A novel AR application for in-vehicle entertainment and education

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***Abstract*—Passengers of different transportation means, used for private (travel, commute) or revenue-generating (tours, sightseeing) purposes, usually have restricted view of the outside environment, limited by the vehicle's walls, roof and seats. Even short journeys are boring and tiring while sights cannot be experienced properly. Currently there are no proper ways of overcoming this problem, but merely escaping it, which are not particularly constructive and isolate from co-passengers. In this paper, a novel integrated augmented reality solution is proposed, which can be installed in vehicles of different types and simultaneously used by multiple co-passengers. Using current vehicle location, a live surroundings video, captured by a 360-degree camera, can be overlaid in real time with co-passengers video, on-spot information of touristic value, Points of Interest, tailored advertisements and other messages. Remote, cloud-based technologies can be utilised, which exploit available data sources of different types and sources, in order to offer intelligent added value services. End users can experience an improved reality world by wearing a VR headset and moving their head around. Journeys can become more interesting, educative and entertaining. (*Abstract*)**

***Keywords—application, augmented reality, vehicle, passengers, travelling, entertainment, education** (key words)*

I. Introduction

Recently published surveys in Europe [1], America [2] and Australia [3] show that the average person consumes daily at least one and a half (1,5) hour of their life in the car as a driver or passenger. Passengers and especially those sitting in the rear seats find time in the car lost and non-qualitative. The hitherto available ways of utilising it (e.g., movies, music, video games) are equivalent to "escaping" from the venue/ situation, and are not rather constructive while at the same time involve their isolation from other passengers. In addition, advertising surveys [4] show that time spent by passengers in vehicles is very suitable for displaying promotional content and selling products.

At the same time, autonomous driving vehicles are very close to becoming part of our daily reality and automotive manufacturers already offer semi-autonomous driving systems [5] in most of their models. According to the available data and official projections [6], autonomous vehicles are expected to have appeared in most European countries by 2020. With the advent of this technology, the role of the driver is gradually being reduced. The driver also becomes a plain passenger and has similar requirements as the other passengers for quality use of their time. It is further to be noted that while technology developments have contributed in the last few years towards the improvement of vehicles' autonomy, comfort and safety, they have not affected to a similar extent systems related to passengers' entertainment and exploiting of their time in quality manner.

II. Objectives and Related Solutions

The main objective of the proposed solution is to enable passengers of various vehicle types to enjoy unobstructed view of their surrounding environment. Through an improved reality, the offered view should further include information regarding what passengers see around them, events of interest that are planned and activities that can be performed in the areas of vehicle transit, as well as targeted advertisements from businesses operating it the transit, stopping or destination areas of the transportation means. Passengers should at the same time be able to view their co-passengers and enjoy their company. Hence, the means of transportation would become enjoyable even on long journeys and for passengers of "non-privileged" seats.

In this paper we propose such a solution which can capture ambient (vehicle surroundings) and auxiliary (passengers inside the vehicle) video footages, process and edit them, overlay information about Points of Interest (POIs) and promotional messages and advertisements, and finally create a 360-degree panoramic video, in which the end-users can navigate by moving their head while wearing a VR headset. Remote services and cloud technologies can be used for the extraction of useful information from available data sources and the implementation and deployment of intelligent added value functionalities, such as the suggestion of routes and the forecasting of the vehicle's next position, in order to improve the offered experience.

While several applications and solutions exist in similar domains, there are no solutions that combine the aforementioned functionalities and their enabling technologies in a similar manner. The main competitors are in-car infotainment vendors and businesses offering portable entertainment products that can be used in-car by passengers (e.g., video games), and possibly virtual tours applications. Geographic information content providers and vendors of AR/VR equipment are rather potential collaborators (data sources and hardware suppliers respectively) than competitors. AR/VR-focused businesses have not introduced systems focusing on the same or similar domain.

The main advantages of the proposed solution in comparison to traditional entertainment systems are that passengers are informed and educated instead of just spending their time, and maintain touch with the inside (co-passengers) and outside (moving area) environment. The solution can be easily installed in different means of transportation (car, coach, boat, aircraft) and easily expanded for use by many passengers, with obvious exploitation capabilities in areas related with passenger transportation and tourism. Applications utilising AR technologies in the tourism domain are only intended for specific locations or

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slow moving users (pedestrians), hence do not tackle the issues arising from fast moving vehicles and fast changing content, which the proposed solution does.

