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Using AR Technology in Tourism Based on the Example of Maritime Educational Trips—A Conceptual Model

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Abstract: Technological progress in augmented reality (AR) creates new application opportunities for different branches of tourism. The application of modern technology is made possible by the widespread use of mobile devices and dedicated tourist applications. Preliminary market research demonstrates that there are no global solutions intended for tourists on sea voyages that make use of augmented reality. This paper analyzes the use of AR technology in water tourism. The proposed Maritime Educational Trip (MET) system makes it possible to combine geolocation information with the accumulated knowledge of a specific location and to present it with AR. An example prototypical Android application is developed, combining e-navigation with a knowledge base. The developed solutions show how a combination of the real world with a computer-generated world helps to expand the tourism space.

Keywords: augmented reality; Maritime Educational Trip (MET); GNSS; tourist application

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1. Introduction

Global travel has brought about developments in many areas of life—from cultural to economic. Although links between tourism and economic growth are not always so obvious [1–7]), tourism has a beneficial impact on many economies, which confirms the tourism-led growth hypothesis [8–21]. An OECD report shows that the tourism industry generates 4.2% of the GDP in the most developed countries and 6.9% of jobs and it has a 21.7% share in service export [22,23]. This paper refers to the appeal of the United Nations World Tourism Organisation (UNWTO): "RESTARTING TOURISM. Work together to build a tourism sector that works for everyone, where sustainability and innovation are part of everything we do" (https://www.unwto.org/, accessed 8 February 2021). The general secretary of the UNWTO, Zurab Pololikashvili, says that the tourism industry is the main source of income for people in many parts of the world. It provides an opportunity for income, dignity, and equality, and jobs in tourism help people to be socially active.

As our contribution to the discussion, we propose tourism development linked technologically with augmented reality (AR). This innovation affects tourism transformation [24] (p. 8) in the sphere of:

- changing the properties and varieties of the goods and services as they are experienced by the tourists;
- forming new destinations; and

- altering the way of passing information within and across organizational boundaries.

Cutting-edge technological achievements in brain–computer interface (BCI) solutions shift the cognition boundaries and open new opportunities for applications in the tourism industry [25,26]. Although it has been pointed out that virtual reality (VR) can sometimes be a threat to traveling tourism—it can be a substitute for conventional traveling—the role of augmented reality (AR) can be complementary to various forms of travel. This is possible because AR enables interaction with a tourist [27], provides him/her with new sensations [28], and allows him/her to feel extra emotions [29]. Location-based augmented reality also has a positive impact on tourists' satisfaction [30], and it helps one to remember better the content presented in it [31]. The use of new technologies can also promote new attitudes and skills, e.g., related to environment conservation [32]. Cultural and heritage tourism is mentioned as the most frequent method of AR use [33–38]. Up-to-date and instant information (mobile applications) is one of the most important benefits of AR use in tourism. Displaying 3D models makes it possible to provide more information about an object and to update it continuously [39]. To conclude, literature reports stress that AR's potential for the tourism industry lies in its marketing, epistemic, economic, tourist, and organizational value [40,41].

The common use of AR in tourism is possible owing to technological development and miniaturization of computer hardware (smartphone, tablet, etc.), which creates the possibility to integrate geolocation with augmented reality [42]. Dedicated applications for mobile devices allow tourists to explore new places and, at the same time, help local businesses to optimize their profits and to promote their services and products. It is made possible by displaying interactive advertisements, performing easy positioning, providing map views, and creating touristic routes [43]. Moreover, mobile applications that make use of AR must be easy to use, and the system should be useful and intuitive, with few icons on the screen [44]. Other features of applications for tourists should include a specific purpose, multi-language functionality, easy operation, and personalization capability [45]. All this will make the group of its regular users grow steadily.

By using such a tool, one can combine different types of tourism: historical, natural, religious, cultural, etc. Owing to AR's capabilities for generating virtual objects, it can be used for creating completely new attractions in many sectors of the tourism industry. The proposed approach is consistent with the position presented by the Organization for Economic Co-operation and Development (OECD): "Digitalization is bringing unprecedented opportunities … to develop new tourism products and services and the wider tourism sector will need to fully embrace these new technologies to remain competitive, and to take advantage of the innovation, productivity and value creation potential" [22].

In the age of widespread digitization of life, it is becoming increasingly difficult to attract the attention of the public. The offered product must be attractive enough to arouse interest and evoke in tourists the desire to discover the mysteries of the surrounding world. In addition, it must be "mobile" and usable "right away" when something catches their interest. Of course, it is possible to search for interesting information on mobile devices, but it is necessary to know how to formulate a query (which is not always easy) and how to separate information noise. In addition, people increasingly expect a ready-made product that does not require too much involvement.

The authors were looking for a solution that would make tourists entertainingly acquire knowledge through a new, attractive technology that would arouse their curiosity. The technology had to be attractive enough to arouse interest and, at the same time, be operated by simple, intuitive tools. This raises the question, What meets these conditions and can be used in marine tourism? This technology is undoubtedly AR. We use it in marine tourism primarily to facilitate navigation [46–49]. However, it is also applied to recreational behavior [50] and understand elements in underwater environments [51,52]. This technology has also been successfully applied in marine education and encourages students to engage in an interactive learning environment that makes learning fun and interesting [53–55]. The functions described above mean that the use of AR in water tourism can be an important complement and development of this form of travel. Increasing interest in the observed environment and deepening knowledge about it can provide a basis to motivate an interest in and empathy for marine conservation and education at a global level [56].

A major area of use of augmented reality in the maritime industry is in ship navigation assistance systems. The integration of vision systems with thermal and conventional cameras is described in a study by Hugues et al. [57]. The second popular area where augmented reality finds its use is in the education of seafarers. Virtual ship bridge conditions are being created [58–60]. The wide possibilities of using new technologies based on virtual and augmented reality for the maritime sector applications are highlighted by von Lukas [61] and Vasiljević et al. [62]. Von Lukas et al. [63] emphasize that specific AR applications for maritime applications face many technical and economic challenges. The researchers emphasize that each application in practice must have a business case for commercial applications. Closely related to this aspect are the technical conditions that influence feasibility costs. The authors point out the dynamic development of the maritime-transport-related sector and demonstrate the possibility of finding technical solutions that meet business requirements. The literature analysis shows little interest in the use of augmented reality in the education of tourists. Its main area of use is navigation systems. The applications of AR in marine tourism are scattered; hence, the overarching aim of the study was to develop a comprehensive Maritime Educational Trip model, combining the aforementioned application planes. Despite the rapid development of AR, there are still technological limitations that hinder its mass use by end users, such as tourists [64].

