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Concept Paper

Towards Optimal Planning for Green, Smart, and Semantically Enriched Cultural Tours

Konstantinos Kotis [1,*], Asimina Dimara [1,2], Sotirios Angelis [1], Panagiotis Michailidis [2,3], Iakovos Michailidis [2,3], Christos-Nikolaos Anagnostopoulos [1], Stelios Krinidis [2,4] and Elias Kosmatopoulos [2,3]

1 Intelligent Systems Lab, Department of Cultural Technology and Communication, University of the Aegean, 811 00 Mytilene, Greece
2 Centre for Research and Technology Hellas, Information Technologies Institute, 57001 Thessaloniki, Greece
3 Electrical and Computer Engineering Department, Democritus University of Thrace, 67100 Xanthi, Greece
4 Management Science and Technology Department, International Hellenic University (IHU), 65404 Kavala, Greece
* Correspondence: kotis@aegean.gr

Abstract: This concept paper presents our viewpoint regarding the exploitation of cutting-edge technologies for the delivery of smart tourism cultural tours. Specifically, the paper reports preliminary work on the design of a novel smart tourism solution tailored to a multiobjective optimization system based on factors such as the preferences and constraints of the tourist/visitor, the city's accessibility and traffic, the weather conditions, and others. By optimizing cultural tours and delivering comfortable, easy-to-follow, green, acceptable visiting experiences, the proposed solution, namely, OptiTours, aims to become a leading actor in tourism industry transformation. Moreover, specific actions, applications, and methodologies target increasing touring acceptance while advancing the overall (smart) city impression. OptiTours aims to deliver a novel system to attract visitors and guide them to enjoy a city's possible points of interest, achieving high visitor acceptance. Advanced technologies in semantic trajectories' management and optimization in route planning will be exploited towards the discovery of optimal, smart, green, and comfortable routes/tours. A novel multiscale and multifactor optimization system aims to deliver not only optimal personalized routes but also alternative routes, ranked based on visitors' preferences and constraints. In this concept paper, we contribute a detailed description of the OptiTours approach for ICT-based smart tourism, and a high-level architectural design of the solution that is planned to be implemented in the near future.

Keywords: smart city; smart tourism; planning optimization; semantic trajectory; cultural tour

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1. Introduction

During 2021, the direct economic impact of traveling tourism was estimated to be USD 5.8 billion worldwide [1]; however, a catastrophic loss of USD 3.8–4.7 trillion in export revenue per year due to COVID-19 restrictions highlighted tourism's vulnerabilities [2]. According to the World Travel and Tourism Council [3], the global tourism industry lost 174.4 million jobs in 2020, along with suppliers and businesses that rely on employee labor. As a result, the need for technology-enhanced tourism offering physical and/or virtual visiting experiences has been identified in the tourism industry. Integrating emerging ICT technologies supports tourists during several activities (e.g., searching for information and inspiration), while maximizing possibilities (e.g., receiving personalized recommendations) and introducing new opportunities (e.g., for the climate, environment, and the economy). A technology-enhanced tourist experience elevates the user experience while opening new jobs and visiting opportunities. In this paper, we highlight a set of specific key needs that are in line with rules and plans, such as the Recovery and Resilience Facility (RRF) [4] and

REPowerEU [5], and have the potential to significantly improve tourism socioeconomic advantages. The specific key needs are as follows:

- Transition to climate neutrality and pollution reduction: the Paris Agreement dictates that net-zero greenhouse gas (GHG) emissions must decrease by 2050 to limit global temperature by at least 2 degrees Celsius [6].
- Reduce traffic-related air pollution (TRAP): exposure to TRAP due to CO_2, NOX, etc. [7], increases cardiac effects and other serious health problems. According to the "State of Global Air", air pollution has risen to become the fourth-largest cause of early death [8].
- Technology-enhance tourist experience: traditional tourism and cultural tourism are often associated with older and retired travelers [9], affecting the selling proposition, communication, and market activities.
- Leverage tourism management: e-tourism guarantees a win–win methodology for all involved persons [9].

The world is now facing many challenges in various sectors such as the economy, energy, politics, and others while seeking ways and opportunities to recover from the pandemic, the Russian–Ukraine conflict, and unemployment. Many initiatives are launched to facilitate this recovery, such as the smart tourism [9] initiative that targets smarter tourism with accessibility, digitalization, and sustainability, as well as cultural heritage and creativity, and Tourism 4.0 [9] that targets rebuilding tourism with a more tourism-centered approach, exploiting key enabling technologies. The China National Tourism Administration [10] (CNTA) formally launched an initiative to transform tourism into a knowledge- and technology-intensive modern business, which boosted the idea of smart tourism. More and more European countries are actively involved in the smart tourism industry and are taking advantage of it to gain a competitive advantage while gaining popularity around the world.

The future is smart, green, and sustainable tourism that engages people to start their own projects to gain a competitive edge. Exploiting cutting-edge technologies such as IoT, Big Data, artificial intelligence (AI), and augmented and virtual reality (AR/VR), smart tourism solutions greatly improve the traveling experience while also making cities more accessible and discoverable. Those technologies, among others, include mobility models that are of key importance to designing user movements while characterizing their location, speed, and direction movement over time. It is also really important to point out new means of transportation, such as shared mobility services [11]. Such development brings benefits to all stakeholders, such as city and service providers, but above all, respects the principles of sustainable development.

In this paper, a novel approach is introduced to exploit the smart tourism opportunity, as described above, realized in the design and development of the OptiTours system (optimized planning for green, smart, and semantically enriched cultural tours). OptiTours aims to exploit the full potential of ICT, exploiting cutting-edge systems and technologies for the transformation of a smart-ready tourist route tailored to the preferences and constraints of the visitor, city accessibility, traffic, and weather conditions. By transforming the visitor's route into a more comfortable, easy-to-follow, green, acceptable route that enhances his/her experience, while preventing TRAP, OptiTours aims to be a leading actor in this transformation. Moreover, specific actions, applications, and methodologies target increasing visitors' route acceptance while advancing the overall city impression. OptiTours aims to provide a novel platform to meet the requirement to attract visitors and guide them towards enjoying all the city's possible points of interest (POIs), increasing user acceptance. Advanced technologies will be exploited to derive all available information possibilities contributing to increased discoverability of the optimal route, i.e., a smart, green, and comfortable route. Furthermore, a novel multiscale and multifactor optimization system will deliver enormous possibilities, providing not only the optimal personalized route but also alternative routes ranked based on visitors' preferences and constraints.

