Digital Modeling of Territory for Smart e-Tourism Services

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***Abstract*—In the modern world, tourists are faced with the need to use various mobile applications for travel planning and navigation. To provide tourists with comprehensive information about the visited area, a digital model can be constructed, so implementing a digital shadow of given territory and related processes. In this paper, we discuss our concept of a platform for smart e-Tourism services. Such services provide tourists with various information about geographical locations and points of interests as well as about related facts, persons, and stories. A high-level architecture for the services is presented. Enabler algorithms are considered for implementation of the services. The proposed concept support tourists with latest information about the properties of the physical environment, news, social networks, and the number of visitors in relation to geographical locations.**

I. Introduction

The development of modern information technologies nowadays affects a growing number of areas of human activity. The sphere of tourism occupies one of the most significant positions in the world market of services [1], therefore it is impossible to talk about the development of this industry without the introduction of modern technologies. In recent years, the concept of Smart Tourism [2] or Tourism 4.0 has emerged [3].

The widespread development and distribution of Internet of Things systems, mobile applications, Geographic Information Systems (GIS), augmented and virtual reality technologies provide new opportunities for service suppliers and consumers due to the possibility of storing, accumulating, and processing Big Data [4]. With the help of such technologies, tasks such as analyzing and predicting the behavior of tourists [4], implementing information exchange platforms (Information and communication technologies, ICT), personification of advertising offers and points of interest (POI), as well as many others can be solved.

The aim of the work is to develop the concept of a platform for the “Digital Shadow” of the territory, offering comprehensive information about the area for tourist use. Users interact with the digital model of the area using a mobile or desktop application that includes an interactive map with integrated intelligent platform services.

The list of platform services includes:

- Interactive representation of geolocations with the inclusion of data collected through GIS, user posts on social networks, and news articles.
- Interactive representation of environmental data in various districts of the observed area (for example, air quality, temperature and noise level).
- Forecasting the hourly tourist volume of geolocations.

The general class of services in terms of the data provided is shown in Fig. 1. The implementation of such services includes the use of communication technologies, natural language processing methods, forecasting models, recommendation systems, and data fusion methods.

This article proposes a theoretical framework that can serve as a foundation for developers of ”smart tourism” systems. Building on the results of the design process, the authors intend to apply this framework in order to develop their own multifunctional system.

The rest of the article is organized as follows. Section II reviews related work in the smart e-Tourism area. Section III considers the problem area of “Digital Shadow” and GIS systems to introduce our platform concept. Section IV describes the architecture of services operating in the platform for digital modelling of territory. Section V shows example services as use cases for the proposed platform concept. Section VI provides discussion on the proposed concept, platform, and usecases. Section VII summarizes the key findings of this study.

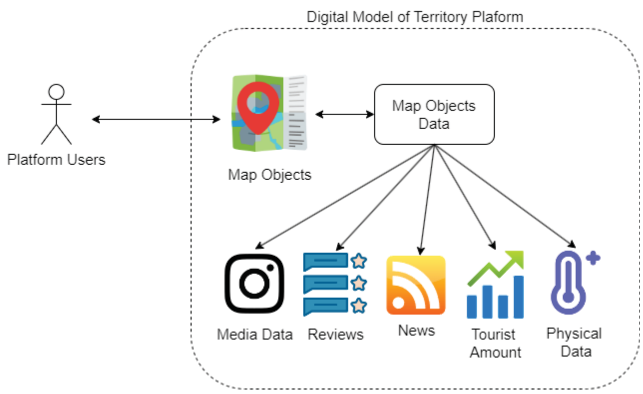

Fig. 1. Provided services

II. Related Work

A significant number of studies in the field of smart tourism focus on the development of platforms that integrate information technologies. For instance, the paper [5] proposes a platform for recommendation services in tourism based on a microservice architecture. This approach allows for the implementation and development of services independently, providing high scalability and compatibility with various devices. In this scenario, the single point of data input is the orchestration gateway, which coordinates the operation of application modules. Compared to a monolithic architecture, this approach offers ease of deployment for web applications, as well as a high level of fault tolerance thanks to the separation of individual services. Despite the obvious advantages of the micro-service approach, its application can lead to problems such as delays and deterioration of application performance, increased workload on the development team, and the difficulty of ensuring data integrity.