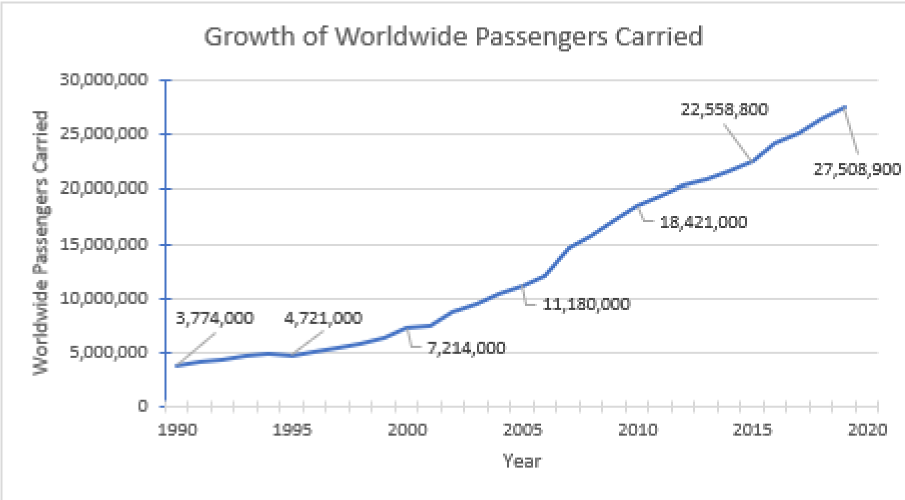
Individuals traveling on the water can use a suitable mobile application not only to learn about but also to "see" past events, sunken ships, different flora and fauna species, etc. This application combines technologies for Global Navigation Satellite System (GNSS) positioning, mobile devices, and displaying of 3D images created in augmented reality. Images generated by AR will raise traveling to a new level and will make it more attractive. This will ensure that tourists remember their trip not only for the aesthetic and visual experience but also for the newly acquired knowledge about the surrounding world. The proposed solution combines e-navigation with education platforms. Such solutions enjoy increasing popularity, and they can become an indispensable element of a voyage. Every implementation of a new market solution starts with analyses conducted in three areas: user needs and requirements, technological capabilities, and business solutions. In the AR literature, there are few studies combining these three areas. This causes companies implementing AR-based solutions to start from scratch each time. The literature focuses on proposing detailed technological solutions or on describing business models independently. The services described in the manuscript and the solutions adopted will allow users to streamline the process of implementing similar projects.

The work is an example of research and development (R&D) work, where it is often difficult to draw the line between industrial research and development. During this type of project, theoretical foundations and assumptions are verified in practice—whether the theoretical assumptions can be implemented in a practical solution is checked. In the case of IT works and the creation of IT systems, innovation is usually the development of a new service and the scheme of its operation. The novelty of this work lies in another implementation of AR technology in a new area—in this case the area of water tourism. It is an example of work verifying the existing state of knowledge and its practical application (verification is done experimentally). Also new are the proposed system solutions in the complex model of the Maritime Educational Trip system, combining different levels of AR applications.

Further parts of this paper present the principles of the MET system using new technologies in sea voyages and the effects provided by a prototypical application developed according to those principles. In addition, business assumptions are presented in the form of the Business Model Canvas designed for Maritime Educational Trips. The following sections present the cruise market and a functionality review of some application for tourists. The technical principles of the MET system are described, and a prototype solution is presented. All technical aspects are described against the background of a market analysis of competing solutions and the main risks associated with the implementation of the MET system.

1.1. The Cruise Market

Marine tourism comprises traveling on cruise ships, ferries, yachts, and catamarans on the ocean, sea, and inland waters; tourist transport on offshore waters; sailing trips on sea and inland waters; kayaking; etc. Internationally, the cruise industry is the fastest-developing industry. The global cruise market worth was estimated at 45.6 billion USD in 2018. The oceanic cruise industry reported an annual passenger number growth rate of 6.63% starting in 1990 (Figure 1). The number of cruise passengers globally amounted to ca. 28 million in 2019 and dropped by 70–80% in Q1 2020.



Source Region of Passengers

Year	North America	Europe	Other	Worldwide Passengers Carried
2017	12,645,600	6,996,000	5,536,400	25,178,000
2018	12,927,800	7,285,100	6,291,700	26,504,600
2019	12,929,200	7,564,900	7,014,800	27,508,900
2020	3,225,500	1,935,300	1,931,800	7,092,600

Figure 1. Cruise market growth. Source: https://cruisemarketwatch.com/growth, accessed on 8 February 2021.

The development strategies for this tourism branch followed so far were based on the construction of larger-capacity vessels and vessel diversification, an increase in the number of local ports, and increasing activities on land/on-board that are in line with tourists' needs. These actions helped to increase the number of tourists using this form of leisure. To make cruises more attractive and, in consequence, to increase this market segment, new, modern technology-based solutions are being sought. These issues are discussed in the report of the Cruise Lines International Association (CLIA), which predicted consumer trends for the cruise market in 2019. These included achievement over experience—experiential travel evolving into achievement travel and on-board with smart tech—and on-board smart technology continues to become more sophisticated. Another study, the Cruise Industry Overview 2018, drawn up by the Florida–Caribbean Cruise Association, also mentions similar top cruise travel trends:

- Transformational cruise travel: The next evolution of experiential travel sees travelers taking a step further and seeking "transformational" experiences, from cultural immersion and voluntourism to extreme adventures.
- Smart travel technology: In the coming years, there will be a rise in traveler-friendly on-board technologies. Several cruise lines are introducing wearable technology for cruise guests that provide a personalized and seamless experience while on-board.

A review of the state of the art confirmed the lack of an AR-based solution available for mobile devices for water tourism. Based on the Internet analysis and field intelligence, seven main competitors were selected. The evaluation was performed in three categories: user reviews (based on comments/opinions published in the Google Play Store), price (5—free, 4 and below—paid), and popularity (number of installations). The ratings were assigned points from 1 to 5, where 1 means the weakest rating and 5 the best one. Table 1 presents a summary of the analysis.

Table 1. Overview of applications for mobile devices.

	Form of Earning			Charges	Registration Is Possible	Social Media			Services in Technology		Working Area				The Range of Impact	Readiness for Duplication of Technology	Contact			Language Versions
Competitors	**Displaying Ads**	**Ordered advertising**	**Subscription**		**Yes/No**	**Facebook**	**Twitter**	**Other**	**AR**	**VR**	**Tourism**	**Education**	**Promotion**	**Other**	**Local/Regional/International**	**low/Medium/High**	**Phone**	**E-Mail**	**Internet Assistant**	**1 Language/2 Languages/More**
1	yes	no	no	free	no	yes	yes	-	no	no	yes	no	no	no	r	low	no	yes	no	1
2	no	no	yes	yes	yes	yes	yes	yes	no	no	yes	no	no	no	i	low	yes	yes	no	m
3	yes	no	no	free	yes	-	-	-	no	no	yes	yes	no	yes	i	low	yes	yes	no	1
4	no	no	no	free	no	yes	yes	yes	yes	no	yes	no	yes	yes	r	high	yes	yes	no	1
5	yes	yes	no	free	no	yes	yes	yes	yes	no	yes	no	yes	yes	i	high	yes	yes	no	1
6	no	no	no	free	no	-	-	-	no	no	yes	no	no	no	i	low	yes	yes	no	1
7	yes	no	no	yes	yes	yes	yes	yes	no	no	yes	no	no	no	i	low	yes	yes	no	m

