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Smart tourism: State of the art and literature review for the last six years

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ABSTRACT

In the modern era, the tourism sector has grown to be one of the dominant sectors globally while technology continues to evolve. These facts have given birth to the "Smart Tourism" concept which can be characterized as a progression from traditional tourism. In order to realize an actual Smart Tourism experience, the proper services need to be delivered to the right user at the right time with the best possible way. During the last six years, there has been a significant amount of research in the Smart Tourism field which, to the best of our knowledge, have not yet been presented in a thorough literature review. In this paper, after carefully reviewing a wide number of papers, we have managed to identify the most commonly used approaches and basic concepts in the Smart Tourism sector and present them in detail along with the papers that focus on them. In this study, "key concepts" include: Privacy Preserving, Context Awareness, Cultural Heritage, Recommender Systems, Social Media, Internet of Things, User Experience, Real Time, User Modeling, Augmented Reality and Big Data. At the same time, major Smart Tourism challenges are presented so as to lay the foundations for future researches in the field.

1. Introduction

The tourism sector, one of the biggest sectors globally [1], is a crucial component of the social and economic activity of a plethora of countries as it generates job openings and business opportunities [2]. The tourism industry steadily increases its growth yearly, with tourist arrivals having reached the amount of 1.19 billion in 2015, from 528 million in 2005, while it is expected to grow even more than 1.8 billion by 2030.2017 statistics indicate that the tourism industry contributed directly the tremendous amount of approximately 2.57 trillion U.S dollars, creating millions of jobs worldwide [3]. The realization that the travel industry can be highly beneficial for a country has led to the demanding need to make tourism destinations as appealing as possible, both for the less traveled and also for the well-established ones.

While the tourism industry grows, we are witnessing an era of radical evolution of software environments that allow access to a plethora of tourist related data. These data may regard accommodation, food and beverages establishments, cultural heritage points of interest, etc, along with reviews, ratings and tourist generated suggestions [4]. With such a data explosion, though, choices increase dramatically along with the risk of information overload. Thus, the need to comprehend tourists' needs and behavior has become even more important so as to improve the whole tourist experience by offering the proper service to the right user at the right time. The aforementioned facts have led to the creation of the "Smart Touris" concept, which can be defined as the progression from traditional tourism [5,6].

Based on [7], a Smart Tourism Destination has a primary goal to offer a smart experience to tourists enhanced by personalization, context-awareness, real-time data and mediation by technologies. While a Smart Tourism destination should be an innovative place accessible to all visitors that can experience an improved, more interactive and of higher-quality travel, it should also improve residents' quality of life [6]. When aiming to create a "Smart Tourism" Destination, a number of challenges arise such as how to personalize the content presented to a user [7], which are the most appropriate sources for data collection, how these data should be extracted ie. implicitly or explicitly, privacy issues etc. At the same time, technological infrastructures like sensors, cloud computing services, smartphones, radio-frequency-identification (RFID) and Wi-Fi could also have a vital role in Smart Tourism development [8]. Currently, there are several attempts to offer Smart Tourism services, like recommender systems that aim at suggesting the most relevant tourist attraction based on users' profile [9], location tracking systems that try to assume users' behavior and achieve location-based advertising [10], apps that utilize Sensors to help tourists that have limited amount of time to visit a city [11] etc.

In the last six years, there has been a number of research efforts, concepts, challenges and concerns discussed in Smart Tourism related papers. The interest in these sectors continues to grow, as illustrated in

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Fig. 2, and the need to collect all knowledge produced up to this point in this newly established sector in a single paper arises, so as to offer better insight into this field and set the ground for further research. In this literature review, we take up this challenge and after reviewing a wide number of papers that focus on the Smart Tourism sector we attempt to identify the most commonly used approaches/concepts, something that, to the best of our knowledge, is yet to be done. Eleven "key concepts" have been identified and presented within the scope of this paper. Namely, these concepts are Privacy Preserving, Context Awareness, Cultural Heritage, Recommender Systems, Social Media, Internet of Things, User Experience, Real Time, User Modeling, Augmented Reality and Big Data, along with a number of researches that offer theoretical contribution in the Smart Tourism sector. At the same time, this study also illustrates major challenges that need to be faced in this field. It comes at no surprise that a sector with research still undergoing has many challenges that have already emerged and others that are expected to be "discovered". Thus, it is of great importance for practitioners and researchers to have an insight into issues that have already been identified in a number of papers so as to either attempt to resolve them, or discover areas that require further study and even build upon them.

2. Criteria for inclusion in the literature review

The literature review presented and discussed in this research, is based on an extensive study of Smart Tourism relevant papers that have been published from 2013 to 2019. Our paper research was conducted mainly through DBLP [12], Google Scholar [13], Scopus [14], Academia [15] and ResearchGate [16]. DBLP is a bibliography website that lists all important journals, proceedings, conference papers as well as books and thesis on computer science. Starting in 1993 and with more than 4,5

Table 1
Smart Tourism literature approaches: 2013–2019.

	Context Awareness	Reco-mmender system	Social Media	IoT	User Experience	Real Time	User Modeling	Augme-nted Reality	Big Data	Theore- tical Condtribution	Cultural heritage	Privacy preserving
[19]	✓			✓		✓						
[20]								✓		✓		
[21]					✓		✓				✓	
[22]										✓	✓	
[23]								✓				
[24]		✓	✓				✓					
[7]										✓		
[25]				✓				✓		✓		
[26]										✓		
[27]	✓		✓		✓	✓	✓					
[11]	✓	✓		✓		✓				✓		
[28]			✓							✓		
[29]		✓	✓									
[30]	✓	✓		✓		✓			✓		✓	✓
[9]										✓		
[31]							✓		✓		✓	
[32]	✓	✓			✓	✓	✓					
[33]			✓						✓			
[34]										✓		
[35]				✓						✓		
[36]									✓			
[37]	✓	✓		✓		✓						
[38]	✓	✓			✓	✓	✓					
[39]										✓		
[6]		✓	✓				✓				✓	
[40]			✓						✓			
[41]										✓		
[42]	✓				✓		✓				✓	
[43]										✓		
[44]	✓	✓			✓		✓					
[45]					✓		✓			✓		
[46]												✓
[47]	✓	✓			✓							
[48]												✓
[49]	✓		✓								✓	
[4]		✓	✓				✓		✓			
[8]									✓	✓		✓
[50]				✓								
[51]			✓							✓		
[52]		✓										
[10]									✓	✓		✓
[53]										✓		
[54]								✓				
[55]					✓			✓				
[1]	✓		✓									
[56]	✓	✓					✓					
[2]			✓						✓			
[57]	✓					✓						
[5]				✓					✓	✓		
[58]								✓				
[59]										✓		✓
[60]								✓		✓		
[61]	✓		✓									

Table 2
Literature review: Smart Tourism systems.