Another approach would be to develop a multi-layered architecture for recommendation systems, which allows for the grouping of abstractions and tasks [6]. From a high-level perspective, three distinct levels can be identified: data producers, service users, and the presentation level of services and information. This example utilizes open-source Big Data technologies, including Eclipse Zenoah, OpenFaaS, Apache Kafka, Apache Spark and ElasticStack. In this instance, the intermediate layer is divided into a Blending Layer, Processing Layer, Data Layer and Presentation Layer. The main goal of the development in this case is the creation of a platform that will allow for data processing from a variety of sources. The authors have focused on two crucial aspects of data processing in a distributed application: data collection from sources with various topologies, and data processing and integration, along with the possibility for reuse. These properties of the system are reflected in the results obtained in this study.

The architecture of a crowdsourced platform for visualizing the popularity of attractions within an urban environment has also been considered [7]. Users can make decisions regarding visiting a particular place based on where people gather. The platform's architecture includes a layer for data collection (using Facebook, Google, and FourSquare APIs), a layer for preprocessing, storage, and extraction, and a layer for users with APIs for desktop and mobile applications.

The concept of the Internet of Things (IoT) can also be applied in the field of smart tourism. In particular, this architecture has made it possible to address the challenge of sustainable management of tourist flows in urban environments [8]. The proposed platform consists of four layers: the Application Layer (providing high-level services), the Service Layer (coordinating high-level and lower-level data), the Virtualization Layer (containing representations of physical objects), and the Real-World Layer (representing the physical objects in the urban environment itself). By introducing a virtualization layer, it is possible to create a unified communication environment for these objects, to separate user requests from the physical objects, and to expand the search for services. The application of virtualization can be seen as one of the areas of development for the multilevel architecture proposed in this paper.

As it can be seen, most of the reviewed materials focus on implementing the platform architecture for an application that supports one complex use case. However, in our proposed solution, the system performs several functions, each of which is implemented as a separate service. These functions include predicting user behavior, providing open source data, and providing physical environment data. The proposed architecture includes methods that allows to jointly store service data and process it in parallel. In the following sections, the architectural solutions that make it possible to implement such system are considered.

III. Concept for Digital Model of Territory

The subject of interest of a user accessing one of the ”Smart Tourism” information services is a certain territory where this user arrives during his journey. Methods of digitizing a physical object by processing large amounts of data about the simulated object include the development of a “Digital twin” or “Digital Shadow”. Both of these concepts imply a digital independent model of the physical system associated with the observed object and changing depending on the state of this object [9]. Both “Digital Twin” and “Digital Shadow” include the process of automatic cognitive processing of data streams emanating from a physical object, but unlike “Digital Twin”, “Digital Shadow” does not create a reverse flow affecting a physical object. Thus, “Digital shadow” depends on the current state of the physical object, but cannot control this state. Thus, “Digital shadow” is one of the methods of big data processing that can be used in the implementation of a service that provides tourists with attributes of the observed territory.

To implement the digital model of the territory (in the form of digital shadow), we design a platform containing services for providing heterogeneous information. Currently there is a wide variety reference map services that can be used by tourists when traveling to a new location (such as 2GIS, Yandex Maps, Google Maps, Apple Maps, etc.). These software products provide information for the navigation and route planning in the specified areas, the selection of attractions, restaurants, hotels, and other facilities.

However, the services listed provide only a limited amount of information about the area of interest to users. Often, users' preferences can be influenced not only by reviews of a place, but also by parameters such as occupancy at certain times, noise levels, and environmental cleanliness. Certain applications, such as Google Maps, provide similar information, but these services are only available in specific regions [10]. If such information was available through the digital model services, users could make decisions about their visits to certain places based on a more comprehensive view of them.

In addition to the physical characteristics of the object being monitored, tourist users may also be interested in receiving up-to-date news about a geographical location. Typically, the user would need to independently conduct a search query that contains keywords related to the place of interest. If newsfeed data were integrated into a mobile app's map as a separate layer, then the user could make decisions based on continually updated information. In addition to news data, such a service could also incorporate user posts from social networks, tweets, and newly uploaded photos.

Modern navigation services typically provide information on traffic conditions and can display busy areas of a city [11]. This data is collected and displayed in real time. However, if a user wishes to schedule a visit to a particular place at a specific time, they need to know how many other people typically visit that location during their working hours. A forecasting service, based on historical data about visits or from social media, could solve this issue and visualize the expected workload at a particular geolocation during a specific opening period. Such a service could allow users to make more accurate plans for their visits and choose the optimal time to attend to their destination.