The proposed system further has low processing power requirements and is hardware, information and data source agnostic, hence a large pool of available hardware suppliers and information providers can be utilised. Given its modular architecture, it is highly adaptable to emerging trends and technologies, and can be easily periodically modified to take advantage of newly emerging low-cost, high-performance hardware, as well as new/ different information sources. This can aid towards constant improvement of representation and content quality, and ultimately user experience.

III. Methodology

A modular, service-oriented architecture has been introduced, which provides great flexibility for connecting external data sources (data providers) and devices, and allows independent modification of the basic system parts without affecting the rest of the system. The architecture consists of three basic layers, depending on the location of the corresponding functionalities execution, as follows: a) a remote smart services and data fusion layer (cloud-based), b) a local video editing and data integration layer, and c) a peripheral input/ output devices layer.

While designing the cross-layer interactions, a great deal of attention was paid to (a) the minimisation of data transferred between the remote and local layers for reducing mobile data costs, minimizing operation delays and maintaining system operation in case of intermittent Internet connectivity; (b) the lightness in terms of computing requirements of the processes performed at the local layer.

A. Remote smart services and data fusion layer

The inherent capabilities of remote connected and cloud-based services and infrastructures, such as on-demand scalability, availability, security and accessibility to huge volumes of open/ free or paid third-party data (e.g., stemming from user communities and social networks of various types), were exploited by the proposed solution to a) perform functionalities/ services with increased or varying computing resources requirements, b) collect and store data from the solution's user community and advertised businesses, and (c) access third-party providers' POIs and big data sources, while these services can be accessible by mobile users from various different locations.

The remotely deployed components of this layer are:

1) Database of application's end users, in which personal preferences, route historic and other data resulting from the sytem's use are stored for all application's users.

2) Database of advertised business and other POIs, in which the data and geographical coordinates of advertised businesses and other POIs are stored, which are not available in external accessible data sources or are to be kept internally by the application. This database is implemented in Oracle MySQL [8] Server and deployed in the cloud.

3) Web-based appliction for the registration of advertised businesses, which serves for the introduction of additional POIs in 2) above. The developed Web application enables authorised users to specify the location of a POI or business on the map and provide additional information (such as the category that it belongs to, e.g. "Restaurant") and the advertisement validity period, through a form.

4) Smart route suggestion and vehicle's next position forecasting service. It combines a wealth of data to (continuously re)evaluate the route that the vehicle is to follow and the location in which it is to be found in the near future. The service incorporates information such as:

a) previous/ recent locations of the vehicle during the specific trip, as well as its current location;

b) the user's preferences, which they have implicitly declared in the system;

c) the user's profile, which indirectly results from the analysis of their data and/ or the persons' who are connected with them (friends, followers, etc.). These data could stem from: i) the application's users community and in specific the user's behaviour during past system use, the type of routes that they usually prefer to take, the routes taken by other users, which the user has liked, and ii) other data sources such as social networks and user communities of various types, from which the system can automatically retrieve such information, if permitted by the users;

d) data and metadata stemming from various big data sources which can, after being appropriately analysed and combined, provide useful information about the behavior of people in general under certain conditions, and then be evaluated in relation to the particular user's profile. E.g., routes that the largest proportion of vehicles select depending on the prevailing weather conditions or recently announced news that may affect the public, routes along which other users have taken and posted more photographs, which in turn caught a lot of attention of others (based on reactions and comments and their analysis), and thus may be of increased touristic interest or particular natural beauty.

By analysing and combining such data it is possible to predict the route that a driver aims to follow and the location that the vehicle is to be found in the near future, or suggest the most attractive routes for a particular driver and the prevailing conditions. How such data can be combined by the automatic extraction and usage of weights is discussed in the highly relevant work of Yiakoumettis et al. [7].

5) POIs collection service. POIs (e.g., historical sites and monuments, restaurants, etc.) are already available in publicly accessible data sources in a computer-based format and can be used by the proposed solution, provided that the necessary credentials (e.g., API key) for accessing them have been obtained and the data requests are in accordance to the data provider's terms and conditions. The POIs collection service accepts as input a broader area (i.e., the current vehicle position and a radius around it) and collects from different data providers the POIs within that area. Each time that the service is called, it renews a list of nearby POIs, which is available to the lower layer whenever requested. In the current implementation the system's database of advertised business and POIs, the NAVTEQEU public data source, accessed using the Microsoft Bing Query API [9] and the Google Places API [10] are utilised.