Paper	System	Systems' Goal	Methods used	Year
[19]	iTour	a Java-based IoT framework that aims to involve citizens in the tourism development process		2018
[21]	MuseFy	a mobile application which adapts its' UI and provides personalized assistance to users		2017
[24]	CURUMIM	a tourism recommender system that uses data available on the Facebook social network, in order to offer personalized recommendation to its' users and positively surprise them	Content Based (CB) and Collaborative Filtering (CF) techniques to discard from the whole set of possible places to recommend	2017
[11]		a mobile app that utilizes Sensors placed in entrances of Points of Interest so as to help tourists that have limited amount of time to visit the city	The optimisation problem for recommending the optimal route to tourists is dealt as a typical Travelling Salesman Problem (TSP)	2017
[30]	TreSight	a context-aware recommendation system named that integrates IoT and big data analytics for Smart Tourism and sustainable cultural heritage in the city of Trento, Italy		2016
[2]	Find Tourist Profile	detects users' preferences implicitly, based on the geolocation of social media photos	Deep Learning and Fuzzy Logic techniques	2017
[38]	UTravel	a mobile app that utilizes user profiling in combination with context based data in order to guide individuals to POIs based on their current location as well as their previous evaluations via the collaborative filtering principles	UTA algorithm [62]/K-Means clustering algorithm	2017
[61]	HotCity	a social context crowdsourcing platform that exploits users' social geo-tagged data such as likes and check ins as well as their location in order to highlight popular "spaces" and locals' preferences		2017
[54]	ARTS	smartphone based AR Tourism System that deploys 3D scans in order to achieve interaction between urban fabric, cultural heritage tourism and pedagogy.		2019
[4]	Novel Pre-Tourist Experience module	used in the Find Trip Platform so as to implicitly gain tourists' preferences via social media photos and recommend attractions	For tourist classification: Convolutional Neural Network and Fuzzy logic/For Tourism recommendation: collaborative filtering approach	2018
[32]	Madrid Live	system that takes into account user's preferences in conjunction with some other factors such as location and weather to suggest tourism and leisure activities in Madrid	The recommender process is based on a Case-Based Reasoning (CBR) algorithm [63]	2017
[37]		a Smart Tourism Recommendation System that predicts tourist' real-time context and offers individualized services	The proposed algorithm is described in the paper	2018
[52]	Space-Based Tourist Recommendation System	a system that makes recommendations based on users with similar interests	context generalization method, collaborative filtering	2014
[44]		a Smart POI recommendation algorithm that considers tourist preferences as well as location when recommending new places to visit	collaborative filtering	2017
[44, 45]	HGRM - Happy Guest Relationship Management system	a unique platform that offers dynamically formed personalized experience between guests and employees		2015
[44, 55]	ToARist	a tourism AR application that is based on User-Centered design	combination of task analysis, expert guidelines and user-centered evaluation	2017
[56]		Smart Tourism service mechanism that offers personalized recommendations		2014
[47]	South Tyrol Suggests	recommender system that generates context-aware recommendations from a dataset of 27,000 POIs	a method called Largest Deviation is used to measure the usefulness of a specific contextual factor	2017
[48]	BloHosT	a framework that allows safe interaction between tourists and stakeholders via a wallet identifier connected with a cryptocurrency server to initiate payments		2019
[57]		app that transmits both real-time location and survey data that aims to capture user experiences, preferences, etc		2017
[64]	SHCity	a mobile application that integrates real-time data and routing algorithms so as to enrich tourism experience	genetic algorithms	2018
[50]		an IoT system that attempts to achieve Smart Tourism management	Improved Simulated Annealing algorithm	2019
[58]	AudioNear	a prototype that enriches users' experience when visiting open urban environments by providing speech-based assistance regarding his/hers surroundings		2018

million publications by 2017, its number of publications per year is constantly increasing as statistics indicate [17], with the total number of publications rising to 330.755 in 2018. Google Scholar a freely accessible web search engine, released in 2004, contains most peer-reviewed online academic journals, books, conference papers as well as other publications. With its number of publications estimated at 389 million at the end of 2018, it can be considered the worlds' most comprehensive academic search engine [18].

At the same time, researchers that contributed to the writing of the included papers are at their majority prominent scientists, renowned in their scientific sector. Thus, their work is internationally recognized and used in a plethora of papers. Moreover, another qualitative criterion for inclusion in this literature review is the scientific documentation of each paper like the references used in order to support theories and proposed approaches, as well as already proved methods exploited in researches. With that being said, papers included in this literature review are assumed to be of high quality.

3. Smart tourism

After an extensive research in the scientific literature regarding the "Smart Tourism" sector we identified the most widely used approaches and concepts in this field in terms of "key-concepts", as already mentioned. The bar graph illustrated in Fig. 2 displays the number of papers reviewed per approach/concept. Nevertheless, it should be noted that many papers focus on more than one of the concepts mentioned above. In order to provide a clearer picture of the papers reviewed and the approaches discussed in each one of them, Table 1 has been created.

Moreover, inspired by Ref. [61] and as a number of papers present Smart Tourism systems of great interest, that could be an inspiration for researchers and practitioners in the Smart Tourism sector, we created Table 2 that focuses on presenting developed systems described in reviewed papers along with their goal, methods used and year published. In this section we attempt to extensively present the aforementioned concepts, along with papers that refer to them, organized in subsections.

3.1. Theoretical contribution

Contributing to theory and improving it, is both a challenging and an important task. Theory can aid to the development of science as it offers structure and cohesion to several research questions [55,65]. It helps understanding what factors should be studied, the relation between them as well as how they can be applied to practical situations [65]. In the Smart Tourism sector too, there is a number of papers that attempt to offer theoretical insight.