Thus, this paper considers the concept of a software platform that implements the "Digital Shadow" of the territory, containing the listed functions in addition to cartography and navigation tools. This system can be based on the SDK of any of the interactive map platforms and provide additional services on top of the existing ones. The inclusion of these services will allow the user to have a more complete and extensive understanding of the objects of the visit, optimally plan their time and travel routes. The visual representation of the concept is illustrated in the Fig. 2. As can be seen, the system collects data from various sources in order to provide targeted services. Examples of the data collection and processing for each service are provided in the following sections. The combined services allow the creation of a representation of the area with which the user interacts. It is worth noting that users themselves constitute an important source of data.

This platform and the proposed architecture is a conceptual model of a system that utilizes the latest technologies in Big Data, Artificial Intelligence, and the Internet of Things. As this system integrates several different functions, users can access Smart Tourism services through a single interface, rather than using a variety of disparate applications. This approach necessitates the use of distributed systems and methods for data integration, which are discussed in detail in the following section.

IV. Architecture of e-Tourism Smart Services

To implement the concept of a digital terrain model, we propose an architecture that includes layers for collection, transformation, processing, and integration of heterogeneous data. It is based on a combination of open-source solutions that demonstrate their effectiveness. This architecture provides Data Mining methods for creating specific services, whic includes real-time processing of large data sets and intelligent decision-making based on analytics. These services could be integrated into a RESTful architecture in order to meet modern web application standards.

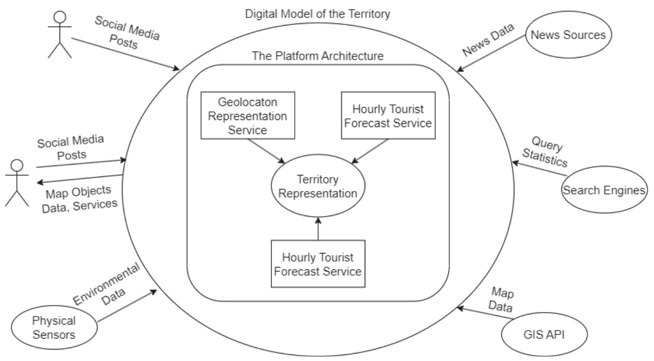

Fig. 2. Digital Model of the Territory Concept

Each of the services can be described using a four-level architecture consisting of the following elements:

1) Level of data generation and collection.
2) Level of presentation and storage of data.
3) Level of data mining.
4) Application level.

At the first level of service, the main function is performed by data generators. These can be sensors that measure physical environment indicators or unstructured text data from news sources, user posts from social media platforms, or GIS data. Depending on the type of data source, different methods of data collection are used. For example, a message broker or REST architecture may be used to collect data. Once collected, the data is sent to a presentation processing layer through data transmission networks, such as Wi-Fi, Zigbee, or cellular networks.

At the data representation and storage level, data is filtered, dimensioned, and converted to a more manageable format before being stored in a data warehouse or data lake. For convenient storage and processing, distributed file systems such as Hadoop Distributed File System (HDFS) are used. Data access and query management are performed using a Database Management System (DBMS) for distributed storage systems such as Apache Hadoop's HBase [12]. The use of these tools simplifies the process of reading and writing data in real-time.

The data mining level includes various AI techniques: forecasting algorithms, NLP methods, and machine learning. These techniques implement the logic for processing the corresponding intelligent features of the platform. Information is retrieved from the presentation and storage level and processed in real-time according to the task being performed by the service. The results of the processing are integrated with cartographic and GIS services, and then the information is published in relevant sections of the system.

At the application layer, the processing results are presented in the user interface of a web-based application or mobile or desktop software. Users interact with this layer through the RESTFUL architecture, which allows each service to be accessed through a unique Uniform Resource Identifier (URI). Each service is represented as a distinct layer on the geographic information GIS map. The architecture of the platform's services is shown in Fig. 3. Based on the aforementioned architecture, the internal design of the planned features of the future system has been developed. The following section provides a detailed description of each service, indicating the stages of data processing they contribute to.

V. USE CASES

A. Geolocation Representation Service

The proposed geolocation presentation service will include the processing of data collected from the geographic information system (GIS) and user posts on social media and news platforms. Due to the diverse nature of the information collected from multiple sources, the service aims to provide travelers with up-to-date information about the current conditions in various locations. This could include events, weather conditions, public transportation options, and other factors that influence travel decisions.