Mass use of modern technologies is made possible by the widespread use of mobile devices and dedicated applications for tourists. Augmented reality is one such technology. One of the main problems in using educational applications with AR on mobile devices is the method of displaying objects. In most cases, applications use a solution based on identifying objects in an image. This is influenced by the rapid development of computational methods related to artificial intelligence and machine learning. This approach provides a highly accurate display of 3D models. However, the development of

GNSS satellite technology and the increasing number of navigation satellites, as well as the improvement of mathematical models for positioning, are continuously improving the positioning accuracy of mobile devices, among others. Positioning with decimeter accuracy will ensure a dynamic growth of applications using augmented reality. The advantage of using the GNSS to display information in AR is simpler computational algorithms, and thus these solutions have lower hardware requirements.

Our solution integrates GIS solutions and is based on GNSS technology, which is ideal for educational tourism on water areas.

1.2. A Functionality Review of Some Application for Tourists

There are many dedicated applications for tourists on the market. The following application review covers two groups. The first analyzed group includes applications for water users. The second group contains applications that employ AR technology in their operation. Example application solutions with a description of their functions are presented below.

The first example is an open CPN navigation application for sailors. This application has several functions: route planning, route and point handling, Automatic Identification System (AIS), handling high and low tides, sea currents, raster and vector maps, remote control connections, man overboard alert, weather forecast, a printout of planned and covered routes, and maintaining the yacht log or switching on a clock.

Navionics Boating is another dedicated application for sailors. It ensures access to sailing maps used for cruises, angling, sailing, diving, and other water sports. It contains detailed sea and lake maps and advanced functions, such as the best GPS plotters. One can find here all ports around the world and places known to sailors. With this application, one can determine the current position, plan the exact route, and obtain information about what to see along with it. It can also be used to download dedicated sailing magazines, which can help in critical situations, enrich one's knowledge, and fill one's free time. The routes covered are automatically saved in the application memory. While sailing, one can watch photos and films shared by other users. One can also share one's adventures on Facebook or other social media.

Maritime World Ports is another application. It is a database of over 4000 seaports in 191 countries. With this application, one can find a port and obtain useful information about it, e.g., its size and depth. This tool can be useful, especially for those traveling for the first time to an unknown region. The functions available in it include positioning, access to the port website, the port or port area description, size and type, depth, access restrictions, communication types available in the port and/or its immediate vicinity, loading and unloading sites, where normal port operations are conducted, and services available in ports.

Another group of applications under analysis is those employing AR technology. One of them is the Arguido APK travel guide, which can be used as a city guide. The application allows a user not only to see elements of real life but also to see virtual objects generated by mobile devices. It offers such functions as a walk along any thematic route using AR-supported visualization, searching for tourist attractions, service points, cash machines, bars, and restaurants in the vicinity.

Another application is the World Around Me (WAM)—a tool for tourists who look for information about the surrounding area. When using WAM technology, one points to an object with one's telephone to obtain all useful information about it. It provides information about restaurants, cash machines, museums, cinemas, parks, petrol stations, metro stations, pharmacies, hotels, gyms, shopping malls, churches, etc. WAM combines modern AR technology with an intuitive, fast interface, which provides useful information about all places in the user's surroundings.

The main area of use of applications based on augmented reality technology in education are solutions dedicated to museums. They use image or model recognition technology to display additional information. Such solutions ensure high accuracy of content display.

However, these are mainly local solutions dedicated to specific places. The use of GNSS technology for display allows the creation of global solutions. However, it has its limitations related to the accuracy of positioning by mobile devices, which oscillate within a few meters. This limitation of the technology does not allow for a precise display of the 3D model. The use of GNSS technology for visualization of 3D models on water is an ideal solution to meet the needs of tourists. However, among the analyzed dedicated solutions for tourists, there are none combining water tourism and AR. This opens up the opportunity for developing a new system using AR that can be applied in water tourism.

2. Maritime Educational Trips

2.1. System Principles

Preliminary market research demonstrates that there are no dedicated global solutions for tourists on sea voyages that would make use of augmented reality. Long sea voyages may be boring and monotonous because they usually last quite long. This time can be spent learning more about the places visited, their history, geography, and nature. Many travelers need current position data so that they can link them to information about the places they are passing, events that took place in them, etc. Users of the proposed Maritime Educational Trip (MET) system can link geolocation information with the accumulated knowledge about a specific location. The proposed system pictorial diagram is shown in Figure 2.

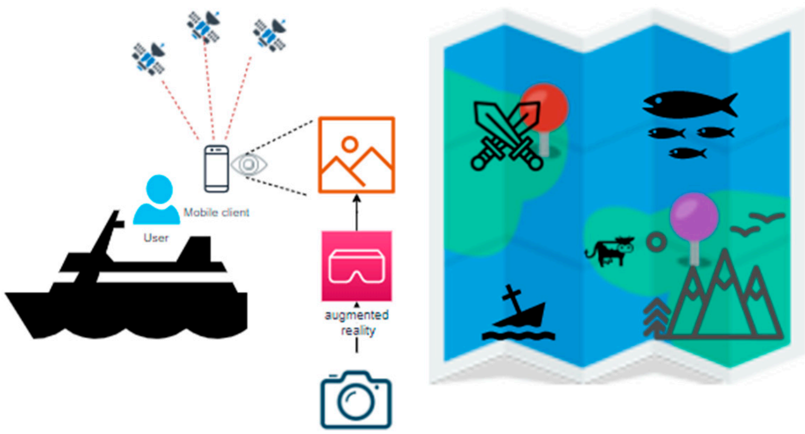


Figure 2. Pictorial diagram of the Maritime Educational Trip (MET) system. Source: prepared by the author.

The system can be used to create personalized tourist routes. Each of the created routes should have a leading theme, e.g., fauna and flora living at a specific location. When one knows the routes of individual cruise ships, detailed information about the places one passes can be displayed for defined locations. It can include data on the place's history, fauna and flora, unique landscape, trivia, etc. Such a solution offers multiple ways of spending free time during the journey and of expanding one's knowledge of places along the route, according to the tourist's interests. Moreover, mobile application users' behavior becomes a source of statistical information. Information about tourists' choices concerning the most frequently displayed places will allow the application authors to improve tourist service management. Like most Internet forums, the platform should be a place of exchanging experience and industry information. Technological details of the proposed MET system are presented in Figure 3 below with a supplementary description.