Jasrotia et al. in their research [53] focus on reviewing the existing literature of concepts of both Smart Cities and Smart Tourism destinations. Authors in Ref. [39] attempt to offer a definition for Smart Tourism as well as outline the differences between Smart Tourism and e-tourism. In particular, a quite interesting conclusion which arises from their research is that e-tourism is focused on digital connections like linking consumers with businesses, while Smart Tourism is more about linking the physical world with the digital one by taking advantage of social media, cloud computing and IoT. An insight on the types of recommender systems along with a thorough presentation of existing mobile tourism RSs is offered in Ref. [9]. The authors of this paper attempt to classify mobile tourism in terms of architecture, degree of users' involvement and the criteria that the recommendations are based on. Finally, challenges in the field are presented, which reveal that this sector is far from being fully explored and reach maturity. Another theoretical, methodological and practical approach regarding Smart Tourism from organization, business and tourist points of view is presented in Ref. [34] where 11 papers that include research in the Smart Tourism field are presented.

Authors in Ref. [41] suggest an innovative, more artistic point of view for Smart Tourism. Their approach is based on a concept they name "Creative Computing". Another introduced concept named "service--dominant logic" which can be used as an alternative approach of understanding Smart Tourism development implications, is presented in Ref. [43]. The authors invite readers to consider three perspectives when it comes to creating a Smart Tourism destination: the transformation of tourist experience, the development of a two-way communication strategy and the competitiveness of a destination. Buhalis et al. [26], attempt to identify both opportunities and challenges in the Smart Tourism Destinations sector as well as how it affects various stakeholders governments, tourist organizations, tourists etc. Realizing that blockchain technologies could highly affect the Smart Tourism sector, Calvaresi et al. in their paper [59] provide a systematic scientific literature review of researches that involve blockchain in tourism systems. In this review both theoretical contributions and practical implementations of blockchain in the Smart Tourism sector are analyzed along with a discussion of future challenges. Concluding, Table 1 illustrates all papers that contribute to Smart Tourism theory.

3.2. Context awareness

A concept highly studied when referring to Smart Tourism is "Context Awareness", as illustrated in Fig. 2. In an era of technological explosion, humans seem to tend to develop a tight "bond" between them and their smartphones with the number of actual interactions with these devices being calculated in terms of tens per hour [66]. It would not be an exaggeration to say that these portable devices have become some kind of "wearable", accompanying users almost everywhere and at any time, in contradiction to personal computers or laptops. Thus when travelling, these powerful ultramobile devices that contain a plethora of sensors, are constantly in the users' context. In the Smart Tourism area of interest, we are focusing on the aforementioned sensors that offer an interaction between the smartphone and the environment and consequently context awareness [67]. As an example, extracted data could include current date, time and month, location, environmental temperature as well as users' speed. As context plays a crucial role on user preferences [68], the aforementioned data is quite important in order to offer personalized services in a Smart Tourism system. Contextual information impact in decision-making processes in a wide number of domains along with the tourism one is already recognized by researchers [32].

In the present literature review a wide number of systems that focus on context awareness are included, such as a context-aware recommender system named Madrid Live [32] and HotCity [61]. A user-centered service mechanism based on context awareness is presented in Ref. [56]. The structure of the proposed Smart Tourism system is composed of data deriving from human input and sensors, the platform that offers high data processing ability and compatibility that can be supported by cloud computing and finally the Service that adapts to tourist needs. Another context-aware recommender system that makes use of user contextual information so as to also generate the personalized recommendations that shall enrich user experience is presented in Ref. [47]. Based on the fact that only appropriate contextual factors should be taken into account in a recommender app, authors in Ref. [47] propose a method that predicts the contextual factors that affect users when rating an item so as to use the aforementioned factor in the recommendation process and thus result in more accurate recommendations.

3.3. Recommender systems

Decision and recommendation making in the era of Big Data can prove to be a challenging task. In some cases there is too much data to process, in others sufficient knowledge regarding the alternatives is not available, while there are cases when even time and place is not the suitable one for the right decisions to thrive [47]. Personalized information filtering and decision support tools that aim at suggesting relative items to users [32], namely recommender systems, pose a solution to the aforementioned issues [69]. Recommendations in such systems can be produced via a substantial number of techniques, that can be classified to four major classes based on [70] collaborative filtering, content-based, knowledge-based and hybrid ones [47].

In the tourism sector, recommender systems have been widely exploited resulting in apps that offer personalized guides to tourists [6,9,47]. Suggestions in tourism recommendation tools can be produced via filtering information, services, products [71], contextual data, such as time, location, budget, weather conditions [32] and an enormous dataset of options, locations, cultural heritages points of interest, hotels, attraction, etc. so as to cover users' interest, preferences and needs [6,71]. With such diversity in tourists' profiles and services available it can transform the recommendation process to a quite challenging one [6], a fact that enables a great number of researches to propose viable solutions.

Authors in Ref. [32] propose a context-aware recommender system they name Madrid Live, that takes into account users' preferences in conjunction with some other factors such as location and weather to suggest tourism and leisure activities in Madrid. In particular, the system recommends plans as a timetable that consist of a collection of activities. Each plan performed by a user is stored and proposed to other users with similar preferences. The contextual information that affect the recommendations are time, location, weather, users' budget and if they wish to use public transport. As contextual information may contradict users' preferences resulting in a plan that does not suit his/her wishes, an alternative plan is proposed with an explanation as to what context restrictions occur in the aforementioned plan. Another recommender system that makes use of uses tourists' context is presented in Ref. [52]. Smirnov et al., in this research present a Smart space-based Tourist recommendation mobile application that is able to recommend and

provide access to tourist Points of Interest as well as suggest the appropriate transportation means for reaching them. The system exploits users' context (location, weather, etc), profile (trip length, interaction mode, etc.) and a collaborative filtering method so as to make recommendations based on users with similar interests.

Khallouki H. et al. [37] suggest another approach that attempts to integrate context awareness in a mobile tourism recommender system. So as to provide the appropriate services via predicting tourists' real-time context, a combination of Internet of Things technologies with semantic web ones is made. An app based on a Smart POI (Point of Interaction) recommendation algorithm that takes into account both the geographical location and user preferences so as to make suggestions to its' tourists is presented in Ref. [44]. Two versions of the algorithm are set to be developed, one that takes into account only user preferences and an extended one that considers the geographical influence too for the recommendation process.