The paper is structured as follows: Section 2 presents key technologies as background knowledge on the topic. Section 3 presents the OptiTours approach to smart tourism. Section 4 presents proposed implementation and evaluation choices. Section 5 concludes the paper and presents future plans.

2. Background Knowledge and Related Work

2.1. Semantic Trajectories Modeling and Analytics

A moving entity's trajectory can represent and integrate information about the cause of the movement and the different navigation styles, but also the entity itself (vehicle/bus, human/tourist). To enrich the represented movement information with context [12,13], trajectories can be semantically annotated and fused with additional data beyond the spatiotemporal one (time, location). Such semantically enriched trajectories are called semantic trajectories (STs) [14]. SotA research in the field of ST management and analysis [15,16] provides useful information about human (pedestrians) [17–19] and nonhuman (vehicle) [20,21] movement. One of the key challenges is to recognize and interlink movement patterns and correlate them with entities' movement behaviors to extract and infer new related knowledge. Knowledge graphs (KGs) are data structures that usually represent and integrate heterogeneous data in the form of linked triples/statements in the form of a directed graph. The exploitation of KGs as representations of STs provides advancement for ST enrichment and management [22].

2.2. KG-Based Recommendations of Cultural Tours

Recommender systems (RSs) are broadly used to ease and enhance trip/visit planning by suggesting locations or entire routes. One of the main challenges in RSs is the integration of dynamic user profiles with contextual data and POIs. Several approaches, such as content-based, collaborative filtering, and knowledge-based, have been proposed in order to increase the efficiency of RS. KG-based methods tend to have better results than traditional RS, especially in cases with a lack of user preferences and sparse rating matrices [23]. SotA approaches [24,25] integrate geospatial information with RSs but lack semantic information about movement, while others [26,27], although integrating contextual information and user interest, do not include users' visiting style.

2.3. Visitor-Tailored Optimized Tours

Planning can be performed by utilizing several different approaches; spanning from simplistic rule-based algorithms [28], up to geometric Voronoi diagrams and heuristic graph search algorithms [29,30]. In all cases, the solver is called to export a probabilistic sequence of steps (mission) that may (or may not) consider different metrics to optimize, depending on the application's needs. Urban city touring (especially for touristic and cultural purposes) involves making decisions within a highly uncertain environment where the planning agent needs to take into consideration several different emerging factors: available means of mobility, traffic conditions, weather conditions, weekdays, site-visiting hours, costs, visitors' preferences, and travel profiles; without jeopardizing their convenience as much as possible. However, city touring must be performed well in advance so that visitors can plan their excursions in the most reliable way possible. As a result, the predicted measures of the emerging factors are needed to build a corresponding graph-based model to apply the appropriate graph-search algorithms.

2.4. Related Work

The modern topic of smart tourism/e-tourism [31] and tourist trip planning (https://www.journals.elsevier.com/applied-soft-computing/call-for-papers/tourist-trip-planning-algorithmic-foundations, accessed on 1 December 2022) has attracted a number of research efforts lately. Representative examples include a framework for mobile walk-through applications [32], an approach for understanding tourist behavior using large-scale mobile sensing [33], and an analysis of the use of tourism apps for the sustainability of the world heritage sites [34].

In [35], a critical review of affordances (to apprise, plan, order, network, socialize, stream, transact, and rate) and concessions in e-tourism is presented. Affordances are remunerated with concessions in the form of consumer data that are used to determine product/service marketability and to predict and manipulate consumer choices. Tourism is a driver of ICT introductions, an arena for testing and trialing, and a global market. This related work critically examines related developments and their linkages to tourism and sustainability goals, concluding that existing academic assessments are optimistic, simplistic, and monocausal, with a focus on business and marketing opportunities. Authors conclude that e-tourism brings new opportunities and risks, and the need for more critical evaluations of the implications of the ICT economy.

In the forthcoming work of the Encyclopedia of Tourism Management and Market [36], the author stimulates and enhances collaborative practices focused on smart sustainable tourism strategies. As stated, smart strategies (technology-empowered business ecosystem optimization) should lead to tourism transformation, supporting sustainable development and inclusive societies. Digital transformation and smartness improve the efficiency of the entire ecosystem and fundamentally disrupt traditional market structures and practices. As stated, smart sustainable strategies should actively contribute to the wellbeing and prosperity of local communities and support the distribution of value for all involved. Smart solutions will support personalization and contextualization in real time. Wireless networks, 5G, and satellite communications empower networking and support Big Data collection. Artificial intelligence and machine learning applications lead to real-time and context-based value co-creation. The Internet of Things/Everything increasingly supports interoperability between devices/entities. Digital implants and wearable technologies gradually introduce the Internet of Bodies and the Internet of Senses, which will be available soon with the forthcoming 6G networking. Such developments lead to personalized, individualized, and contextualized experiences supported by recommended systems and digital assistants.

In the latest related book [37], an extensive overview of how information and communication technologies can be used to develop tourism and hospitality is presented. It covers the latest research on various topics within the field (as proceedings of the ENTER 2022 eTourism Conference, 11–14 January 2022), including augmented and virtual reality, website development, social media use, e-learning, Big Data, analytics, and recommendation systems. The readers will gain insights and ideas on how information and communication technologies can be used in tourism and hospitality. Academics working in the field of e-tourism, as well as students and practitioners, will find up-to-date information on the status of research.

In [38], a web-based recommendation system for smart tourism using multiagent technology was presented. A hybrid recommendation system based on agent technology was designed, considering the online communication with sectors such as the tourism supply chain, agency, etc. The proposed web application improved the rate of recommendation for customers up to 30%.