The retrieved POIs can be further filtered based on the explicit preferences (e.g., specific POIs types) set by the user and stored in their profile. The API requests are minimized by using a prediction of the upcoming vehicle location.

B. Local video editing and data integration layer

This layer undertakes all processes which are performed locally, on equipment (e.g., laptop computer) installed in the vehicle, for creating and transmitting the final panoramic live video stream. It includes the following components:

1) Asynchronous current vehicle location collection, improvement and recording service, which continuously retrieves the location from the current location unit of the underlying layer and stores it in a local database, keeping a short location historic. The service further tries to improve the location points accuracy by providing the previous vehicle locations as input to the Google Roads API [15], which returns the corrected ones based on the assumption that the vehicle travels on the existing roads network. The location is then provided to the smart services residing in the above layer, while also being used by the POIs selection and projection application at the local layer. Two versions of this service have been implemented: a) in Java and deployed in Apache Tomcat Server [11] and b) as Microsoft ASP.NET MVC Project and deployed in Microsoft IIS Server [12].

2) Visible POIs selection and geometric projection service, which runs regularly (e.g., every 1 sec). It gets:

a) From the remote smart services layer, the aggregated POIs list which it temporarily stores locally until it is renewed with a new call of the service. The list of POIs includes their name, type (e.g., paid advertisement, monument, tourist service, etc.) and geo location.

b) From the asynchronous vehicle location collection and recording service its current and previous coordinates.

The service first uses the corrected current and previous coordinates of the vehicle and its speed in order to define its spatial movement vector. Based on this and the POI's position it then calculates a) the angle of the POI's location in relation to the vector's origin (e.g., the POI is to be seen at 40 degrees to the left of the vector) and b) the POI's straight-line distance from the vector's origin (e.g., 75 meters away from the vehicle). It consequently uses the above information for the presentation of each POI in the appropriate location in an image file. Taking into account that this image will be merged with the video feed of the 360-degree surroundings camera used, the created image file should follow the same format as the video (i.e., equirectangular in the current prototype). The width of an image in the equirectangular format covers the whole 360-degree field of view and hence the calculated angle of the POIs indicate where exactly the appropriate annotation should be placed on the image. Additionally, the surroundings camera should be carefully installed on the outside of the vehicle so that the middle of the image file corresponds exactly to the front of the vehicle.

The POI's distance is used by the application in order to define the font size used for its presentation, i.e. larger for the POIs which are closer to the vehicle and smaller for the ones further away. Also, POIs which are further away than a predefined threshold can be filtered out and not displayed at all. The vehicle's velocity is also taken into consideration, so that it can be automatically decided for how long each POI is presented in the video. The image file is constantly being updated so that it always depicts the current POIs existing in the close vicinity of the vehicle to be shown in the virtual world. In the current prototype, this application has been implemented in Java and the image files' format is PNG.

3) Real time processing and mixing of input video streams service. It receives as inputs the video streams from the surrounding and auxiliary video units (underlying layer) as well as the POIs image files from the Visible POIs selection and geometric projection application and combines them in a predetermined manner to produce the final real-time panoramic AR video stream. In the current prototype OBS [16] is used, which initially combines the two input video streams coming from the surroundings camera (i.e., one 180-degree video stream for the front and another one for the rear part of the panoramic video) into a single video stream that follows the equirectangular format. This video stream is accordingly merged with the one coming from the passengers camera and the image files of the POIs locations, which are inserted as video frames in the final video.

4) Final video streaming server. It accepts the final panoramic AR video stream and transmits it to the end-user navigation units. Their connection can be wired (USB) or wireless (wifi). In the current prototype, the final video stream is directly provided as input to NGINX [13] server, which broadcasts the video stream to all passengers' devices via the Real-Time Messaging Protocol (RTMP) .

C. Peripheral input/ output devices layer

This layer includes all peripheral devices that serve as inputs to the system or outputs to the end users.

1) Current location unit. It provides the current location of the vehicle. It can be a smarphone or an autonomous GPS device and its connection can be either wired or wireless. In the current prototype, an Android smartphone *Location collection application* was developed, which collects the smartphone's (and hence the vehicle's) location using a combination of its built-in GPS unit and Mobile Network services and provides it to the Asynchronous current vehicle location collection and recording REST service at the local video editing and data integration layer. The smartphone connects via USB tethering to the system laptop at the local layer.