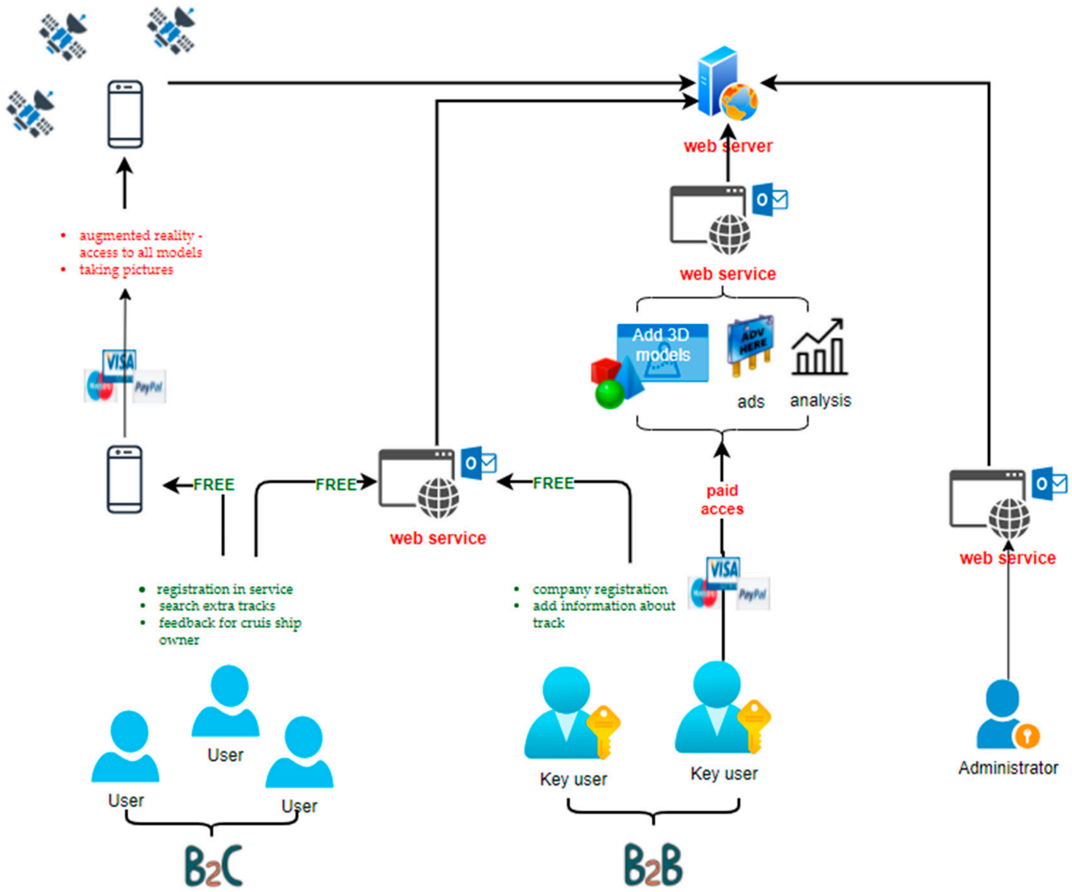


Figure 3. Technological structure of the Maritime Educational Trip (MET) system. Source: prepared by the author.

The system assumes the existence of the following elements:

1. Mobile application: an application used by a user, with the following main tasks:
   - Providing the user with access to tourist routes stored in the MET database with their points of interest (POIs)
   - Enabling the user to log on to the system, to make payments, and to browse through the contents of the private MET account
   - User positioning based on Global Navigation Satellite System (GNSS) technology and device orientation using an accelerometer, a gyroscope, and an electronic compass
   - Projection of a 3D image generated with a mobile camera onto a 2D display system of the smartphone screen with the assumed parameters:
     - Marker use for thematic POIs at a known geographic longitude, latitude, and altitude, presented with pictograms with a description
     - Use of 3D visualization for POIs at a known geographic longitude, latitude, and altitude, presented with a description
     - Sharing data on markers and 3D visualization for a specific user
     - Differentiation of the availability level for individual POIs and extra information, depending on the user account status
     - "Depth" of AR visualization for the user's current position
   - Recording video material with a mobile device with an expanded presentation in AR technology
   - Taking static images with a mobile camera (while using the application) with added POI descriptions and 3D models in the AR technology
   - Acquiring video images recorded while using the application

- Storing one's images and POIs on the MET server (together with a description)

2. Account Internet interface: a browser application that makes the account management by the user easier and more convenient:
    - User account registration, modification, suspending, and removal
    - Payments
    - A quick review of the proposed standard journeys (set of POIs) intended for a specific type of cruise
    - The possibility of importing standard routes onto one's locally saved routes with personalization of their points, the possibility of removing points, and adding one's own
3. Financial account WWW interface: a browser application with which one can analyze and manage the payment and accounting department in the MET
4. Administrator's network interface: a browser application responsible for the administrative control of all the server-based MET elements:
    - Adding new routes with the global access status for MET users
    - Status changes for individual user groups and MET resource availability
    - Data update, etc.
5. Network services: part of the MET base responsible for:
    - MET business logic
    - data provision within the MET, including user status, account validity, and authorization
6. WWW server: a WWW server (e.g., Internet Information Services (IIS)) with application-hosting capability and content delivery with the Hypertext Transfer Protocol Secure (HTTPS) protocol
7. Database server: a relational database server
8. Internet Payments External Operator: an external component with API, which allows for making and documenting safe payments, e.g., PayPal

The market analysis was based on the following sources of information: surveys conducted in a group of people taking cruises, questionnaires/consultations among travel agency employees, analysis of available source materials, and consultations with specialists involved in the development of modern mobile applications.

Surveys were conducted using forums/blogs devoted to maritime tourism and inland tourism (questionnaire attached at the end). In the first stage, 248 potential tourists were examined, of which almost 40% were working people and about 60% were students. Most tourists said they take part in sea excursions/boats once every few years (about 70%), and only 10% several times a year. Other tourists (20% of respondents) said they participate in cruises on average once a year.

To run the MET application, it will be necessary to use the smartphone on board a cruise ship. According to preliminary surveys, respondents (around 93%) use smartphones during tourist cruises and would like to read information about the current surrounding landscape. Only 7% declared not using mobile devices during cruises.

One of the MET's functionalities will be putting the information about the object in the picture. Respondents (78%) are interested in a solution in which the name of the place where it is located in the picture will be added. The declared price that tourists are willing to pay for the described solution is 3 euros (78%), and only 4% of tourists are ready to pay for inserting information in the photo (amount of 10 euros).

Surveys were also conducted among travel agency employees offering cruises. Detailed results are presented in the graphs in the annex. The surveyed companies have on average 5 to 10 customers choosing a cruise on the Atlantic Ocean per year as a form of sightseeing. In addition, 79% of respondents answered that tourists ask for additional information.

Most of the respondents (86%) declared that multimedia presentations or other forms of visualization are not used during cruises.

Most of the respondents declared that they mainly use the Internet and radio to advertise their offer.