In [39], a support system for on-site trip planning based on dynamic information about tourism spots was presented. To provide satisfactory experiences for tourists, they provided tourist information in a timely manner by considering dynamic information (information that changes over time), such as current congestion information in destination spots and travel route information, in addition to static information, such as the preferences and profiles of tourists. The proposed system consists of two mechanisms: (a) a mechanism for acquiring preference information from tourists (including preference on dynamic information), and (b) a curation mechanism for realizing on-site tourism. The authors concluded that (a) on-site tourism spot recommendation is effective for tourists who do not make detailed tourism plans before sightseeing, (b) preference information for participants can be reflected in the tourism spot recommendation while massively reducing the burden on participants, and (c) it is possible to obtain a higher satisfaction level than is achieved with model courses, which are often used for sightseeing.

3. The OptiTours Approach

3.1. Analysis and Requirements Specification

Tourism supports over 12.5 million people in the EU and is growing rapidly while generating 10.4% of the global GDP [40]. Furthermore, tourists tend to advertise the service provider online and through social media, boosting its visibility and the competitiveness of the location. The OptiTours approach was designed to meet a number of key requirements identified in the domain of smart and green tourism.

3.1.1. Enable a Smart, Green, and Comfortable Tourism

Render traditional tourism to a smart, green, and comfortable one, through an integrated user-centric methodology with cutting-edge technologies. Nowadays, traditional tourism offerings may not satisfy the needs and requirements of modern tourists. Therefore, OptiTours aims to make traditional tourism smart, green, and comfortable by delivering a visitor-centric system that suggests the optimal route based both on environmental/contextual conditions and visitor preferences. OptiTours will be supported by KGs, exploiting all available integrated and unified data, transforming it into valuable information/insights to enhance visitors' decision-making in optimal routing. Therefore, OptiTours aims to integrate ICT tools, technologies, and, especially, a number of AI algorithms, to enhance the city's smartness while enhancing visitors' experience. The expected outcome is to increase tourism smartness and, at the same time, increase green and comfortable routes.

3.1.2. Enhance Tourism Experience

Systematically enhance tourism experience through smart route planning. Visitor experience is of ultimate importance for tourist satisfaction. Therefore, OptiTours aims to pay more attention to the tourism experience utility of route planning. The planned route will be provided to the visitor through an excessive combination of AI algorithms, KGs, and ICT processes to maximize the visitor's experience, while considering other important facts such as the available visiting time, their preference to attractions, the available budget, the current and forecasted weather, the available means of transportation, the current and forecasted traffic, and others. Visitors tend to search for data from personal travel blogs, travel guides, Internet pages, or even friends to arrange their routes. This process is time-consuming, difficult, and of unknown quality. OptiTours aims to deliver recommendations for routes of high quality in terms of enhanced tourism experience. The expected outcome is to increase the visitors' experience while increasing the city's accessibility.

3.1.3. Deliver Smart, Green, and Comfort Cultural Tours

Deliver the next generation of smart, green, and comfort cultural tours. Throughout the visiting area/city, there are POIs, themed itineraries, and attractions that promote historical sites, cultural landmarks, natural areas, and unique locations. However, if these are visited in a random/incidental sequence or day, they lose significance and will eventually minimize visitor satisfaction. Therefore, OptiTours aims to enhance the visitor's experience by providing optimal smart routes. In addition, OptiTours will recommend the routes among all possibilities that minimize the environmental impact, towards supporting a green economy. The expected outcome is to provide faster, smarter, and greener routes while exploiting all available data through KGs. Furthermore, following the suggested routes, it is expected that TRAP will be significantly mitigated.

3.1.4. Deliver an AI-Based Recommendation System

Deliver an integrated cultural planning route recommendation system enhanced with AI technologies. Visitors not only have various and specific preferences, but they encounter certain constraints concerning their route planning, such as how much time they need to spend at each location, the time they need to start their visit, the medium of traveling between locations, how much time they want to spend at each location, and more. To address these issues, OptiTours aims to deliver an enhanced KG and AI-based recommendation

system that will suggest tours considering all facts, preferences, constraints, and the latest city conditions. The expected outcome is to provide recommendations with at least four routes that are based on user preferences and/or weather data, city's accessibility, and/or traffic prediction while suggesting a recommendation for the optimal route combining all preferences and constraints, and city conditions.

3.2. Scientific and Social Impact

The OptiTours approach was designed to achieve both scientific and social impact. A technology-enhanced smart tourism framework needs to guarantee the sustainable development of tourist areas, facilitate their accessibility to everyone, enhance the potential visitor's interaction with cultural elements, increase the quality of the experience at the destination, and additionally improve residents' quality of life. Using advanced IoT technologies, OptiTours aims to collect and fuse (big) data from various sources such as social networks, government agencies, and physical infrastructure to create a personalized and enhanced experience for its customers. In such a way, OptiTours will optimize the visitor experience in a real-time manner, while promoting the resolution of a wide area of scientific, economic, environmental, and social challenges [25].

3.2.1. Sustainable Tourism

Introduce smart, green, and sustainable tourism methodologies and policies. The key exploitable results, the novel knowledge, and the Big Data generated by the implementation of OptiTours will guarantee the establishment of smarter green, combined, and holistic methodologies that will eventually lead to useful conclusions and action plans. Operations and outcomes are also expected to positively impact the implementation of national/international policies, decisions, and practices toward the potential societal, economic, and environmental targets. The market replication of the solution may contribute towards the optimization of the established tourism activity methodologies.

3.2.2. Tourism Management Education

Foster tourism management education. In the long term, OptiTours is expected to have a significant impact on the national educational systems: universities and academies may start producing new graduates capable of adjusting to the new market needs. By adopting best tourism practices, the aim is to foster the introduction of education that offers potential candidates with high capacity and skills.