3.4. Social media in smart tourism

"Six Degrees", created in 1997, is considered to be the first social media site that offered users the ability to upload a profile and add friends. Since then, a number of social networks have emerged with their use, nowadays, being the most favoured activity online, as web traffic reports indicate [72]. In particular, as also depicted in number statistics, the monthly active users of social media shall reach by 2021 the titanic amount of 3.02 billion [73]. As more and more users tend to be active in a plethora of social networks, like professional, photo sharing and travelling ones, more and more practitioners and academics are allured by the resources these networks offer. With that being said, it comes as no surprise that a substantial number of researches has been published that combine Smart Tourism with social networks as illustrated in Table 1 and Fig. 1.

Social media channels store a big amount of data regarding their users both via the profiles directly filled by them, as well as information that is generated from their interaction with the social network media channels such as uploading images, making reviews and checking into locations. Raw data of such size can be fairly considered as valuable resources for user modeling. For example, a tourism recommender system that exploits data available on the Facebook social network, in order to offer personalized recommendation to its' users and positively surprise them is presented in Ref. [24]. Authors in Ref. [4], aim to propose a new module that detects tourists' preferences implicitly, based on social media photos and personalizes its recommendations of tourism attractions. Initially, a micro service architecture is presented that gathers and processes a big amount of photos that derive from Facebook, Instagram and Google Plus, depending on users' choice. This process consists of two steps, namely users' login using one of the aforementioned social networks and the collection of his/hers photos via a web interface component that utilizes the permissions given through the authentication process. Thereafter, an approach is presented that exploits Deep Learning and Fuzzy Logic techniques to determine users' preferences from photos and classify them to the following categories: Historical/Cultural; Adventure; Urban; Shopping; and Landscape. The last module is a tourism recommender system that matches tourists' profiles with the more suitable attractions. The experimental results indicate that at least 90% of the attractions provided by the system can be considered relevant for each tourist, proving the feasibility of this research.

Another undeniable fact is that social networking services websites like Facebook, Instagram and Twitter can offer users the ability to both acquire and share, in real-time, a plethora of data [28]. Based on the fact that users have real-time access on travel information like reviews, ratings, etc. that derive for smartphone social networking services, authors in Ref. [28] attempt to explore mobile users' trust regarding this information. Another attempt to exploit a social media channel, namely Facebook, for Smart Tourism purposes are presented in Ref. [51]. This paper focuses on the ways that local Korean governments utilize social networking sites in order to promote tourism. Another contribution of this work is the theoretical and practical implications of the Smart Tourism sector. Based on Twitter data, authors in Ref. [1] focus on spatial analysis and text mining in order to reveal how social networks can provide a platform to develop smart services for urban tourism. They have exploited a dataset containing more than 600,000 tweets for the city of San Francisco, where each one of them contains text, geographical location, the user who posted it, as well as other supplementary information like images and videos. By analyzing the aforementioned data, the paper's authotrs provide evidence that information contained in social media data offers awareness regarding the presence, the engagement with the environment and topical engagement of users across the San Francisco. Apart from the contribution in the tourism sector understanding where benefits arise for businesses, governments and tourists, these dynamics are crucial in a Smart City scenario too and offer solutions that do not require financial investment and can improve urban life. Last but not least, a paper that attempts to spot cultural heritage resources from geotagged social media is presented in Ref. [49].

3.5. Internet of Things

A concept that could add another dimension to Smart Tourism is the Internet of Things. Internet of Things (IoT) was firstly brought into existence by Kevin Ashton (MIT) in 1999 and was defined as an interconnection among devices anytime and in anyplace [76],[102]. In other words, IoT is the network of physical objects that incorporate the technology required which allows them to communicate with each other and sense or interact with their internal state, or with the external environment [74]. In an IoT world, real-time interactions between physical objects and users leverage the gap between the real and digital world [9], [21] With statistics indicating that IoT will consist of almost 75 billion interconnected devices by 2025 [75], an evolution in a plethora of sectors like manufacturing, smart grids, security, healthcare, education as well as the tourism sector is highly expected [76].

When it comes to tourism, IoT can enable the creation of smart technological environments that connect their physical and digital infrastructures. This shall allow systems to be able to identify tourists' context in a pervasive but not intrusive way and attend to their needs. With that being said and based on the fact that sensors integrated in tourist attraction may offer location based assistance to users [5], authors in Ref. [11] propose an IoT architecture for a sustainable tourism app where sensors are utilized in Points of Interest. In particular, this scenario focuses on tourists that have limited amount of time to visit the city of

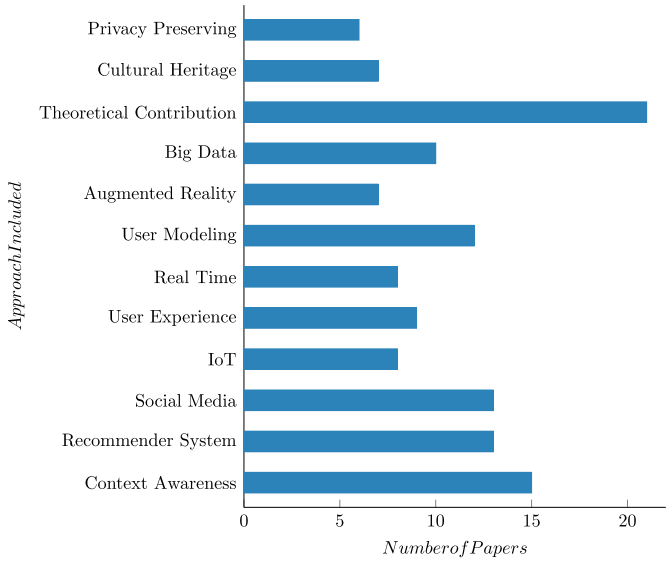

Fig. 1. Number of Papers focusing in each investigated category.

