Cyber-Physical-Human System for Connected Car-Based e-Tourism

Approach and Case Study Scenario

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***Abstract*—Cyber-physical-human systems find new applications in various areas of human lives. The paper proposes usage of a system of this class to achieve a synergy between the connected car and e-tourism ideas. The developed approach is presented with more attention paid to the situational awareness and behavioral awareness. The approach is illustrated via a case study aimed to organization of infomobile support of tourists taking a ride in a car with a driver. The connected car technologies are used to integrate car information system with tourist's personal information device to deliver speech, image and video-based tour guiding synchronized with the ride.**

Keywords—connected car; e-tourism; cyber-physical human system; situational awareness; service

I. Introduction

The newly appearing concepts such as Internet of Things, ubiquitous computing, connectivity, etc., are penetrating our lives deeper and deeper. The result of this change is not only appearance of new products, product-service systems or production processes, but also a growing world of new business models that allow companies to transform from product suppliers to service providers or, further, to virtual companies acting as brokers.

For example, Rolls-Royce instead of selling aircraft engines now charges companies for hours that engines run and takes care of servicing the engines [1]. Another illustrative example is Uber, that does not only provides taxi services, but it does this without actually owning any cars and acting just as a connecting link between the taxi drivers and passengers. Timely changed business model can provide for a significant competitive advantage (e.g., the current capitalization of Uber is about $68 billion, which is $20 billion higher than that of GM [2]).

As a result, all significant players of the global markets are searching for various ways to extend and update their businesses in order to keep pace with the changing markets.

Thus, car manufacturers are continuously developing the in-vehicle electronic systems that have made a significant step forward recently. Such systems have transformed from simple audio players to complex solutions, referred to as "infotainment systems". Such infotainment systems enable not only integration and communication with smartphones but also sharing information from different vehicle sensors and information presentation through in-vehicle screen (visual information) or stereo system (audio information). These are just few of such systems to mention: Ford SYNC[1], GM OnStar MyLink™[2], Chrysler UConnect®[3], Honda HomeLink[4], Kia UVO[5], Hyundai Blue Link[6], MINI Connected[7], Toyota Entune[8], BMW ConnectedDrive[9], Apple CarPlay[10], Google's Auto Link[11], etc.). A detailed review of infotainment systems can be found in [3].

Usage of infotainment systems does not only improve the driver's experience but also opens a wide range of possibilities in the area of cyber-physical and cyber-physical-human systems through the "connected car" technologies (e.g., [4]). "Connected car" or "connected vehicle" is a relatively new term originating from the Internet-of-Things vision. It stands for the vehicle's connectivity with its surroundings on a real time basis for providing the safety and expedience to the driver [5].

Cyber-physical systems are based on continuous interrelations between resources of the IT world and physical world [6], [7]. Currently, we face a considerable amount of research efforts and developments in the area of cyber-physical systems and their applications including transportation [8], production [9], and many other.

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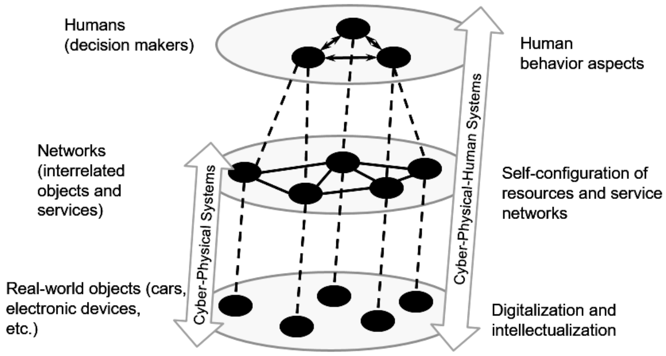

Fig. 1. Cyber-physical and cyber-physical-human systems

The problem of cyber-physical system configuration appears to be a complex task, which is intensively researched [10], [11], [12]. An interesting observation has been made by Horvath and Gerritsen based on the state-of-the-art analysis in the areas of cyber-physical systems and supporting technologies. They conclude that "the next-generation of CPSs will not emerge by aggregating many un-coordinated ideas and technologies in an incremental fashion. Instead, they will require a more organized and coordinated attack on the synergy problem, driven by an overarching view of what the future outcome should be" [13].