3.2.3. Tourism Industry Knowledge

Improve tourism industry knowledge and enable intelligence on current tourism practices. In-depth user and market insights will be obtained throughout the evaluation of OptiTours. Fostered by its targeted dissemination and exploitation activities, the solution would enhance knowledge of the end-users' needs. By optimizing knowledge representation and engineering methods, the solution aims to efficiently model and correlate heterogeneous information, describe dynamic routing and planning, and foster users with data and knowledge-driven decision support. Using IoT and SW technologies, knowledge from different disparate sources would be made available in a unified manner, and fully exploited by dedicated OptiTours modeling and simulation tools, providing an optimally improved trip service.

3.2.4. Sustainable Competitiveness

Improve public finance and promote sustainable competitiveness. Acting as a tailormade ICT solution towards the potential end-user, OptiTours investment can bring a fruitful return—within a minimal time period—considering the cost-efficiency impact on tourism products. Moreover, OptiTours supports the sustainable growth of national productivity within a context of global competition for (i) raising the shared of tourism in national/international GDP, and (ii) increasing the added value of tourism activity.

3.2.5. Reduction of Traffic Congestion

Reducing traffic congestion, greenhouse gas emissions, and waste generation. The primary aim of OptiTours is to transform cumbersome and tedious city tours into an enhanced visiting experience. By generating dynamic trip planning, the solution fosters users with dynamic smart, green, and comfortable tour recommendations, ensuring comfort and minimizing the traffic congestion and overpopulation. In such a way, OptiTours fosters a low-carbon tourism concept in alignment with national/international climate goals for tourism decarbonization (reduction of GHG and air pollution). The solution also aims to prevent the waste and waste-extensive generation by mass tourism.

3.2.6. Cultural Activities and Values

Promoting cultural activities and values. By promoting cultural events and experiences, OptiTours is increasing cross-cultural interaction, understanding, and main training, and keeping local culture, arts, crafts, and traditions. In such a way, the initiative empowers host communities and strengthens cultural values.

3.3. OptiTours Proposed Architectural Design

Based on the analysis and requirements specification presented in Section 3.1, in this section we present the proposed architectural design, the implementation choices, and the proposed evaluation plan of OptiTours.

To enhance the tourist experience, new methodologies and technologies must be exploited. ST's analytics and personalized RS that enhance visiting experience are modern research topics that are increasingly receiving attention. ST can efficiently model integrated/interlinked knowledge related to location-based planning of visiting experiences, enriched with contextual data such as weather, air pollution, traffic, availability of shared/municipal mobility assets, etc. Such integrated and interlinked knowledge is suitable for further analysis, feeding personalized RS that can adapt to the constantly changing visitors' needs/preferences (dynamic profiling) and provide meaningful and optimized planning of visiting suggestions. OptiTours focuses on the development of a parsing engine, interpreting semantically enhanced city maps to logic-based representations (policy function, domain, and problem model) that will allow for the effective roll-out of the corresponding touring graphs and the application of the appropriate heuristic search algorithms. Ultimately, this technical approach aims to secure the delivery of a dynamic smart, green, and comfort city tour planning recommendation service for visitors, emphasizing continuous semantic map enhancements based on routing uncertainties (weather, air pollution, traffic, availability of shared/municipal mobility assets, etc.). The goal of OptiTours is to model and analyze visiting trajectories in cultural spaces such as cities' open museums or cultural tours, recommending various tours that may optimize visitors' overall experience. Based on visitors' profile, preferences, contextual information, and ST analytics, OptiTours aims to deliver smart, green, and comfort tours upon request:

- Smart city tours: cost- and time-efficient tours, saving time and money by recommending shorter and cheaper tours.
- Green city tours: energy (car fuel)- and pollution (CO_2, noise)-efficient tours minimizing fuel consumption and air/noise pollution by recommending the greenest tour.
- Comfort city tours: comfort-efficient tours that will not disturb visitors' comfort, based on weather or/and traffic conditions.

OptiTours aims to provide capabilities for deciding and recommending a pedestrian-over a vehicle-based tour, a group over a self-organized guided tour, an open space or an in-house tour, a one-day or an hour tour, etc. Initially designed and recommended tours of OptiTours knowledge base will be updated constantly with new information as well as with new tours. To deliver the aforementioned concept, a high-level technical architecture of the OptiTours main framework is proposed (see Figure 1). It consists of five distinct layers: (a) visitor; (b) data; (c) semantic; (d) service; and (e) visualization.

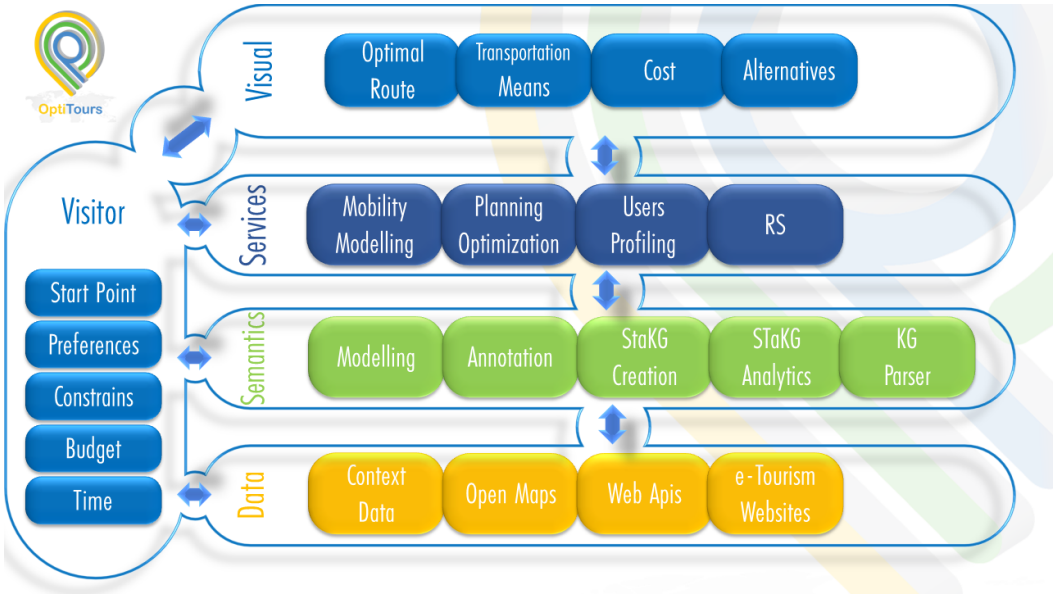

Figure 1. OptiTours proposed conceptual architecture.