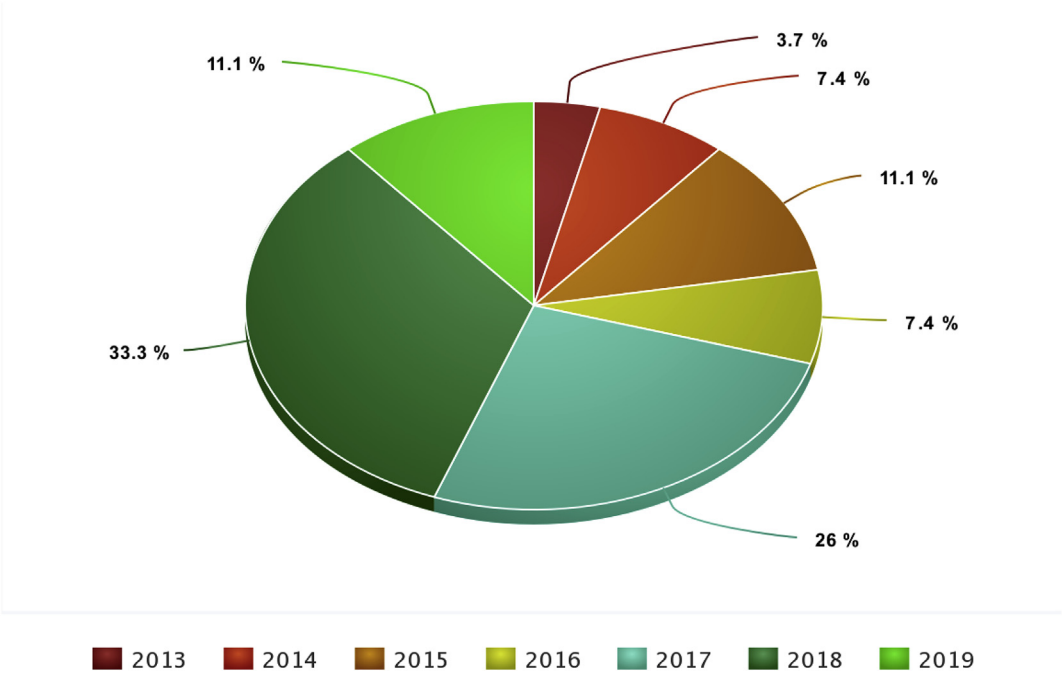

Fig. 2. Papers included in the literature review per year.

Cagliari in Sardinia Italy and in order to do so they specify the Points of interest they wish to see via a mobile app. These authors' approach attempts to resolve two factors that may cause delay when visiting a location, namely choosing the wrong transportation, or face delays due to long queues. The aforementioned sensors placed in entrances of Points of Interest measure queue waiting in combination with specific timestamps during the day. This estimation along with required time to access a location are used to recommend the best route so as to visit all points of interest to tourists. Authors also deal with the underlying optimisation problem, as a typical Travelling Salesman problem. Further contribution is made in their work as key requirements for an IoT platform in a Smart City environment are set, that specifically are Security Requirements, Flexibility and Data Requirements.

Moreover, firmly supporting that IoT can be used so as to overcome tourism issues, Tripathy et al. [19] introduce a Java-based IoT framework named iTour, which aims to involve citizens in the tourism development process. With the help of a smart map, tourists have the ability to spot information about hotels, points of interests, volunteers as well as traffic and on-road police and request assistance. At the same time, the iTour manager, tourism department, home department, and other government officials are able to view all the resources on the city map in real-time and measure their effectiveness.

As wearable devices like bracelets, watches and glasses can significantly affect tourists' interaction with their surroundings [35] it comes at no surprise that Atembe in his research [35] seeks to conceptualize the use of wearable devices in the tourism sector and determine how the aforementioned devices could affect tourism behavior. Tussyadiah et al. support that wearable devices are able to extend the way tourists sense, comprehend, orientate and interact with tourism attractions when navigation in a destination of touristic interest [25].

A system that makes use of wearable bracelets in a tourism scenario is proposed in Ref. [30]. In particular, a case study is presented of a context-aware recommendation system named TreSight that integrates IoT and big data analytics for Smart Tourism and sustainable cultural heritage in the city of Trento, Italy. The aforementioned system gathers dynamic data from real-time monitoring of weather stations, wearable bracelets and hotspots that offer data about availability in the places, how crowded they are as well as opening and closing hours. All dynamic data will be exploited by a mobile app that will "communicate" with the bracelet and make recommendations to tourists, offer promotions and present valuable information about Points of Interest. Another IoT system that relies on wearables is proposed in Ref. [50]. This system takes into account 3D topographic differences in order to integrate Smart Tourism management. The aforementioned system deploys wearables and sink nodes in a recreation park that gather data from tourists' wearable devices so as to offer a number of services like interaction with the landscape, detection of physiological data etc.

3.6. User experience

The user experience (UX) concept is a multidimensional one [77] with a wide number of models being proposed in this sector in the last decades [32,65,77]. A primary goal in user experience design is to reach and maintain a high degree of user contentment via the usefulness, convenience and joy that derives from human-system interaction that goes far beyond basic usability [77]. UX can be considered as the users' realization of a system, once interaction with it has taken place that is affected by three factors: system in question, the user and the context of use (ISO 9241–210, 2010) [28]. User experience in Smart Tourism related applications is quite crucial too. Being able to positively affect users' evaluation of a tourism system and maintain a great enthusiasm for it, may lead to the creation of a long lasting bond with the app in question as well as recommend it to other potential users [28,77]. Based on this fact, the undeniable need arises to thoroughly comprehend travelers' needs as well as their way of interaction and communication with others [4] so as to offer personalized services that shall enrich the quality of their travel and cultural experience [22,31].

To exemplify, so as to enhance visitors' user experience of a cultural heritage point of interest via personalization, authors in Ref. [42] propose a multilayer framework that supports personalization by combining the physical and the digital world. The "personalization" term contains three types of system behavior; adaptability so as to adjust to each visitor based on their preferences, visit motivation and expectations; context-awareness that empowers the sensing of the current state of an environment; adaptivity where a system dynamically changes so as to adapt to new circumstances. In particular, they attempt to create a cultural space filled with smart objects, where each and every one of them comes with a story which will be presented once conditions are right e.g.

visitors have picked up an object.