Cyber-physical-human systems go one step beyond the ideas of the current progress in cyber-physical systems, socio-technical systems and cyber-social systems to support computing for human experience [14]. They tightly integrate physical, cyber, and social worlds based on interactions between these worlds in real time (Figure 1). Such systems rely on communication, computation and control infrastructures commonly consisting of several levels for the three worlds with various resources [15] as sensors, actuators, computational resources, services, humans, etc. Cyber-physical-human systems belong to the class of variable systems with dynamic structures. Their resources are too numerous, mobile with a changeable composition.

The paper extends the previously presented work [16], [17] aimed at self-organizing networks for situation response via shifting to the cyber-physical-human systems and incorporating social aspects to the decision support.

The paper is structured as follows. The description of the developed approach to connected car-based e-tourism is discussed in the next section. Section III presents the situational awareness in cyber-physical-human system followed by behavioral awareness in cyber-physical-human system explained in section IV. The case study illustrating the proposed approach is presented in section V. Main results are summarized in the conclusion.

II. Cyber-Physical-Human System for Connected Car-Based E-Tourism

Integration of different mobile apps with in-vehicle information systems has caused the appearance of the "connected car" concept. Joint operation of on-board infotainment systems and various cloud services can help in creating various intelligent decision support systems capable of providing a richer driving experience and seamless integration of information from various sources. Recent advances in car on-board infotainment systems make it also possible to provide for the above mentioned infomobile support to both the driver and the passengers. Such systems do not only address the driver's experience, but also are capable to entertain the passengers of the car, e.g. engaging the video subsystems for rear seat passengers, multi-zone climate control, etc.

Development of tourist services and apps (mobile device applications) has drawn attention of researchers and practitioners recently (e.g., [18]). "In a field trial in Görlitz (Germany), 421 tourists explored the city with one of two different mobile information systems, a proactive recommender of personalized tours and a pull service presenting context-based information on demand. A third group of tourists was tracked by GPS receivers during their exploration of the destination relying on traditional means of information. Results point out that both mobile applications gained a high level of acceptance by providing an experience very similar to a traditional guided tour. Compared to the group tracked by GPS loggers, tourists using a mobile information system discovered four times more sights and stayed at them twice as long." [19]

"The findings of the evaluation carried out have demonstrated that the widget-based solution is better than the notification-based solution. Despite the fact that both options are considered good solutions to achieve proactivity, the second one is considered by the users more annoying. <...> We can state that the "time pressure" factor is a good indicator to know when a proactive recommendation is reasonable or not, because in these situations users give less feedback." [20]

All together such trends have caused an appearance of the "infomobility" infrastructure aimed at operation and service provision schemes whereby the use and distribution of dynamic and selected multi-modal information to the users is done both pre-trip and, more importantly, on-trip [21]. Infomobility is a new way of service organization appeared together with the development of personal mobile and wearable devices capable to present user multimodal information at any time. It plays an important role in the development of efficient transportation systems, as well as in the improvement of the user support quality. In accordance with the forecast of [22], the market of such technologies as mobile Internet, automation of knowledge work, and Internet of Things by 2025 can exceed 20 trillion USA dollars.