All respondents gave positive answers to questions 7–11:

7 Would you use the possibility of advertising in the tourist application?
8 Do you think that the application displaying the name of the tourist attraction when taking a photo would be a nice souvenir?
9 Would you use an application that would allow the use of augmented reality (displaying information about the image from the camera of a mobile device) to expand tourism programs (see the figure below)?
10 Would you recommend such an application to tourists using cruises?
11 Would you be able to pay for such an application?

Based on market analyses in the proposed solution, we can distinguish two groups of recipients:

- companies: B2B (customers—cruise companies, tourist agencies)
- final users: B2C (users—tourists).

The first analysis concerned potential buyers—people participating in cruises (group 1). The research was conducted on the awareness of potential buyers regarding new technologies. At the same time, the following were checked: technical requirements for AR applications (working environment of mobile devices), the extent of funds spent on the purchase of mobile applications, and interest in the proposed solution. A survey form was used to check the above-mentioned issues, and surveys were conducted among potential tourists (248 people).

The second analysis focused on potential buyers—travel agencies offering boat cruises and other water transport (group 2). This group of buyers includes companies that organize or arrange water cruises and water transport. To find out the preferences of this group regarding the possibility of building a MET system, 14 companies were surveyed. The survey was conducted through direct contact and via the Internet.

Table 2 presents the proposed products. They are divided into two groups, depending on access, which can be free or paid. The proposed solution allows the client to check for free whether the users' mobile phones have appropriate technical parameters to support AR application technology.

Table 2. Breakdown of services in the system, taking into account B2B and B2C customer groups.

Access Type	Functionality	B2B	B2C
Free access	basic	- Company registration - Downloading the mobile application with the possibility of displaying maps with interesting places (presenting the most entertaining tourist routes in GoogleMaps, for example) - Adding information about a track	- Registration in service - Searching for extra tracks - Feedback for cruise ship owner - Possibility to take 3 pictures with a 2D/3D information object - Downloading the mobile application with the possibility of displaying maps with interesting places (presenting the most entertaining tourist routes in GoogleMaps, for example)
Paid access	basic	- Add attractions (3D models and information) on ship routes - Receive market analysis - Advertisement on the selected route	- Augmented reality (AR) access that enables to visualize shipwrecks and geographical objects in real time - Taking pictures, together with the description of geographic places and routes

2.2. System Architecture

Augmented reality is increasingly often used in various applications. The simplest of them are based on dedicated pictorial markers. They are used on a mass scale in contemporary mobile applications. In general, they refer to computer vision methods—image detection (mainly flat objects) in a real 3D system of coordinates and their transformation to the coordinate system of a visualized 2D scene—on the screen or display plane. The use of geolocation solutions is another method of marking and labeling an AR scene. These solutions are applied in the designed system architecture. In a general view, the proposed system architecture is shown in Figure 4.

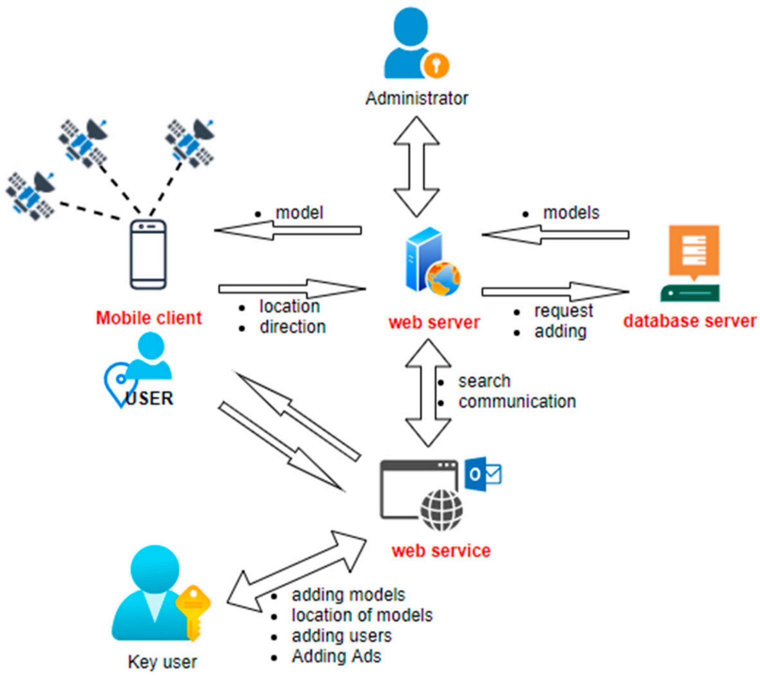


Figure 4. Maritime Educational Trip (MET) system architecture diagram. Source: prepared by the author.

It is assumed that the system architecture includes:

- The positioning module: responsible for analysis of the real world. Sensors embedded in the device (measurement sensors, camera, GNSS receiver) will be used at this stage. The positioning process runs in multiple stages. The first stage involves position determination with one or several sensors. Subsequently, information about the position is sent to the system.
- Interaction module: a subsystem responsible for the process of communication (application interaction) with the user.
- Presentation module: a subsystem responsible for displaying content with sound, image, feel, etc.
- World module: a database with information about the real world, with data on objects and methods of their presentation.
- Communication: located on the part of both the client and the server. This component is responsible for sending/receiving data with information about the presented objects.
- Data filtering: a module responsible for selection/adjustment of content to variable information acquired from the user position-tracing module (positioning, video stream) before it is displayed.
- Browser: a module responsible for content selection based on queries generated by the system client.

Data presentation with augmented reality requires the use of equipment that meets specified technical requirements. They are a consequence of the proposed solution architecture.

2.3. Technical Service Feasibility

2.3.1. Solutions for Position Tracking and Orientation

The following elements were analyzed during the system and its structure examination: solutions for position tracking and orientation, contents of the presented AR scene, use of the mobile platform, and its software.

For the proposed functionality, a MET requires GNSS positioning; therefore, the methods for its determination have to be distinguished, and the solution adaptability in the planned system must be evaluated. Currently, information about the user's location can be obtained in the following manner:

- The coordinates can be entered manually with external tools.
- The coordinates can be entered actively with the following solutions: mechanically (detecting objects in the space); magnetically, with ultrasound (measurement of the distance from obstacles—building a map of the surroundings and comparing it to saved maps); with a proximity sensor—for measurement of small distances; GNSS (the most popular mobile solution requiring an open space—the accuracy ranges from several to several dozen meters); Wi-Fi (WiPS/WFPS) within an accuracy of several meters; and the Global System for Mobile (GSM) positioning (mobile phone positioning).
- Passively with internal sensors, such as a compass (enables simple mobile phone orientation in the Earth's magnetic field), an accelerometer (measures the linear acceleration of a mobile phone movement), a gyroscope (gives an additional dimension to information provided by the angular velocity), a barometer (it can help the GNSS module to approach quickly the real altitude coordinate), and ComputerVision (mainly based on unique image markers that can be found on images captured by a camera with a possibility of assigning a location in the accepted space).
- Hybrid: as a combination of the previously mentioned solutions.