Unlike traditional news sources, open-source data and social media content are non-traditional sources of geographic information. Information on social media platforms consists of a vast amount of media content (photos, videos), as well as text messages. Additionally, there are many other forms of information, such as emojis, product reviews, geospatial data, and more. The availability of this information depends on the terms and conditions of the platform.

The Data Generation and Collection Layer of this Service contains tools for collecting data from open media, such as social networks and news websites. To build a service, it is necessary to associate objects (locations) on the map with data from social networks or news. To do this, a point on the map (an object with coordinates, metadata, description) must be designated by a set of tags, which will be used to match the data obtained from open sources. With the help of the received tags (keywords), information is collected from the news sources. Relevance determination and ranking of news sources can also be performed based on sets of keywords. In this case, the class label defining the relation to geolocation is defined in the form of a dictionary of correspondences: ”Name” - ”Set of keywords”. To find tags in the text, regular expressions can be implemented. The score metric for ranking news documents can be calculated by summing up the frequency of keywords in the document. [13]. News data can be collected from a limited set of sources, such as regional groups or websites. It can also be obtained through a global search, using a web scraper that uses the API of one of the search engines, such as Google [14].

There are multiple methods for collecting data from social media platforms. For example, Twitter and Flickr provide Application Programming Interfaces (APIs) that allow users to access their user-generated content (including uploading photos, text descriptions, metadata) [15]. The high volume of user-generated data on social networks necessitates the need for data filtering. Keywords, hashtags, or area of interest (AOI) on Twitter can assist with solving this issue.In this case, due to the high speed of data acquisition and the lack of a clear data structure, it is necessary to use approaches from the field of big data (storing data in distributed file systems and assigning data keys using hash functions).

The Data Representation and Storage layer, along with other described services, contain a collection of data that is stored in distributed storage systems in its raw form. This approach allows for the ability to access the data again, as well as to read information in real-time.

The Data Mining level in this service uses ML and NLP tools to tools to process textual data. Any user post must go through preprocessing, which includes removing personal data, links, nicknames, punctuation, stop words, and emojis, using NLP libraries like NLTK and Gensim. Basic information from user posts, such as the location of the post, can be extracted through summarization methods, as well as LDA, TF-IDF and deep learning algorithms, such as RNN or CNN.

Even if the location information is not directly contained in the post, it may be extracted from the text or the image using machine learning techniques [15]. This information can then be attached to geolocation data provided by the GIS API, allowing users to view the posts in relation to their locations.

It is most convenient to present news information on the map in the form of an annotation of the full text. Summarization methods are used to solve the problems of annotating texts. Among these methods are Latent Semantic Analysis (LSA), the heuristic Lunh's method, graph-based methods such as TextRank and LexRank, and others [16]. These approaches differ in their performance and accuracy.

SDK packages are currently available for integrating the GIS API into mobile and desktop applications [17], [18]. Such libraries provide the ability to display interactive maps, integrate geolocation, add annotations, routes, polygons, etc. Thus, the integration of the SDK API provides access to a minimum set of services of the corresponding GIS application. Therefore, SDK tools can be used at the Data Mining Level of the system.

The Application Layer represents the result of data collection and analysis, the service provides users with information, displayed together with metadata, about a location on the map. This means that when a user is viewing their geolocation, they can see the latest news related to that location, as well as the reactions of other users on social media (reviews, photos, and opinions). Additionally, the user can get a more comprehensive understanding of the area than would be available from a GIS directory. Since the information in a GIS API may not be updated frequently, the use of this service allows users to access up-to-date information in real-time about the location they are interested in.

B. Environmental Data Representation Service

An interactive weather and environmental data presentation service can significantly enhance the travel experience by providing tourists with the information they need to make