In this paper, we have tried to achieve a synergy between the connected car and e-tourism ideas. The proposed approach is based on the cyber-physical-human system concept (Figure 2). Such a system would be capable to

- generate recommended attractions and their visiting schedule based on the tourist and region contexts and attraction estimations of other tourists;
- collect information about attractions from different sources and recommend the most appropriate attraction images and descriptions to the tourist;

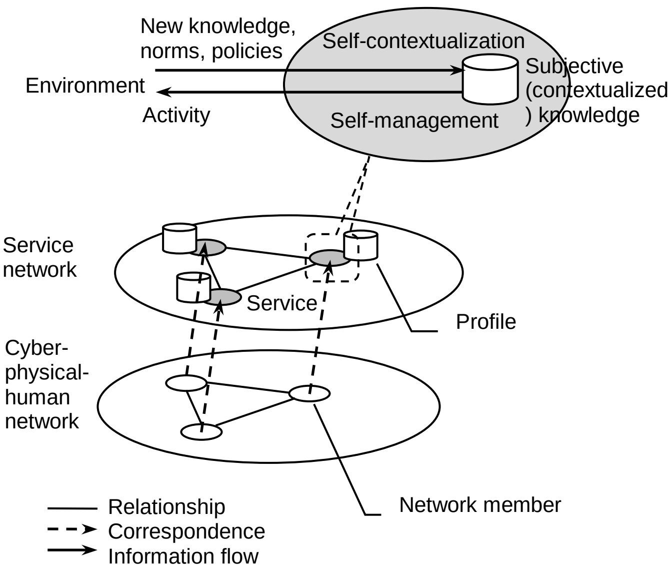

Fig. 2. Cyber-physical-human system configuration approach: an overview

- update the attraction visiting route and schedule based on the actual and predicted development of the current situation.

The resources of the real world (humans and physical resources) interact through the “cyber”-world, where they are represented as services. The services exchange information, negotiate and come up with some solution recommendations meeting human needs and preferences. In other words, the services “self-organize”.

Self-organization of services is considered as a threefold process of (i) cognition (where subjective context-dependent knowledge is produced), (ii) communication (where system-specific objectification or subjectification of knowledge takes place), and (iii) synergetic co-operation (where objectified, emergent knowledge is produced). The individually acquired context-dependent (subjective) knowledge is put to use efficiently by entering a social co-ordination and co-operation process. The objective knowledge is stored in structures and enables time-space distanciation of social relationships.

The interoperability of the services is achieved via the usage of common standards (such as WSDL and SOAP) at the technological level, and common ontology at the semantic level.

Very important aspects of such system are:

- *situational awareness*: infomobility support is supposed to be context-dependent and the situation is changing continuously;
- *behavioral awareness*: efficient infomobile information support has to be proactive, what assumes predicting human actions.

Below, these aspects are considered in detail.

III. Situational Awareness in Cyber-Physical-Human System

In dynamic environments, correct decisions can only be made in the right context related to the current situation [23], [24], [25]. Context is usually defined as any information that can be used to characterize the situation of an entity where an entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves [26]. Thus, situation-aware (context-aware) decision support is mandatory when situations take place in dynamic, rapidly changing, and often unpredictable distributed environments [28]. Such situations can only be described by highly decentralized, up-to-date data coming from various information sources. As a result, the goal of self-contextualization (organization of situational information and their access by services / agent, promoting more informed adaptation choices by them and advanced forms of stigmergic / indirect interactions) is to timely provide the decision maker (human or service) with up-to-date information, to assess the relevance of information and knowledge to a decision, and to gain insight in seeking and evaluating possible decision alternatives.

"Self-contextualization" is one of the key enablers for defining the current context of a connected car-based system. In the proposed approach, the knowledge is described via a common ontology representing only structured knowledge (A-Box). The information from various sources and sensors instantiates the context (T-Box) forming the parametric knowledge that can define the behavior of services. Here the behavior stands for the capability of service to perform certain actions in order to change the own state and the state of the environment from the current to the preferred ones. The proposed approach exploits the idea of self-contextualization to autonomously adapt behaviors of multiple services to the context of the current situation in order to provide their services according to this context and to propose context-based decisions. For this reason, the proposed conceptual model enables context-awareness and context-adaptability of the recommendation, user context, and car context services (section V).