(a) Visitor. This layer manages all data and information provided for the visitor. These data consist of specific information, such as visitor's routing starting point, budget, and available time to be exploited, as input features for the optimization algorithm. In addition, this layermanages profiling information that is exploited to update the dynamic visitor's profile.

(b) Data. This layer provides all available data and information retrieved by various sources such as public open datasets and the web, and is exploited for the design and creation of semantic models and semantic data annotations. Furthermore, these data are used as a key feature, along with the visitor data, for mobility modeling, the RS, etc.

(c) Semantics layer. This layer is the core of the system's metadata. All available information is transformed into valuable knowledge (STaKG creation), while providing all the necessary analysis and visual analytics. Furthermore, the developed KGs are parsed and transformed into a logic-based representation language to be used by the services layer.

(d) Services layer. This layer includes all the applications developed to support optimal routing (planning optimization) by combining all the processed data, information, and knowledge. All information coming from the data and semantics layers is processed to this layer, delivering input for the visualization layer.

(e) Visualization layer. This layer provides all the information for visitors to start their smart, green, and comfortable tour. The visitors are also provided with cost, means of transportation, and alternative routes to choose from.

The main functionality of the designed OptiTours system is described in the next subsections.

3.4. OptiTours Main Functionalities

3.4.1. Semantic Modeling of OptiTours Trip Data

This functionality concerns the semantic modeling of the disparate and heterogeneous data collected from all the available data sources OptiTours integrates. The modeling approach examines different types of data, such as movement, geospatial, weather, traffic, user, and other contextual data, to provide a bottom-up (data-centric) semantic description and representation of the domain that OptiTours concerns.

3.4.2. Semantic Annotation and Integration of OptiTours Data

This functionality concerns the exploitation of the OptiTours ontology to semantically annotate the available data. Ontology-based semantic annotation provides an efficient unified representation and integration of the related data. The semantic annotation and integration process utilizes the Resource Description Framework (RDF) W3C standard and dedicated software for data transformation in an automatic way. The semantically annotated integrated data are stored in a purpose-built knowledge base in the form of a knowledge graph that supports efficient semantic querying in well-known standard languages (SPARQL and Cypher). Annotated data are enriched with available external linked open data (LOD) from the web.

3.4.3. STaKG Creation and Reasoning Support

This functionality concerns the conversion and handling of STs as KGs, based on the STaGK methodology [41]. Specifically, (a) the specification phase includes the specification of the involved stakeholders of the engineering team, and data requirements, (b) the development phase includes the creation of the explicit knowledge related to the STaKGs, (c) the evaluation and exploitation phase includes the evaluation of the quality of the modeled STaKGs, management of the STs, and expansion of the knowledge about STaKGs. Knowledge expansion is possible through the inferencing capabilities of the populated OptiTours ontology, and the rules that are described in it.

3.4.4. STaKG Visualization and Analytics

This functionality concerns the visualization and analysis of STaKGs in order to provide useful insights about them. Different types of visual representations, such as enriched maps, graphs, etc., aim to facilitate users to recognize patterns in trajectories and relations between entities. Further analysis of STaKGs will be performed by applying clustering, classification techniques, and utilization of specialized algorithms for pattern mining, shortest path discovery, and behavior extraction.

3.4.5. KG Translation to Logic-Based Language Representation

This functionality concerns a parsing mechanism for translating the enriched KG, populated based on real-time and forecasted information related to city touring and planning, into a reusable logic-based representation language. The mechanism aims to pursue integrating parsing rules for the forward interpretation of KGs back into planning domain description languages (e.g., PDDL) which corresponds to a widely and openly used representation in the AI planning scientific domain. Such a parser ensures the reusability of the city-touring environment from other external contributors.

3.4.6. Mobility Simulation Modeling

The mobility simulation environment is constituted by enriching open geospatial city data (e.g., from open street maps) with semantically annotated data. The aim is to enrich conventional touring maps with culturally valuable information about visiting sites' location, entrance fees, visiting hours, traffic conditions, mobility means, environmental impact costs, nearby shops, local traditional food, etc., collected by dedicated web-semantics scraping tools. The enriched data will enable complex utility-based graph search by constituting a knowledge base with instantiated city nodes for cultural touring.

3.4.7. Multidimensional Optimized Planning

This functionality concerns the city-tour plan optimizer. The setup considers a graph-like environment where a dedicated solver is called to generate a set of feasible optimized city tours according to the end-user's (traveler's) profile. The algorithm considered supports model-based (episodic) reinforcement learning for optimizing a complex "value" (utility) function. A multifactor heuristic utility function is responsible to quantify the "value" of the different proposed trips/paths in order to direct the solver on the fly. The

trip-planning agent considers the current and predicted values of the aforementioned affecting metrics, so the path search becomes computationally feasible in practice. The search environment is based on a semantically enriched city map, as populated to form the corresponding knowledge graph.

3.4.8. Visitors' Dynamic Profiling Management

This functionality concerns the visitor's/traveler's profiling and matchmaking. In this context, a standardized ontological model is reused/considered, and pruned as needed, to produce an appropriate one for OptiTours profiling purposes. On the same matter, a dedicated form is created to promptly collect static information about the different visitors' traveling habits, demographics, preferences, budgetary limitations, etc. This information serves as input to create the profile of different visitors. On top of that, an elaborated machine-learning mechanism is responsible for the clustering and matchmaking of visitors according to their defined profiles to the same group, so similar city-tour suggestions could also be proposed to similar traveler cases.