Since global positioning (in the general Earth view) and the relatively low computational capacity of mobile devices (computer vision-based solutions also have a low application potential) were adopted as the MET system application functional assumptions, a hybrid approach was adopted. It is a combination of GNSS-based positioning (global positioning) and accelerometer + compass + gyroscope (device orientation during the image acquisition—scene visualization based on an image from the mobile device camera).

To fully control the calculation of the location of objects built by AR visualization in relation to the position of the user, a script created in the Unity environment using the C# programming language was used. The local system of rectangular rectilinear coordinates in which Unity describes the Euclidean space was used. It was assumed that the user at the beginning of the scene was located at the beginning of this system Po = (0,0,0), all objects for visualization were placed relatively to this location, and the user's direction of view coincided with the azimuth of the axis of the camera he/she was using. Knowing the coordinates of the user's position read from the GNSS receiver (in the WGS84 system) and the recorded locations of the scene objects (recorded in the same system), the average Earth radius for the scene location was determined based on the formula:

$$R_o = \sqrt{M \times N} \tag{1}$$

where:

M = radius of curvature in the meridian

$$M = \frac{a\left(1 - e^2\right)}{\left(1 - e^2 \sin^2 j\right)^{\frac{3}{2}}} \tag{2}$$

N = radius of curvature in the prime vertical

$$N = \frac{a}{\left(1 - e^2 \sin^2 j\right)^{\frac{1}{2}}} \tag{3}$$

A = ellipsoidal equatorial radius (a = 6 378.137 km for model WGS-84)
e = the eccentricity of ellipsoid (e^2 = 0.00669437999 for model WGS-84)
j− geodetic latitude (positive north)—center of the scene

Assuming limited visualization accuracy—not exceeding 0.5 m—it was reasonable to simplify the Earth surface model to a spherical surface with previously calculated R_o. For such a model, azimuths A to all points in the scene from the user's point of view and distances Dr were calculated (Equations (4) and (5)).

$$\cos dr = \sin \varphi_o \sin \varphi_o + \cos \varphi_o \cos \varphi \cos (\lambda - \lambda_o) \text{ (dr in radians)} \tag{4}$$

$$\sin A = \frac{\sin(\lambda - \lambda_o) \cos \phi}{\sin d} \tag{5}$$

where:
λ = longitude of the location of the scene object
λ_o = longitude of the geographical location of the user
φ = latitude of the location of the scene object
φ_o = latitude of your location

With these values, objects were placed in the Unity scene (3D rectangular system) using Equations (6)–(8):

$$x = dr \times R_o \sin A \tag{6}$$

$$Y = dr \times R_o \cos A \tag{7}$$

$$Z = E - E_o \tag{8}$$

where:
E and E_o are the ellipsoidal heights of the visualization object and the user's camera, respectively.

2.3.2. Compliance with the Service Requirements

The study (surveys, technical analyses, market competition analysis, and consultations) resulted in two groups of service requirements: necessary and optional. The following requirements were assigned to each group based on what is expected of the MET system and its operating application.

Necessary requirements:

- The application should be available for various systems (Android, IOS, Windows).
- Models displayed in the AR (2D and 3D) should be entered from a device on which an application is run, following its downloading via mobile Internet. The user will indicate the type of information of interest to him/her that should be displayed in AR to choose the suitable models together with the application.
- The application should be available in several language versions.

Optional requirements:

- The possibility to choose a more attractive cruise route and to create one's educational path.
- The possibility to take conventional photos with added augmented reality information and the geographic name.
- The application will have a common interface for users to share their experience and knowledge.
- The application will have a module to send alerts of any Internet access problems along the user-defined route.
- The application will be able to display information about a selected AR object.

3. Presentation of a Test Version of the Application for the MET System

An example Android application was developed for these assumptions. The test application main screen is shown in Figure 5. Models displayed in AR (2D and 3D) were entered from the device with the application after it was downloaded from the Internet.

Figure 5. Test application main screen. Source: prepared by the author.

The user indicates earlier which images/events are of interest to him/her and which should be displayed in the AR technology, and the application downloads the appropriate models. All the positions and descriptions of objects visualized in AR scenes in the test version were stored on a WWW server and were downloaded from it with the HTTPS protocol each time the MET mobile application was run. Currently, the application has a file with information about tourist attractions and things worth seeing in the analyzed space (Figure 6).

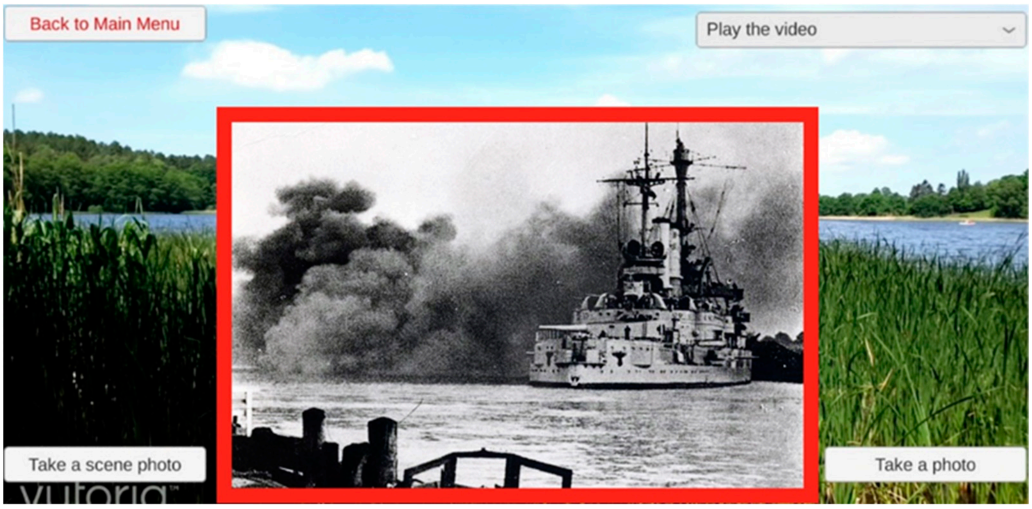


Figure 6. Test application main screen—a frame with historical material [65] displayed in AR. Source: prepared by the author.

The way of data registration for an individual tourist offer, as proposed now, is not final, but it indicates an absence of conflicts when information resources change. The final version will involve data storage in a relational database, from which data can be retrieved by way of queries to be sent as a single data stream to the client application. Apart from these functions, the application can display information about a selected object (Figure 7).