In the tourism business sector, a potential way of how businesses should take advantage of smart technologies, enhance tourism experience and increase their competitive advantage is presented in Ref. [45]. Based on the fact that smart technologies via personalization may assist tourists to develope their own memorable experiences [78], Neuhofer et al. in their research attempt to present how smart mobile technologies can lead to these personalized experiences in the tourism and hospitality industry. A case study of a hotel that exploits a unique platform that offers dynamically formed personalized experience between guests and employees is presented.

Another attempt to improve User Experience is presented in Ref. [55], where authors aim at resolving the usability problems in an Augmented Reality context. Though AR offers a great potential in the way information is delivered to users, it also comes with the risk to impose users with data overload or result in a system with high usability issues [54,55]. In order to overcome that issue, authors developed through 4 rounds of iterative development a tourism AR application named ToARist, which is based on User-Centered design.

3.7. Real Time

When discussing about "Smartness" in the tourism sector, beyond the individual technological advances some quite game changing factors are the interconnection and synchronization of technologies [5,48] in combination with real-time data [79]. In other words, Smart Tourism can be considered to be a technological ecosystem rather than independent systems where real-time connectedness, synchronization and awareness of users' context hold a major role [5,7].

That being the case, it comes as no surprise that the "real-time" term appears with high frequency in Smart Tourism related literature. To exemplify, one of the biggest tracking studies in the tourism sector is presented in Ref. [57], where tourists' movements have been recorded via a mobile and GPS technology in real-time mode. Specifically, an app transmits both real-time location and survey data that is provided by tourists in each location and aims to capture their experiences, preferences, etc. Another system based on real-time location is presented in Ref. [38] that guides individuals to POIs based on their current location as well as their previous evaluations. Moreover, authors in Ref. [64] present the development of a mobile application that integrates real-time data and routing algorithms so as to enrich tourism experience when visiting the city of Avila, Spain.

3.8. User modeling

The "User modeling" concept has been in the epicenter of many researches for years now. Three decades ago, twenty five prominent researchers discuss and present the developed user models at that point in time [80], paving the way for future research in the field. In the related scientific literature, the "user modeling" term is the thorough recording and categorization of the various aspects of users' behaviors and interests [27,38]. Based on Gao et al. [81] and endorsed in Ref. [38], user profiling consists of behavior modeling, where user–devise interaction information is used to estimate future behavior, interest modeling and intention modeling which aims at locating users' goals.

In a Smart Tourism scenario, a quite important task is to offer personalized services to the user [27], offering the right information, at the right time, via the right channel [27,91]. For personalization purposes, a user model is required that can be developed via Feature-based, Content-based and Collaborative filtering or other approaches [31]. What is definitely required, though, is the collection of individuals' data and the effective use of them while preserving their privacy. Data collected regarding users can be harnessed both implicitly and explicitly. Explicit user data are those directly submitted by the individual to the system while implicit user data can be gathered from a wide number of sources like sensors, social media channels, smart devices etc. It seems that collecting data from variable sources regarding individuals and their environment is a one-way path in order to achieve user modeling in adaptive, recommender systems.

Many research papers in the Smart Tourism field attempt to overcome issues that may arise in the aforementioned process, attempting to set the ground for deeper research in user modeling in the Smart Tourism field. Authors in Ref. [21] developed a mobile application that goes by the name MuseFy, which uses a double stereotype system for achieving user modeling so as to adapt its UI and provide personalized assistance to users. Moreover, the main objective of [27] is to present how user modeling could be accomplished in a Smart Tourism application scenario via data originating from users' social networks, as well as data collected from their smartphones implicitly, requiring no user interaction. Amoretti et al. in Ref. [38] present a mobile app namely UTravel, where user profiling in combination with context based data are exploited in the recommendation production. The application in question guides individuals to POIs based on their current location as well as their previous evaluations via the collaborative filtering principles.

3.9. Augmented reality

Augmented reality is a concept that actually exists for over five decades now and refers to the "augmentation" of the real-world with computer-generated data, such as video, audio, graphics, GPS data as well as other multimedia formats via the camera/speaker of a computer, smartphone or other devices [82]. In this way, AR can enrich ones' perception of a real world environment and his/her surroundings with virtual objects [83]. In a typical AR system the user points their device towards an object and they are able to see/hear additional virtual information superimposed on the real word [84]. As AR systems can assist tourism roaming in unknown environments and enhance the whole touristic experience via an entertaining way of accessing additional valuable information [82], a number of mobile AR applications have emerged in this sector. For example authors in Ref. [23] aim at creating location adaptive augmented reality application in the tourism context. In Ref. [54] a smartphone based Augmented Reality Tourism System is presented that exploits 3D scans so as to offer interaction between urban fabric, cultural heritage tourism and pedagogy. Ilhan et al. in their study [20] attempt to identify the potentials of AR systems in the tourism industry as well as present a number of challenges for these systems. Moreover, authors present how AR could be utilized in the tourism marketing industry and more specifically in museums, hotels, restaurants as well as in the transportation sector.

A highly promising concept in the augmented reality field and the Smart Tourism sector in general is the one of image based localization. Image-based localization methods attempt to calculate the position from which an image is taken, in terms of both location and orientation [85]. As these methods can be exploited in a plethora of application such as tourism guides, robotics, augmented reality etc., they draw increasing attention [87,95]. Authors in Ref. [86], having located this academic and industrial interest, present an overview of image-based camera localization approaches. Moreover, authors in Ref. [87], attempt to develop a faster localization method that could increase the performance of augmented reality applications as well as real-time navigation ones, amongst others that ultimately could facilitate the development of Smart Tourism systems.

Augmented reality offers a great potential in the way information is delivered to users, but is also accompanied by the risk to impose users with data overload, or result in systems with high usability issues [54, 55]. Aiming to resolve the usability problems in the AR context, the authors of [55] developed through 4 rounds of iterative development a tourism AR application named ToARist which is based on User-Centered design. Individuals taking part in the development of the aforementioned app remarked it as simple and useable, nevertheless challenges still exist that need to be faced.

Aiming to overcome the disadvantage of visual AR applications that

may cause disorientation to users when both observing the environment and interacting with the device [88], the authors of [58] present how audio augmented reality systems could be integrated in an urban Smart Tourism scenario. In particular, a prototype has been developed, namely AudioNear, which is designed to enrich users' experience when visiting open urban environments by providing speech-based assistance regarding his/hers surroundings. More specifically, users launch an audio tour guide mobile app which gets their location via GPS and triggers an audio track with information regarding a sight that is placed within a certain radius.