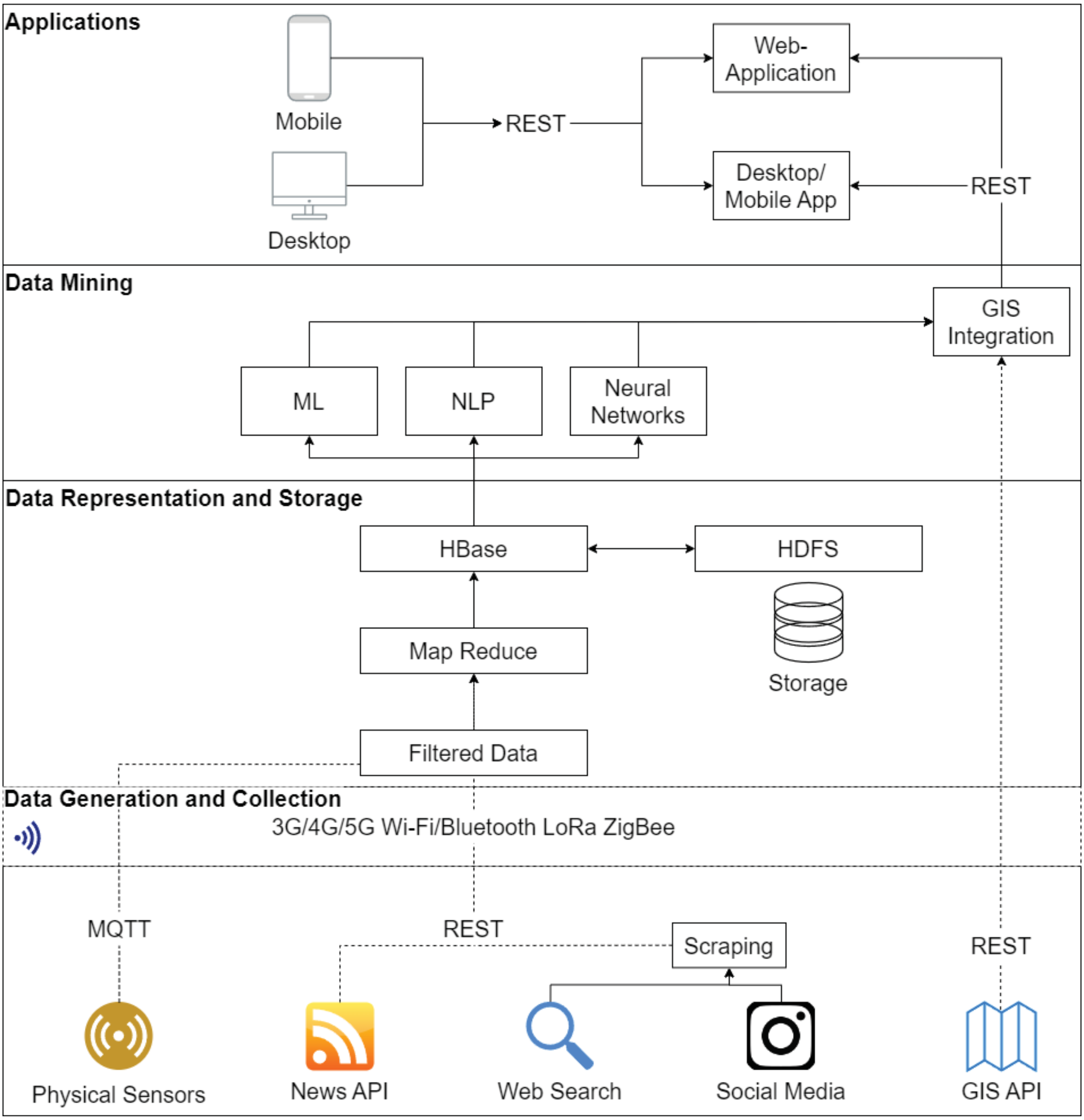

Fig. 3. Architecture of the platform

informed decisions during their trips. Providing data on air quality and other environmental parameters will help tourists make decisions related to their health and safety during travel, especially if they have allergies or diseases that worsen under adverse conditions. Tourists can use information about the weather, air quality, temperature and noise levels to select suitable places and times for various activities such as walking, picnics, sports, etc.

Solving the challenge of providing data on the physical environment in a virtual interactive object is currently a relatively straightforward task due to the rise of the Internet of Things (IoT) and monitoring systems [19]. In the Smart Tourism platform, indicators of interest for a given object (location) include noise, air quality, and temperature readings. It is assumed that sensors measuring these indicators are distributed across the monitoring infrastructure, contributing to the level of Data Generation and Collection. Data is gathered using software message brokers and IoT gateways, which redirect information to a distributed storage system using data transmission networks. Each sensor transmits data in the form of a graph containing the observed changes and metadata about itself (location, status).

The Data Representation and Storage layer uses distributed data warehouses such as Apache Hadoop and Apache Spark to process and analyze data with large volumes and at high speeds. The use of these distributed storages in sensor networks ensures scalability, fault tolerance, quick data access, geographic distribution, and efficient data management. These features are crucial for successful work in the Internet of Things field.