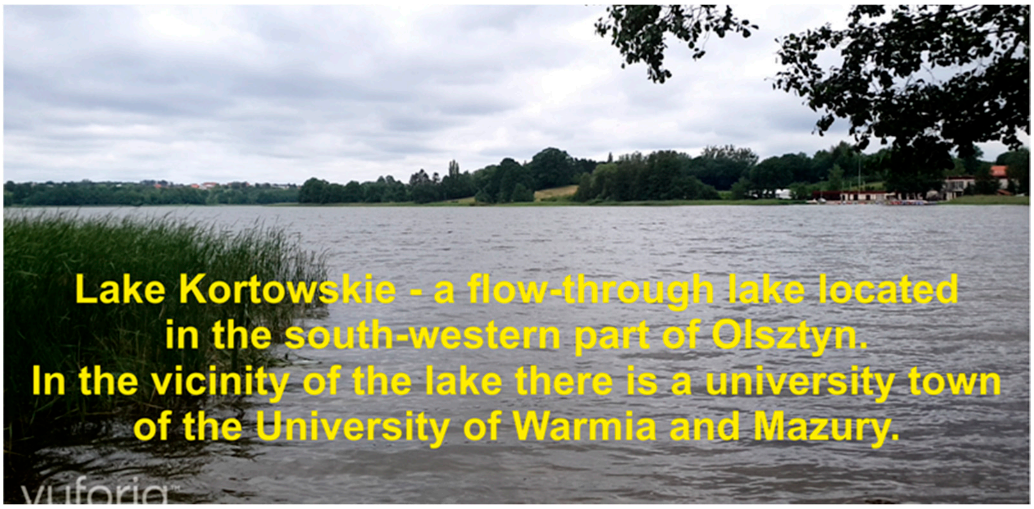


Figure 7. Test application main screen—text information about a selected object. Source: prepared by the author.

Moreover, a user can take a conventional photo of the real world and superimpose on it AR information, which will enable a dual perception of the terrain fragment. Ultimately, the application will have a common interface for users to share their experience and knowledge.

The system concept proposes a prototype solution to verify the basic assumptions of the system. The presented version is created for mobile devices based on the Android system. The solution related to the choice of language version is based on the default language settings in the phone. After starting the application installation, one language version will be automatically installed. This solution was adopted in order to reduce the size of the application and minimize the downloaded data for display. Taking into account the implementation cycle of the application, we started the tests with a minimum range of functionality. Only after the users accept the proposed solution based on their requirements collected in surveys and face-to-face interviews will new functionalities be added to the system.

4. Discussion of the MET System Proposal

4.1. Discussion of Technical Solutions

The authors are aware of the technical risks associated with implementing the MET project. The risk is defined in three groups. The first one applies to AR technology and the pace of change in it. Problems/limitations of the solution flexibility and their integration with other technologies could emerge during the MET system construction. The technological solutions that use AR could soon become obsolete. Second, this technology is associated with mobile devices. The most popular mobile devices (smartphones) are used mainly as mobile phones. Their other functionalities (positioning, photo/video recording, activity monitoring, etc.) are only supplementary. However, the additional functionality requires large amounts of energy. One should bear in mind that energy demand from an application affects the battery efficiency in popular mobile devices. Another threat is the flexibility of the target application for various devices operating under various operating systems. There is also a human factor. A team of specialists/software developers—experts in AR and its integration, e.g., with the GNSS—is needed to develop the system. The team members have to cooperate effectively and must be aware of the issues they will have to face during the task completion (chance factors, illness, accidents, lack of skills, etc.). The technical risks associated with the MET system development are listed in Table 3.

Table 3. Threats and proposed actions to limit the risks associated with the MET system. Source: prepared by the author.

Risk Identification	Description	Probability	Severity	Preventive Measures
Technological solutions	The AR system must handle huge amounts of information.	Medium	High	Filter information, save useful information, discard unneeded data, and display it conveniently.
A version of the mobile operating system	The diversity of operating systems in the mobile device market is still an unsolved problem. It affects the potential for problems with the correct running of applications on various device types (models).	Medium	High	Test the application on a different mobile device model. Implement a dedicated application for a specific mobile device type. Publish a list of supported devices on the project website.
Mobile device efficiency	Real-time data processing on cheap devices can be problematic.	Medium	Medium The application will run slowly but will not be shut down. Only work comfort will decrease.	Prepare data for cheaper devices—lower resolution and lower image detail level.
No internal memory	Operation in off-line mode—due to high transfer cost outside one's GSM or Wi-Fi network—requires that data be downloaded on the mobile device earlier and used when the application is used off-line.	Low	High	The application will store data in the external device memory—expansion cards, e.g., SD. Their cost is low (it is not a problem to a client)—they can be replaced while working with the device.
Running the application on a device that cannot access the GNSS because of terrain obstacles	Application use near large obstacles causes problems, and it can render e-GNSS positioning impossible.	Low	High	Our project is intended for external use.
Wrong accelerometer and compass readings	Use of a device uncalibrated against a compass or accelerometer can result in application maloperation—imprecise detection of the device orientation.	Medium	Mean	Calibration.
Battery discharge	Use of sensors: camera, GNSS receiver, and accelerometer (especially simultaneous use) may discharge the battery.	Medium	Mean	Determination of a specific GPS position results in switching off the receiver, stopping the image recording, and switching off the camera. Use of external power sources—power banks.

4.2. *Discussion of Business Solutions*

The business model is defined by the connections between the elements from three areas: market model, products and services model, operating model. The proposed business model is presented in Table 4.

Table 4. The Business Model Canvas designed for the Maritime Educational Trip (MET).

<table>
<tr>
<td>Key Activities
We provide an app for mobile devices that allows its users to view geographic locations and historical events in augmented reality (AR).</td>
<td rowspan="2">Value Propositions
B2B
• An additional attraction for tourists (movies, photos)
• Adding advertisements along tourist routes
B2C
• Our application will help in interestingly spending free time during the cruise.
• Places of shipwrecks with an option to display a 3D model.
• Places of historical events, e.g., sea battles.
• Indicating an interesting place (on the coast) for travelers, with names of geographical locations ascribed.
• The possibility of taking a picture with geo-tagged photos.
• Following the trails of animal migration.</td>
<td>Customer Relationships
Belonging to the application users’ community, users receive information about the best travel routes (the biggest number of attractions in the AR technology).
The ability to exchange opinions on routes, rate them, and share the score with the community.</td>
<td rowspan="2">Customer Segments
B2B
• Travel agencies (˜95 000)
• Cruise ships owners (˜10,000)
B2C
• Adults and youth taking transatlantic travels (at the moment, there are about 26 million passengers, and until 2020 the number of travelers is estimated to reach 27 million).</td>
</tr>
<tr>
<td>key resources
• IT team designing systems using GNSS technology for smartphones and computers
• -marketing team
• -project management team</td>
<td>Channels
B2B
• Personal contact
• Internet (website, YouTube channel)
B2C
• Information (posters) in travel agencies
• Information in the ferry/ship ticket sales place
• Internet (website, YouTube channel)</td>
</tr>
<tr>
<td colspan="2">Cost Structure
CAPEX:
• Computers (5 pcs)
• Conferences
• Consultations of the system prototype with the company—testing
• Consultations of the system prototype with customers—testing
• Customer service training
• Interface module B2B
• Interface module B2C
• Introduction of amendments
• Database module
• Navigating user module
• Payment module
• Tracking tourist module
• Preparation of the AT system structure design
• Preparation the guide
• Preparing agreement for participants
• System development in different cities
• Translation into other languages (English)
• User registration module
OPEX:
• Billboard 12 m^2 (400–1000 PLN/month) (6 months)
• Billboard design (PLN 50–450)
• Bookkeeping
• domain
• Facebook (5 $ daily)
• Legal support
• Marketing support
• Office (PLN 1500/month)
• Poster printing PLN 150/unit (20 items)
• Project management
• Sales of the product
• Server—access to the server
Website/system monitoring</td>
<td colspan="2">Revenue Streams
Without payments:
• Registration in service
• Searching for extra tracks
• Feedback for cruise ship owner
• Possibility to take 3 pictures with the 2D/3D information object
• Downloading the mobile application with the possibility of displaying maps with interesting places (presenting the most entertaining tourist routes in GoogleMaps, for example)
• Adding information about a track
Paid services:
• Augmented reality (AR) access to visualize the display of shipwrecks and geographical objects
• Taking pictures with the possibility of displaying a description of the geographical places and routes
• Add attractions (3D models and information) on ship routes
• Receive market analysis
• Advertisement on the selected route</td>
</tr>
</table>