3.10. Big data

In the first decade of the 21st century the concept of Big Data suddenly gained attention [89]. The Big Data term stands for the productive exploitation of data [90] in units of measure way greater than megabytes and gigabytes [91], with huge variety and velocity, that has a number of attributes like "too large, too unstructured, and too fast-moving" [89].

In the Smart Tourism sector, there is a massive size of heterogeneous data deriving from social networks, apps, sensors, etc. waiting to be properly mined and exploited [10]. This abundance of free information [5], that derives from users' actions (voluntarily offered, observed or inferred [10]), combined with interconnectivity, analysis, real-time synchronization and meaningful use of data [5,98], has grown to be a fountain for value creation that can lead to the delivery of a smart travel experience [89]. That being the case, a number of Smart Tourism concerned papers focus on Big Data. Particularly, the goal is to determine how Big Data can be most effectively exploited in the Smart Tourism sector as well as the challenges arise when it comes to big data exploitation in the aforementioned sector. Some challenges, for example, would be how to transform a plethora of variables like physical, biological and social into a single meaningful electrical signal [30] or how to ensure the preservation of users' privacy. Indicatively, some studies in the Big Data and Smart Tourism sector are presented below.

Vecchio et al. in Ref. [33] aim to show how Social Big Data can be exploited in Smart Tourism Destinations scenarios. A plethora of studies presented in this research in combination with a multiple case study methodology consisted of a number of digital tourism initiatives that take place in Apulia Italy, demonstrate how Big Data generated from tourists' social media are capable of creating value for STDs and allow organizers to predict tourists' behavior and needs. An exploratory study that attempts to predict tourists' response to a certain attraction via open data analysis is presented in Ref. [40]. In order to achieve this goal, authors implement the random decision forest algorithm approach on data deriving from tripadvisor.

3.11. Cultural heritage

With the Heritage term, we are referring to two major categories, namely both cultural and natural heritage. When referring to cultural heritage elements as tradition, history, language and folklore are included [30]. Cultural Heritage and tourism are two concepts highly connected, with cultural tourism being a powerful tool for economic and social change [92], leading to a wide number of cultural-based regeneration policies being developed in several regions [93].

When combined with technology, cultural heritage attractions can be delivered in a new, more engaging, activating and exciting way to tourists. An undeniable fact is that for more than two decades now cultural heritage is a widely researched field in terms of user personalization and once mobile technology appeared, many researchers and practitioners focused on how to offer context-aware cultural heritage data to individuals [94]. Thus, it was a natural consequence a substantial number of Smart Tourism related papers to focus on the cultural heritage sector.

Authors in Ref. [49] for example focus on "cultural tourism" and attempt to provide tourist with some useful information related to their trip, recommending some famous places around them. In order to achieve that, they firstly attempt to spot cultural heritage resources on geotagged social media data based on users' location and secondly rank them based on the aforementioned user context.

3.12. Privacy and data protection

A major challenge in the Smart Tourism sector is definitely the preservation of the users' privacy. An undeniable fact that derives from the literature review in this research area is that tourist related data like geographical locations, academic and professional background, interests, preferences, likes, opinions etc. is huge. This data can be voluntarily given, observed, gathered from digital data, or even implicitly inferred and mostly concern data of personal nature [95]. Even though the aforementioned data can be utilized to offer personalized technology-empowered experiences through smart apps and services, they also come with the risk of building accurate tourist profiles which inevitably lead to data privacy concerns [8,26,66]. Based on [95], privacy objectives can be divided to preserving user anonymity and avoiding the disclosure of private user information. Given the fact that all systems must comply with the EU General Data Protection Regulation (GDPR), one of the most important changes in data privacy regulation the last 20 years, a fundamental reshape is expected in how data is handled in the Smart Tourism too [96].

With data lying at the core of all Smart Tourism systems, legal consequences of unsuccessful data protection and how potential risks should be avoided are yet to be explored [10]. With that being said, it comes as no surprise that a number of papers focus on the risks of Smart Tourism destinations privacy and data protection [8,8,26]. Masseno et al. in their study [8] present a number of compliance tools that shall enable Smart Tourism destination developers meet their data protection obligations such as privacy policies, anonymization techniques, data protection impact assessment (DPIA), algorithmic transparency and privacy certification.

A promising technology that can alter the way data is stored and promote transparency and security is blockchain. Blockchain is one of the latest technologies with various applications in most sectors and industries like finance, healthcare, education and of course tourism [48,97]. Based on this fact, a number of papers emerge that aim at either highlighting existing applications of blockchain technology in the tourism industry or at proposing new frameworks that embed blockchain in Smart Tourism systems. For example, authors in Ref. [46] identify the importance of crowdsourcing in Smart Tourism systems and point out the significance of maintaining the quality of crowdsourced data. Thus, they propose the use of blockchain technology so as to insure the trustworthiness of the aforementioned data. Aiming to maintain trust between travelers, tourism and hospitality stakeholders authors in Ref. [48] introduce BloHosT, a framework that offers tourists the ability to safely interact with stakeholders via a wallet identifier connected with a cryptocurrency server to initiate payments. This paper also provides insights regarding the significance of embedding blockchain technology in Smart Tourism. Blockchain is also the subject of interest for authors in Ref. [97] who aim at explaining the blockchain technology as well as how blockchain/cryptocurrency can be used in the Smart Tourism/Cities sector.

4. Smart tourism challenges

Based on the presented analysis, there is a plethora of research efforts conducted during the last six years that focus on the Smart Tourism sector. As a result, there is a substantial number of challenges that need to be addressed. While at the time of writing there is a significant amount of papers that propose systems and application in the Smart Tourism sector, still the evaluation of such systems with a wide number of actual tourists needs to take place. It is of great importance in this multidimensional sector, which attracts attention of researchers and practitioners in diverse

fields, to have concrete and as much objective as possible results about the effectiveness of such systems. For example, as a number of the proposed applications are based on the power of the crowd, it is vital for their "survival" to be used from a wide range of individuals. Thereinafter, assessing them so as to verify their acceptance by users is essential. Another example where user evaluation is unavoidable is in systems that use social media data. Such systems, in order to be developed need to integrate APIs that may change frequently, or meet strict regulations introduced by several "dynamic" platforms like Facebook. User privacy is another issue that would be quite interesting to be practically dealt with. Moreover, the implementation of methods and proposed systems with a large and diverse number of individuals may bring more challenges to the surface, as well as viable solutions. In this section we present a number of challenges that need to be faced in the Smart Tourism field, both via theoretical contributions but, mainly, with actual development, distribution to tourists and evaluation with more than one methods.