In the connected car-based e-tourism support, the context information includes:

- tourist location,
- co-travelers,
- preferences (both explicit and tacit),
- schedule restrictions,
- weather,
- traffic,
- attraction occupancy and opening hours.

This (contextual) information is supposed to be acquired from corresponding services.

IV. Behavioral Awareness in Cyber-Physical-Human System

The developed approach assumes description of functionality, preferences and strategies of the users via updatable and extendable profiles. Usage of the profiles makes it possible to “individualize” the proactive recommendations. For this reason methods of human preferences revealing have been developed.

The preferences are revealed via the analysis of the situations the network member faces most often, parameters of objects and actions most often occurring or avoiding in the decisions (actions) made by a human, optimization criteria he/she most often follows or not. One of the main features of the developed profile model is the presence of the information related to antecedents and consequences of the made decisions and undertaken actions what makes it possible to perform the functional analysis of the human behavior.

The functional behavior analysis is one of the behavior analysis techniques considering frequency of key behavior events related to certain human activity [29]. It is also known as ABC analysis (antecedent, behavior, consequence) and is based on identification of both antecedents and consequences of the behavior. As a result, it is possible to build a conditional behavior model, which would let one know (to predict) how a human (e.g., a driver or a tourist) would act in a given situation. For example, the research of application of this technique to the driver behavior prediction has resulted in some positive results [30].

The result of such an analysis produces typical decisions (actions) made by the considered person in certain situations (behavior patterns). Example of behavior pattern is presented below, related to visiting an outdoor attraction:

- **Context**: autumn, the temperature is relatively low, no rain.
- **Antecedent**: a new forecast with rain soon has become available.
- **Possible behavior**: continue to the attraction; choose another (indoor) attraction instead.
- **Preferred behavior**: continue to the attraction.
- **Consequence**: low evaluation of the attraction in the given context.

The behavior pattern revealing techniques used in the proposed approach include:

1. Revealing human behavior patterns for problems with the same structure but different parameters. In this case, the structural knowledge constituent (A-Box) will be the same, and the parametric knowledge constituent (T-Box) will be different.
2. Revealing human behavior patterns for different problems solved by the same person. This technique assumes analysis of structures of different problems trying to find similarities associated with the same decisions / actions.
3. Revealing human behavior patterns based on the optimization criteria (problem parameters with highest or lowest values) the person tends to follow or avoid (e.g., the driver prefers moves faster or with less maneuvers). Aggregated (e.g., weighted average) criteria can also be analyzed.
4. The above techniques applied not to one person but to different persons with similar profiles. This technique utilizes collaborative filtering mechanisms [31].

To implement the first three techniques the following methods have been developed:

1. Decision / action clustering method. The decisions made by the person and actions undertaken are grouped into clusters. Based on the clusters built the common properties (parameters) of the problems and decisions / actions grouped into one cluster are identified. The results of this method can be refined if there is enough historical data accumulated and clustering can be done taking into account the context of the situation when corresponding decisions have been made (including and preferences of the person at the moment of decision making as well as information about behavior antecedents and consequences).
2. The alternative analysis method. Unlike the previous method searching for similar person’s decisions, this method is aimed at the analysis of differences between decisions made by the person and actions undertaken. Based on the analysis of the identified differences taking into account the situation context (as well as preferences of the person and information about behavior antecedents and consequences) namely definition of the main generic differences of the made decisions, the behavior patterns are revealed.

To implement the fourth technique of human behavior pattern revealing, a method based on the collaborative filtering mechanisms is used for building collaborative recommendation systems. This technique would enable to predict human behavior even in situations, in which this person has never got. For this reason, the decisions made by persons with similar properties are used.

Application of the above techniques would enable to generate proactive recommendations based on prediction of behavior of real people (e.g., via usage of opportunistic planning [32] mechanisms).