3.4.9. STaKG-Based Recommendation/Ranking

Within the context of this functionality, different metrics and factors are investigated and appropriately formulated in order to deliver a multiobjective utility function for the city-touring optimization scheme. Factors relevant to monetary costs, travel time, visitors' convenience, mobility environmental impact, visitors' profile (e.g., single traveler, couple, small group, family, backpacker, low-budget, luxury traveler, etc.) will be studied, and, based on the availability (real-time and/or historic) of relevant open data, they will be formulated accordingly. These metrics help to proactively evaluate the total "value" of potential different city-touring plans and rank them to eventually prioritize among different solutions that will be, respectively, recommended as such to the end-users.

4. Proposed Implementation and Evaluation Approach

The implementation of OptiTours will be mainly based on semantic technologies. At the heart of the system, an ontology-based semantic description/modeling of the integrated data will be delivered, using the RDF model for linked data and the OWL language for the specification of the ontological schema. The Neo4j graph data platform will be used for the management of STaKGs. Neo4j (https://neo4j.com/, accessed on 1 December 2022) is currently the leading technology for high-performance, scalable analytics, intelligent app development, and advanced AI/ML pipelines. For the mobility modeling and planning optimization, as well as the recommendation system, custom implementations based on recent research results of our research teams will be integrated.

OptiTours implementation will focus on the fusion of pedestrian and vehicle STaKGs, which will be further enriched with contextual data such as weather, air pollution, traffic, etc. Moreover, advanced knowledge discovery and reasoning tasks will be implemented to extract patterns based on several multimodal characteristics of humans, vehicles, and context, such as human profiles, changes in the movement of entities, POIs, or specific touring behaviors. Eventually, the fused STs will be evaluated based on their efficiency to represent, analyze, and recommend smart, green, and comfortable routes in a city, while the cultural (and overall) experience of the visitors/tourists is enhanced.

Regarding RS, the OptiTours approach will implement a hybrid RS approach for cultural experiences/trips, based on STaKG analytics and collaborative filtering methods, that performs path finding and path connection methods for discovering possible trip/visit recommendations in the optimal ranking order. The implemented RS will fully exploit the semantic information and insights of trajectory analytics to enhance the functionality and efficiency of the tourist visiting experience in the city's cultural spaces.

Regarding optimized planning, a graph-search approach will be implemented based on an approximated multifactor heuristic utility function that is responsible to quantify the "value" of the proposed trips/paths. The trip-planning agent will consider the current

and predicted values of the aforementioned affecting metrics, so the path search becomes computationally feasible in practice. Trip planning will be performed in an offline manner, based on the current holistic situation awareness of the fully observable city touring environment. The search environment will be based on a semantically enriched city map, as populated to form the corresponding KG. The city-touring (trip-planning) mechanism will be based on a novel reinforcement learning (RL) mechanism [42], which builds on top of the cognitive adaptive optimization (CAO) algorithm [43]; employing a model-based RL setup to fine-tune city-touring trips according to their impact on cost, time, environment, visitors' comfort, and visitors' acceptance/liking.

In order to provide various routes, related research may be exploited to provide alternative implementation possibilities when planning an optimal path. Walkable cities are such an example that may be used as an alternative type of urban mobility [44]. OptiTours paths that include walkable visiting points may be considered an optimal green path as long as the weather conditions are acceptable to visitors, ensuring their comfort. Within the same concept, exploiting the mobility of public transportation is also a factor that must be considered when planning a route, as the future sustainable solutions must include public transport modes of traveling [45].

OptiTours experimental implementation will be tested and evaluated in a metropolitan city. Various routes, context, and visitor data will be tested through various use-case scenarios. Each scenario will be evaluated based on the extracted outcome. The optimal tour/route is the tour/route that is smart, green, and comfortable. Nonetheless, there might be routes that are smart but not green (e.g., visiting many places using a cab or bus), routes that are green but not smart (e.g., visiting only a nearby place on foot), and routes that are smart and green but not comfortable (e.g., visit many outdoor places of interest on foot during a rainy or cold day). Furthermore, some routes might be more expensive or longer. OptiTours will combine all available data and information, providing not only the optimal route but also alternatives with various labels, i.e., smart, green, and comfortable (see Figure 2).

Figure 2. OptiTours proposed routes.

5. Conclusions and Future Work

This paper presents the concept of OptiTours ICT-based approach for smart, green, and comfortable tourism. The need for a novel approach to ICT-based tourism, the key requirements, and the scientific/social impact are introduced in this paper, along with the OptiTours proposed design of its conceptual architecture, the implementation choices, and the evaluation plan. Experimental implementation and evaluation of the approach is

planned as the next step. It is expected that OptiTours will deliver not only a system to be used in the tourism industry but also a notable framework that aims to guide the analysis and design of future related systems.

Regarding the limitations of the presented approach, there is currently no provision for delivering open map data to support interoperability and open access to third approaches. In addition, there is no provision for easy and continuous access to an IoT network infrastructure and to a city news/events service provider to enable real-time (sensor) data accessibility. Furthermore, other limitations include boundaries of the delivered system itself, local policies based on mobility services.

Regarding further research directions, it would be interesting to investigate open issues and challenges regarding a city-scale IoT infrastructure that will enable efficient and effective OptiTours planning. Such a planning will provide a well-organized trip that provides the maximum visiting points of interest with minimum cost, time, and effort while enhancing the visitors' experience by taking into consideration visitors' preferences and limitations.