A challenge that is highly related to the Smart Tourism field is the fact that the data size is constantly increasing. As available information has reached a point of being overwhelming [98], Smart Tourism systems need to successfully perform data filtering and personalization. The goal is to exploit only useful information, get rid of the "noise" that occurs from data abundance [49] and dismiss irrelevant information [47]. At the same time, in cases where data is sparse or entirely missing for some users, Smart Tourism systems must exploit mechanisms so as to still offer the best possible services [6]. Moreover, a data overload related issue is that storage should meet certain requirements while, at the same time, systems need to process properly and at a reasonable time, in some cases real-time, the aforementioned information. It comes as no surprise that, as more and more data is collected, more space is needed in order to store it and more sophisticated techniques to preserve, process and present it. Taking for example a system that exploits a map interface in order to present Points of Interest to its users, in case where the number of available points reaches large numbers, the time to load them and present them to users substantially also increases.

Another high concern in the Smart Tourism sector is the preservation of users' privacy. As user modeling and personalization are basic components of a wide number of Smart Tourism systems, individuals hand over data that cover many aspects like basic profile information, photographic identification, habits, locations etc. At the same time, a number of applications also automatically extract additional user related data, commonly known as "digital footprints". As an example, the well-known accommodation reservation platform Airbnb collects pages viewed by users, searches, location, ip address etc. from a plethora of other existing or proposed systems [99]. This huge chucks of information gathered via a plethora of sources like the ones mentioned above or others such as users' smartphones, social media channels, both implicitly and explicitly inserted ones used to enhance the tourism experience need to be handled extremely carefully so as to preserve user anonymity and privacy of personal information [5,8,26,66,95]. The new EU General Data Protection Regulation (GDPR) makes the aforementioned need even more compelling, as the way data is handled must meet some very strict standards [96]. It is critical to have privacy rules embedded in a system and keep users fully informed about personal data provided [30,57]. Thus, researchers and practitioners need to "cut the Gordian knot" on the sensitive issue of privacy preservation while, at the same time, required data for user modeling and personalization is still collected.

Another challenge highly connected with the privacy preservation need mentioned above is that most social networks such as Facebook and Instagram have introduced some quite strict security mechanisms that may cause an issue to user data collection that can lead to efficient user modeling [27,49]. Thus, researchers in this sector need to be constantly informed about the changing rules and follow instructions offered by different social media so as to integrate the related APIs successfully in their systems.

Moreover, a number of applications and proposed services in the Smart Tourism sector require the collaboration and synchronization with a number of devices for sensing, data exchange, as well as connecting to social networks, internet and/or a network of things. A challenge here must be faced so as to have all these heterogeneous devices and data sources work together efficiently [30]. Along with that, the rapidly changing technological environments along with the fast changing user attitudes should be considered in order to ensure the success and viability of Smart Tourism systems [57].

Another issue that should be taken into account when dealing with a Smart Tourism destination is that users need enough both processing and battery power in their mobile devices so as to use modern Smart Tourism apps, which, e.g., utilize GPS resource consuming components. In order to offer a solution to this issue and support Smart Tourism, for example, Barcelona offers USB ports for charging mobile phones in bus shelters [100]. Finally, an issue that should be also taken seriously is that some Smart Tourism apps, like ones that include Augmented Reality, may impose users with data overload [5,54,55]. The challenge that arises here is to create systems that are worth the effort and time required to interact with them and enhanced tourism experience [5].

5. Discussion and conclusions

The goal of this paper is to present and discuss the existing literature in the Smart Tourism sector. In particular, this review has focused on researches published from 2013 to 2019 although papers published at an earlier time were also reviewed. It is our belief that in order to develop firm foundations and contribute to the further advancement of a scientific area, a review of relevant literature is essential. A literature review leads to locating challenges and areas where further research is required, while uncovers others where no further progress can be accomplished [101]. Inspired by this fact, we attempted to locate the most popular approaches and concepts in this field and present them in detail. Our review has provided a quite thorough presentation of the analyzed key concepts as well as references to papers that focus on each one of them.

Moreover, we focused on locating the major challenges in the Smart Tourism field. After carefully reviewing the existing state of the art and state of practise in this sector we have identified a number of challenges that need to be addressed so as to have the proposed and expected results and realize a true Smart Tourism experience. These challenges presented in Section 4 in detail along with the aforementioned concepts could be a starting place for researchers that either wish to contribute to this sector or are already involved in this field.

The majority of research papers reviewed in this study are illustrated in Table 1 which visualizes the approaches used in each one of them, which shall enable readers to locate researches per field of interest. Moreover, we gathered all systems presented in papers reviewed in Table 2 so as to facilitate readers locate Smart Tourism systems developed or proposed that may be an inspiration for further research. As presented in Fig. 2 most papers in the Smart Tourism sector are placed in 2017 and 2018. In particular, research papers in 2013 is only the 3.7% of the total number of papers reviewed, while in 2017 and 2018 is 26% and 33.3% additionally, fact that proves that the interest in the Smart Tourism field has escalated. At the time of writing, there is a number of attempts to move from traditional tourism to the Smart Tourism. Researchers and practitioners attempt to take advantage of the constantly emerging technologies so as to enrich the tourism experience and lay the foundations for further development in this sector. The Smart Tourism field, though, could be considered to be still at its infancy. Considering that all these technologies/approaches currently linked with the Smart Tourism sector like augmented reality, social media, image recognition, wearables of all kinds, smart vehicles, sensors, big data etc are still under research and constantly evolving, it would not be an exaggeration to say the Smart Tourism sector has a long way to go before being characterized as a saturated research field. It is of great importance for further researches in the field to implement and evaluate with a large scale of users the proposed systems so as have concrete results about the effectiveness, the acceptance of such systems, as well as what challenges in practise arise.

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