A key element in understanding how to complete and interpret the canvas model is to fill it in and read it from right to left. Starting from the segmentation of customers, we can define what kind of relationship we will have with them and what channels we will use to reach them. With the customer profile, we can define what will be the value of our service. The next step is to determine the key activities we need to undertake to implement our project and to identify the key resources necessary to launch it. Then we move on to the key partners necessary for the business idea to work. With the necessary information about customers, resources, and needs, we can determine our costs, and finally, we are able to determine the sources of income. Based on the canvas model, the entire business model is visualized.

5. Summary and Conclusions

Each implementation of a new market solution starts with analyses conducted in three areas: users' needs and requirements, technological possibilities, and business solutions. The final product is a result of combining these three areas and finding an optimal solution that is a combination of them (usually, none of the parts dominates over the others). Especially important is the matching of technical solutions to user needs and business calculations regarding the costs of system implementation and future potential impacts. In the augmented reality literature, few studies combine these three areas, especially concerning the maritime trip. This causes companies implementing augmented-reality-based solutions to start from scratch each time. The literature focuses on proposing detailed technological solutions or on describing business models independently. The services described in the manuscript and the solutions adopted will allow users to streamline the process of implementing similar projects. The development cycle of a given product is linked to technology readiness levels (TRL). The manuscript shows proposed technical solutions, which are based on market and business analyses.

The presented system design combines mobile device positioning and image display technologies with additional information (augmented reality). Ultimately, the system will provide a tool for mobile devices (e.g., smartphones) that uses positioning data to display information about a selected object/event at a specified place. Such a solution allows for developing interactive tourist guides, provides options for spending free time during a voyage, and provides options for expanding one's knowledge. Passengers can get information about what happened at different points of their cruise route, e.g., a sea battle or a sunken ship. Tourists can also get information about the flora and fauna (e.g., a coral reef, cod, dolphin, or whale routes) and geographic data (geological structure, sea currents, high and low tides, weather phenomena, etc.). This information can be provided as a 3D image with AR technology, video clips, sounds, and text information. It creates an opportunity for learning about reality in a deeper and fuller way—for example, a 3D visualization of a shipwreck supplemented with a historical event description or a 3D visualization of a fish shoal, with sound and text information. The proposed model includes several types of feedback—an attractive app attracts the interest of tourists. Using the application, not only do they absorb new information, but they are also more willing to use water excursions. This in turn translates into the operation of water carriers, causing the frequency of use of this form of tourism to increase. In addition to making trips more attractive, a great added value is the increase in knowledge.

Apart from predefined routes, the system allows for creating user-defined ones. A user can specify the start and end points before each voyage. This information can be used to download the necessary information about the route to the mobile device, and then (during the voyage) it can be used based on the determined position.

There are two potential groups of system users. The first one includes individuals. These are water tourists, looking for new solutions to enrich their voyages and experience and to expand their knowledge about the world. The system can also be used by travelers/bloggers. According to estimates, there are tens of thousands of active travel blogs on the Internet and they can make a sort of a promotional sphere—application users (bloggers) can define their routes and tourists can follow them. The system can be a new tool for them, both for planning and for sharing their travel experience.

The other group is institutional users, e.g., travel offices offering cruise ship voyages and water carriers operating those services. This group is interested in reaching wide groups of end customers and in maintaining an attractive and diverse offer. To keep up with technological progress, travel offices have to sell their services via modern mobile applications. This application can complement guide services on passenger ships. According to the saying "An image is worth more than a thousand words," additional visual information will help a user to obtain new knowledge about the reality he/she is watching. The proposed solution also allows for developing interactive tourist guides. All of this has the potential to increase the number of tourists using this form of leisure and, as a result, to increase revenues and develop companies operating in this industry.

The proposed solution may bring measurable benefits, especially to small waterborne tourism operators. Short cruises on small water reservoirs are treated by tourists as one-offs. They assume that there is nothing attractive about traveling the same route again. Making a trip more attractive, taking into account the model proposed in the paper, may result in the same people making multiple trips. A trip on a small body of water, which consists of contemplation of the landscape and natural values, even if the route is changed, does not bring anything new to the area of experiences. However, using the proposed solution, even a slight change in the route of the journey will translate into new information provided by the application, and thus the next journey will be different from the previous one. What is important, in the presented model, by combining leisure and education, cruise operators have an impact on shaping the tourist offer by adding new routes—they define the coordinates and the related scope of educational information in the form of text, audio, video, and 3D models. Importantly, tourists can also influence the design of the route according to their needs and interests. These activities result in diversification of the offer, new scope of information, and knowledge. Making the trip more attractive this way seems to be beneficial both for the provider and for the recipient of the services.

In conclusion, new technological solutions allow for the development of new tourism products and services [66–70]. Due to the consumption-oriented nature of tourism, it is open to new solutions and adapts them rapidly. Technological progress contributes to enriching the tourist offer. Augmented reality is a manifestation of a new technological trend increasingly often observed in various branches of tourism. A combination of the real world and a computer-generated one helps to expand the tourist space.

From a practical point of view of implementing the solution combining R&D work, the next stage of work is a pilot of the solution. The main task of which is to continue the study of users' opinions on the adopted solutions: technical, visual, and substantive in terms of the presented content and intuitiveness of use. We should also pay attention to the rapid development of technical capabilities in the field of visualization of objects in augmented reality. A particularly important role in this respect will be played by the technical department associated with the issues of digital twins.

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