Data semantics and context need to be defined for the specified service. Therefore, the Data Mining layer should include methods for classifying data, identifying associative rules, and visualizing them. Data is collected from previous levels using the software interface, which sends requests to the data warehouse to retrieve the necessary information. Its task is to obtain measurements from sensors located in a given geographical area. These areas can be assigned in advance to monitoring objects in the database of a web application - buildings, districts, parks, etc..

As a result of the data flow, the user can see information about the physical environment in a specific area in real-time on an interactive map. This data can be displayed as a separate layer on the map, or it can be combined with other geospatial information.

C. Hourly Tourist Amount Forecasting Service

The proposed service would allow users to decide whether or not to visit certain locations based on the predicted popularity of those locations at different times of the day. This would help tourists avoid crowded places and choose the best time to visit their favorite attractions. This service could also be beneficial for attractions' staff, as it would allow them to better plan their operations and allocate resources more effectively based on the forecasted visitor volume.

Most of the research on related topics focuses on identifying long-term trends in tourist destinations (weekly, quarterly, and annual forecasting) [20], [21]. Forecasting hourly workloads allows to more effectively organize the work of staff and allow tourists to choose a convenient time to visit without causing a negative impression.

The Data Generation and Collection Layer can utilize search engines and social media platforms as convenient data sources for solving this task due to their availability and timeliness [22]. NLP methods such as clustering, thematic models, and knowledge graphs can be used to extract geolocation attributes and events from social media user posts [23]. Keyword search query trends can also be used to predict the workloads of specific locations [24]. The data storage strategy at the Data Representation and Storage level coincides with the services described above.

Data Mining level can iclude methods for extracting the daily characteristics of attractions by combining data from search engines, social networks, and the number of visitors to other attractions within the vicinity of the target attraction (e.g., [25]). At the first stage of the method, the attention gated recurrent unit (GRU) model can be utilized to predict daily trends in visitor numbers. In the second stage, graph convolutional neural networks (GCNs) can be used to extract spatial features from social media data, using data on visitor numbers in other locations within the reach of the target attraction's radiation. The output of the GCN is fed back into the input of the attention-based GRU, extracting hourly workloads. This method and others have some limitations, suggesting that this area has great potential for future research.

In the proposed service, the popularity of specific locations, predicted, for example, using deep learning techniques, can be displayed in the form of numerical values (calculated by counting metrics). Therefore, the popularity of various locations on a map during specific monitoring hours can be visualized in the form of heatmaps or graphs [26].

VI. Discussion

The developed architecture of the platform provides data processing capabilities and methods for implementing the services outlined above.

The Geolocation Representation Service and Hourly Tourist Amount Forecasting focuse on obtaining open data from the internet through the use of various API's. However, these existing API's have a number of limitations and pricing conditions that need to be taken into account when developing tools. Developing tools for web scraping, which is another way to obtain service data, may also require additional computing resources, making it more complicated to collect and generate data.

It is also important to mention the legal limitations. The use of personal information from social media platforms is subject to several legal restrictions and guidelines, including privacy policies of social networks, data protection regulations (such as the GDPR in the European Union [27]), and other local laws on data protection. Before using this information, it is essential to comply with all applicable norms and requirements, and to obtain consent from users to use their personal data in accordance with the law .

The Environmental Data Representation Service is based on the idea of the Internet of Things, in which measuring devices are integrated into the network infrastructure and form part of an information sharing system. The application of this concept can lead to several potential problems. The diversity of manufacturers and technologies in the IoT field can create compatibility issues between devices, as well as the need to establish standards [28]. Power outages, communications, or other problems may cause IoT devices to become unavailable or malfunction. Managing a large number of IoT devices and collecting and analyzing data can also be challenging tasks for organizations.

The above-mentioned problems and limitations require a detailed study in each individual case. When developing a system using the proposed platform, these issues will be considered and addressed as much as possible.

VII. Conclusion

This paper introduced our concept of the platform for digital modeling of territory based on artificial intelligence technology and data mining algorithms. Such a platform can be used to implement various mobile/desktop or web application of smart services for tourists. A service provides access to information from news feeds, physical indicators of the environment, information from social networks, and predicting the volume of tourists regarding the locations of interest to the user. The proposed architecture can be used to create a digital terrain model platform for tourist needs. The computation process of data mining for example services is described to show use cases. The further research includes the selection of datasets, experiments with data, and the development of appropriate methods for implementating the studied smart e-Tourism services.

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