification codes (id_cluster, key field), name (cluster_name), and system name (slug). The clusters and industry directories are linked by the relation industry_cluster with the id_industry key field and the dependent id_cluster. Although these relations are one-to-many (see Fig. 6), the researchers decided to avoid deletion and modification anomalies. Since the classification of the industries to clusters ratio is original and was developed by specialists (Evtyanova, 2017; Abd Rahman et al., 2021), it can be changed (e.g. in accordance with the generally accepted OKVED state classification) or modified. Data on the industry–cluster relationship and entity attributes are separated to ensure that data on industries and clusters are not lost when deleting or changing this classification (see Fig. 7). Data on the localisation of industries in the region are calculated annually based on information about the number of people employed in the region's industry. Given that these data must be calculated annually, the lq (the region's industry localisation) and d_ind (the number of people employed in the region's industry) attributes are separated into lq/industries relation with the key id field, which is a foreign key to the ID table.

Data on the region's patent activity are stored in relation to the patent activity. The DEA results are recorded in the DEA relationship, which consists of the following fields: id (key field), rank, theta, is_vtz, is_ospd, is_patent, is_cfti, and is_res_hum. The input data for the DEA product are written on the patent_activity relation:

- vtz – R&D projects' intrinsic value;
- opsrd – the number of entities conducting R&D projects;
- res_hum – the number of people involved in R&D projects;
- patent – the number of patents granted;
- cfti – the cost of technical innovations;
- qing – the volume of innovative goods and services.

One of the platform's functional clusters is the module of the simulation experiments. This allows the user to change the indicators of the region's innovative development to compare the resulting indicators of its innovative development index and the rating in the country, as well as to save experimental data. To implement the option of saving the results in the user's personal account, a sim relation with fields duplicating the regions_indexes relation has been added to the database structure. Since experiments can be performed with the same region for the same reporting year, the code_sim field has been added as the key field. Figure 7 shows a digital platform database diagram for assessing the innovative development of the country's regions.