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Abbreviations

The following abbreviations are used in this manuscript:

AI	Artificial intelligence
AR/VR	Augmented and virtual reality
CAO	Cognitive adaptive optimization
CNTA	China National Tourism Administratio
EU	European Union
GHG	Greenhouse gas
ICT	Information and communications technology
KG	Knowledge graphs
LOD	Linked open data
OptiTours	Optimized planning for green, smart, and semantically enriched cultural tours
POI	Point of interest
RDF	Resource Description Framework
RL	Reinforcement learning
RRF	Resilience Ffcility
RS	Recommender system
STaKG	STs as KGs
ST	Semantic trajectory
SotA	State of the art
TRAP	Traffic-related air pollution

References

1. Global Tourism Industry—Statistics and Facts, Statista. Available online: https://www.statista.com/topics/962/global-tourism/ (accessed on 11 April 2022).
2. Sun, Y.Y.; Li, M.; Lenzen, M.; Malik, A.; Pomponi, F. Tourism, job vulnerability and income inequality during the COVID-19 pandemic: A global perspective. *Ann. Tour. Res. Empir. Insights* **2022**, *3*, 100046. [CrossRef]
3. World Travel and Tourism Council (WTTC), Travel and Tourism Representative Council. Available online: https://wttc.org/ (accessed on 11 April 2022).
4. Recovery and Resilience Facility, European Commission. Available online: https://ec.europa.eu/info/business-economy-euro/recovery-coronavirus/recovery-and-resilience-facility_en (accessed on 11 April 2022).
5. REPowerEU. Available online: https://ec.europa.eu/commission/presscorner/detail/en/IP_22_3131 (accessed on 11 April 2022).
6. Paris Temperature Goal, Climate Action Tracker. Available online: https://climateactiontracker.org/methodology/paris-temperature-goal/ (accessed on 11 April 2022).
7. Zhu, Y.; Fan, Y.; Xu, Y.; Xu, H.; Wu, C.; Wang, T.; Zhao, M.; Liu, L.; Cai, J.; Yuan, N.; et al. Short-term exposure to traffic-related air pollution and STEMI events: Insights into STEMI onset and related cardiac impairment. *Sci. Total Environ.* **2022**, *827*, 154210. [CrossRef] [PubMed]
8. Bai, X.; Chen, H.; Oliver, B.G. The health effects of traffic-related air pollution: A review focused the health effects of going green. *Chemosphere* **2022**, *289*, 133082. [CrossRef] [PubMed]
9. Hamid, R.A.; Albahri, A.S.; Alwan, J.K.; Al-Qaysi, Z.; Albahri, O.S.; Zaidan, A.; Alnoor, A.; Alamoodi, A.H.; Zaidan, B. How smart is e-tourism? A systematic review of smart tourism recommendation system applying data management. *Comput. Sci. Rev.* **2021**, *39*, 100337. [CrossRef]
10. CNTO (China National Tourism Administration)—People's Republic of China. Available online: http://www.cnto.com.sg/ (accessed on 11 April 2022).
11. Turoń, K. Social barriers and transportation social exclusion issues in creating sustainable car-sharing systems. *Entrep. Sustain. Issues* **2021**, *9*, 10. [CrossRef] [PubMed]
12. Andrienko, G.L.; Andrienko, N.V.; Fuchs, G.; Raimond, A.M.O.; Symanzik, J.; Ziemlicki, C. Extracting Semantics of Individual Places from Movement Data by Analyzing Temporal Patterns of Visits. In Proceedings of the COMP@ SIGSPATIAL, Orlando, FL, USA, 5–8 November 2013; pp. 9–15.
13. Maarala, A.I.; Su, X.; Riekki, J. Semantic reasoning for context-aware Internet of Things applications. *IEEE Internet Things J.* **2016**, *4*, 461–473. [CrossRef]
14. Parent, C.; Spaccapietra, S.; Renso, C.; Andrienko, G.; Andrienko, N.; Bogorny, V.; Damiani, M.L.; Gkoulalas-Divanis, A.; Macedo, J.; Pelekis, N.; et al. Semantic trajectories modeling and analysis. *ACM Comput. Surv. (CSUR)* **2013**, *45*, 1–32. [CrossRef]
15. Nanni, M.; Trasarti, R.; Renso, C.; Giannotti, F.; Pedreschi, D. Advanced knowledge discovery on movement data with the GeoPKDD system. In Proceedings of the 13th International Conference on Extending Database Technology, Lausanne, Switzerland, 22–26 March 2010; pp. 693–696.
16. Angelis, S.; Kotis, K.; Spiliotopoulos, D. Semantic Trajectory Analytics and Recommender Systems in Cultural Spaces. *Big Data Cogn. Comput.* **2021**, *5*, 80. [CrossRef]
17. Karim, L.; Boulmakoul, A.; Zeitouni, K. From Raw Pedestrian Trajectories to Semantic Graph Structured Model—Towards an end-to-end spatiotemporal analytics framework. *Procedia Comput. Sci.* **2021**, *184*, 60–67. [CrossRef]
18. Karatzoglou, A.; Schnell, N.; Beigl, M. A convolutional neural network approach for modeling semantic trajectories and predicting future locations. In Proceedings of the International Conference on Artificial Neural Networks, Rhodes, Greece, 4–7 October 2018; Springer: Berlin/Heidelberg, Germany, 2018; pp. 61–72.
19. Al-Dohuki, S.; Wu, Y.; Kamw, F.; Yang, J.; Li, X.; Zhao, Y.; Ye, X.; Chen, W.; Ma, C.; Wang, F. Semantictraj: A new approach to interacting with massive taxi trajectories. *IEEE Trans. Vis. Comput. Graph.* **2016**, *23*, 11–20. [CrossRef]
20. Soularidis, A.; Kotis, K. Semantic Modeling and Reconstruction of Drones' Trajectories. In Proceedings of the The Semantic Web: ESWC 2022 Satellite Events: Hersonissos, Crete, Greece, 29 May–2 June 2022; Springer: Berlin/Heidelberg, Germany, 2022; pp. 158–162.
21. Santipantakis, G.M.; Glenis, A.; Patroumpas, K.; Vlachou, A.; Doulkeridis, C.; Vouros, G.A.; Pelekis, N.; Theodoridis, Y. SPARTAN: Semantic integration of big spatio-temporal data from streaming and archival sources. *Future Gener. Comput. Syst.* **2020**, *110*, 540–555. [CrossRef]
22. Chicaiza, J.; Valdiviezo-Diaz, P. A comprehensive survey of knowledge graph-based recommender systems: Technologies, development, and contributions. *Information* **2021**, *12*, 232. [CrossRef]
23. Cardoso, P.J.; Rodrigues, J.M.; Pereira, J.; Nogin, S.; Lessa, J.; Ramos, C.M.; Bajireanu, R.; Gomes, M.; Bica, P. Cultural heritage visits supported on visitors' preferences and mobile devices. *Univers. Access Inf. Soc.* **2020**, *19*, 499–513. [CrossRef]
24. Hong, M.; An, S.; Akerkar, R.; Camacho, D.; Jung, J.J. Cross-cultural contextualisation for recommender systems. *J. Ambient. Intell. Humaniz. Comput.* **2019**, *10*, 1–12. [CrossRef]
25. Hong, M.; Jung, J.J.; Piccialli, F.; Chianese, A. Social recommendation service for cultural heritage. *Pers. Ubiquitous Comput.* **2017**, *21*, 191–201. [CrossRef]
26. Minkov, E.; Kahanov, K.; Kuflik, T. Graph-based recommendation integrating rating history and domain knowledge: Application to on-site guidance of museum visitors. *J. Assoc. Inf. Sci. Technol.* **2017**, *68*, 1911–1924. [CrossRef]