2) Surrounding video unit. These are cameras or arrays mounted on the outside of the vehicle and used to synthesize the panoramic (360-degree) live video stream of the surrounding area. We initially experimented with a rig of 6 GoPro Hero 4 cameras (6 independent video streams), and then with a Ricoh Theta S camera (2 video streams), which is currently used via USB. WiFi cameras are also an option as well as multiple cameras mounted at the vehicle's edges.

3) Auxiliary video unit. It consists of one or more cameras located inside the vehicle that record live video feeds of the passengers, which can be viewed at a specific area of the final video, so that passengers are in visual contact with their co-passengers and not isolated from them.

4) Navigation units - end-user interface. These are VR-headsets (one for each user) that consume the final panoramic AR video stream. Each user can navigate autonomously within the a AR video stream according to the movement (inclination, orientation) of their head. In the current prototype a third-party mobile application (Wiseplay VR [14], available for both Android, and IOS devices) is used so that the end users can utilize a common smartphone (which serves as the screen) placed in a VR headset for navigating and exploring the virtual world. The application converts the equirectangular video to stereoscopic format (a different video for each eye) for presentation purposes. Alternatively, a standalone VR headset can be used.

IV. Preliminary Results And Evaluation

A. Trips in dense city environment

A first series of testing and evaluation trips were performed by the development team in urban environment. This type of densely built area poses great challenges, since location accuracy is limited due to high buildings and narrow roads while POIs co-exist in virtually the same areas. The system was installed in a team's vehicle, which then cruised for several minutes in different areas of Athens. All main system components, their connectivity and flow of data were tested, and various measurements were taken for offline analysis. These initial observations were used for the improvement of the associated system components in a number of iterations of improvements and testing, and are reflected in the solution components described above.

The team's observations were in line with expectations. First, the accuracy of the collected location points was not very high with some intermittent GPS measurements being quite off. Second, due to the high density of POIs, they were sometimes overlapping each other in the end-user presentation. This was the case with POIs being really close to each other or further away apart but happening to be located in about the same angle in reference to the vehicle's movement vector. Third, positioning and timing of the POIs displayed in the final AR video needed improvement, so that the system-added information would fall exactly on top of the real-world entities which they were referring to, while the vehicle was travelling (i.e., in each video frame).

B. Participation at TEDx NTUA

Within the framework of TEDx NTUA "HEURISTICS" [17] conference, a side presentation and workshop were held regarding the proposed solution. Earlier that morning, the main input/ output devices of the system were installed in the vehicle taking the main conference presenter to the conference venue. The route was known beforehand and the POIs list had been stored offline in the system laptop, also installed in the vehicle. No online services were used in this scenario. The conference presenter was able to try the system for about fifteen minutes en route to the conference, while at the same time the live video stream produced by the system was being recorded. His genuine reactions were very positive. The idea and the generally good functioning of the prototype impressed him. His main comment had to do with the AR video not being completely synchronised with reality. A time gap existed between movement and vision, which caused a strange feeling to the user when the vehicle stopped or started moving. This needs to be improved.

The TEDx conference attendees further had the chance to try the latest prototype. Since the event was held indoors, attendees wore the VR headset and navigated through the panoramic video feed that showed the earlier recorded trip along with the POIs presented while the vehicle was moving. All 42 attendees who tried the system (for about 1-2 minutes each) were impressed with the idea. Most of them (38 persons) described how easily and deeply they immersed in the AR world and how satisfactory the experience was. Most of them (37 persons) agreed that they would definitely use such a system while travelling shorter or longer distances. Regarding limitations, some users (15 persons) mentioned that they started feeling dizzy after using the system for longer time. This had to do with the video feed watched being taken from a moving vehicle while they were stationary. Another factor contributing to this issue was the limited resolution of the mobile phone screen used as display on the VR headset. A higher resolution surround video unit would have further helped alleviate this issue.

V. Conclusion

In this paper, a novel AR application for in-vehicle entertainment and education was presented, which can be utilised in several real-life situations. Its development emanated from contemporary travelling needs and was based on the exploitation of the potential of modern hardware and software technologies. Its early evaluation from end users was positive. While some parts of the presented solution have not yet been deployed to their full potential, the architecture chosen allows for improvement of the initial functionality, addition of new capabilities and utilisation of more advanced hardware once it becomes available.

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