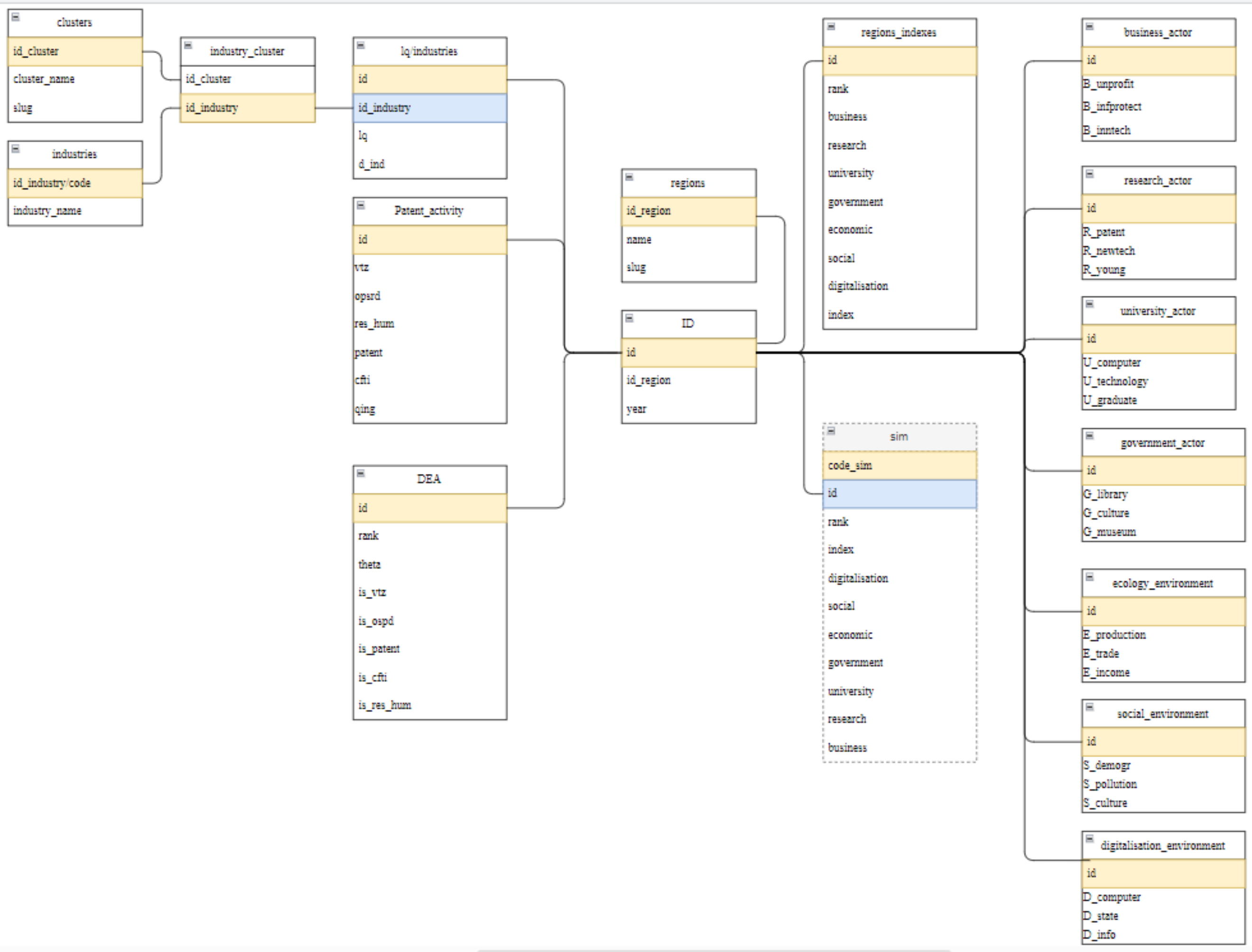

Figure 7. Logical data model

5. Discussion

Based on the application architecture and the requirements for the client and server sides of the proposed digital platform, database management tools were selected. Since React.js was chosen as the main language for the digital platform design, Next.js was selected for client (user) interaction with the platform, which provides SSR (server-side rendering) capabilities, increasing perceived performance.

Nest.js was also selected for the server side, since it meets all the requirements and sets a conveniently scalable architecture. PostgreSQL for relational models was chosen as the DBMS.

The choice of PostgreSQL is informed not only by the popularity of this solution but also by its obvious advantages. Using PostgreSQL ensures data integrity and reliability. As the tool can create a personal user account and store personal data, reliability becomes an important requirement. Further, using PostgreSQL provides extensibility, which is also a necessary requirement for a platform.

The developed database was built from scratch for a specific digital solution. Therefore, it is not versatile and applicable to a wide range of tasks. However, this approach takes into account the various combinations of input parameters necessary for automating methodologies for calculating innovative indicators. The complexity of the techniques and their unique features impose certain requirements on the database, such as flexibility and extensibility (Evtyanova, 2017; Abd Rahman et al., 2021).

An approach to database development based on the design of a data storage system for a specific digital solution, along with data structure and features, has also been used as described in other works. The advantages of the proposed approach are solution flexibility and scalability, as well as user convenience, which involves a query structure adapted to the appropriate specifics (Liu et al., 2022; Cenamor et al., 2019).

6. Conclusion

This study presented the sequential development of the digital platform's server side, which is responsible for data storage and processing. The proposed database's consistent development relies on the data structure and features, as well as on the requirements for data operation as part of using a digital platform on the server and client sides of the application. Thus, the following database modelling levels were outlined: domain model (conceptual schema), infological data model, logical data model, physical data model, and database. This study is an approach to data storage system design based on the analysis of data features and structure, as well as the proposed algorithm for data handling. The approach exhibits the advantages of solution flexibility and scalability, considering the specifics of data and working with them. However, this solution is not versatile and can only be adapted for other applications as an approach or top-level structure.

This paper is part of a project aimed at developing a digital modelling tool for a digital platform-based regional innovation system. In the next stage of the research, the logic and software implementation of the calculation and simulation experiments module will be developed and integrated with the database.

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