27. Gao, Q.; Zhou, F.; Zhang, K.; Zhang, F.; Trajcevski, G. Adversarial human trajectory learning for trip recommendation. *IEEE Trans. Neural Netw. Learn. Syst.* **2021**. [CrossRef]
28. Medio, C.D.; Oriolo, G. Robot obstacle avoidance using vortex fields. In *Advances in Robot Kinematics*; Springer: Berlin/Heidelberg, Germany, 1991; pp. 227–235.
29. Barraquand, J.; Langlois, B.; Latombe, J.C. Numerical potential field techniques for robot path planning. *IEEE Trans. Syst. Man Cybern.* **1992**, *22*, 224–241. [CrossRef]
30. Pohl, I. Heuristic search viewed as path finding in a graph. *Artif. Intell.* **1970**, *1*, 193–204. [CrossRef]
31. Gavalas, D.; El Choubassi, M.; Crespo, Á.G.; Bellavista, P. Special issue on Mobile and Pervasive Applications in Tourism. *Pervasive Mob. Comput.* **2015**, *18*, 1–3. [CrossRef]
32. Fathy, G.M.; Hassan, H.A.; Sheta, W.M.; Bahgat, R. Efficient framework for mobile walkthrough application. *Pervasive Mob. Comput.* **2015**, *18*, 40–54. [CrossRef]
33. Phithakkitnukoon, S.; Horanont, T.; Witayangkurn, A.; Siri, R.; Sekimoto, Y.; Shibasaki, R. Understanding tourist behavior using large-scale mobile sensing approach: A case study of mobile phone users in Japan. *Pervasive Mob. Comput.* **2015**, *18*, 18–39. [CrossRef]
34. Ramos-Soler, I.; Martínez-Sala, A.M.; Campillo-Alhama, C. ICT and the Sustainability of World Heritage Sites. Analysis of Senior Citizens' Use of Tourism Apps. *Sustainability* **2019**, *11*, 3203. [CrossRef]
35. Gössling, S. Tourism, technology and ICT: A critical review of affordances and concessions. *J. Sustain. Tour.* **2021**, *29*, 733–750. [CrossRef]
36. Glebova, E.; Lewicky, W. Smart cities' digital transformation. In *Buhalis, Taheri, Rahimi, Smart Cities and Tourism, Co-Creating Experiences, Challenges and Opportunities*; Goodfellow Publishers: Oxford, England, 2022. [CrossRef]
37. S., C.P.; C., R.F. Are we there yet?: An analysis of the competencies of BEED graduates of BPSU-DC. *Int. Multidiscip. Res. J.* **2022**, *4*, 50–59. [CrossRef] [PubMed]
38. Hassannia, R.; Vatankhah Barenji, A.; Li, Z.; Alipour, H. Web-Based Recommendation System for Smart Tourism: Multiagent Technology. *Sustainability* **2019**, *11*, 323. [CrossRef]
39. Hidaka, M.; Kanaya, Y.; Kawanaka, S.; Matsuda, Y.; Nakamura, Y.; Suwa, H.; Fujimoto, M.; Arakawa, Y.; Yasumoto, K. On-site Trip Planning Support System Based on Dynamic Information on Tourism Spots. *Smart Cities* **2020**, *3*, 212–231. [CrossRef]
40. Škare, M.; Soriano, D.R.; Porada-Rochoń, M. Impact of COVID-19 on the travel and tourism industry. *Technol. Forecast. Soc. Chang.* **2021**, *163*, 120469. [CrossRef]
41. Moraitou, T.; Angelis, S.; Kotis, K.; Caridakis, G.; Ermioni Eirini, P.; Nikolaos, S. Towards Engineering Drones' Semantic Trajectories as Knowledge Graphs. In Proceedings of the 5th International Workshop on Geospatial Linked Data 2022, co-located with 19th Extended Semantic Web Conference (ESWC 2022), Hersonissos, Greece, 30 May 2022; ceur-ws.org: Hersonissos, Greece 2022; pp. 31–36.
42. Pándy, M.; Ying, R.; Corso, G.; Velickovic, P.; Leskovec, J.; Liò, P. Learning graph search heuristics. In Proceedings of the Physical Reasoning and Inductive Biases for the Real World Workshop at NeurIPS, 2021, Virtual-only Conference; Volume 2021.
43. Kosmatopoulos, E.B. An adaptive optimization scheme with satisfactory transient performance. *Automatica* **2009**, *45*, 716–723. [CrossRef]
44. Turoń, K.; Czech, P.; Juzek, M. The concept of a walkable city as an alternative form of urban mobility. *Sci. J. Sil. Univ. Technol* **2017**, *95*, 223–230. [CrossRef]
45. Ceder, A. Urban mobility and public transport: Future perspectives and review. *Int. J. Urban Sci.* **2021**, *25*, 455–479. [CrossRef]