V. CASE STUDY

The case study illustrating the proposed approach is shown in Figure 3. Based on the schedule analysis (e.g., hotel check-out before 11AM and flight at 08PM) the system proposes a tour that would fit the schedule and finish at the airport. Alternatively, the person can schedule a tour on his/her own. The tour takes into account the person’s preferences (preset and revealed via collaborative filtering techniques) and the current situation at the location (season, weather, traffic jams, etc.) based on the earlier developed personalized tourist assistance service TAIS [12]. The person can modify the recommended tour and share its part with other tourists.

[12] https://play.google.com/store/apps/details?id=ru.nw.spiiras.tais&hl=ru

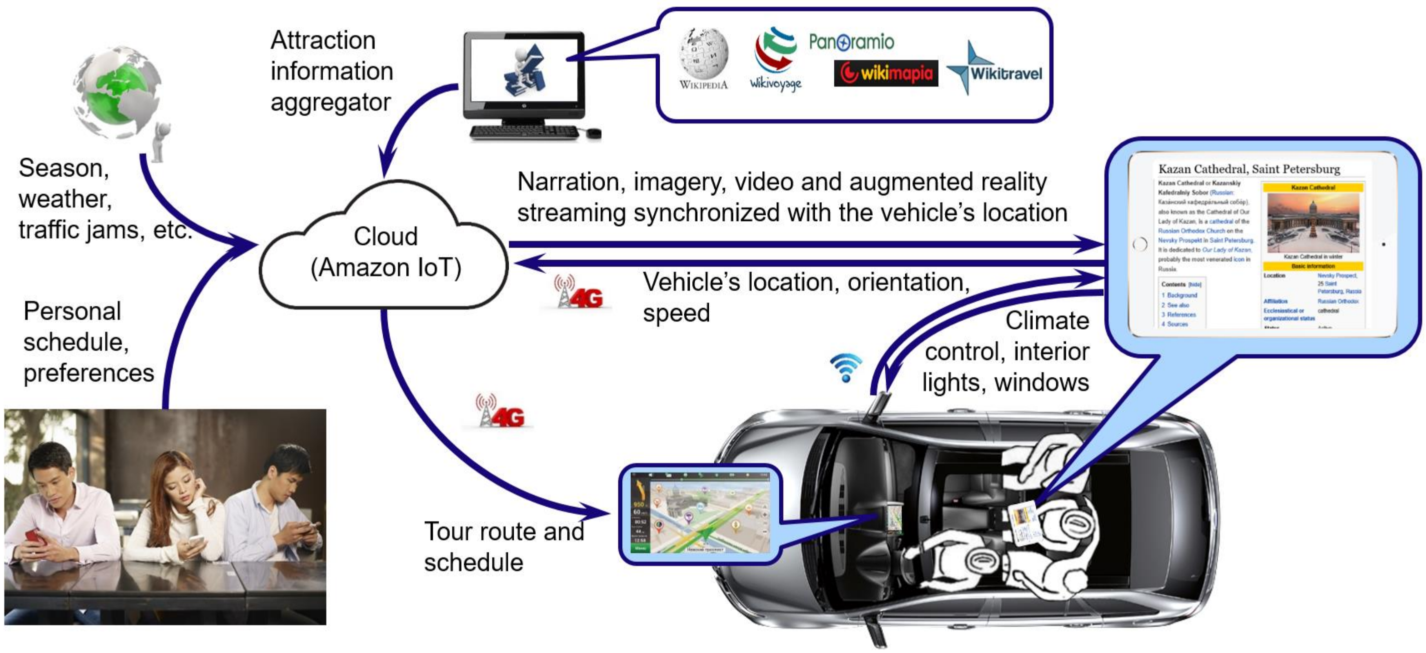

Fig. 3. Cyber-physical-human system for connected car-based e-tourism: case study

Based on the number of tourists a car of required type (standard, minivan, van, etc.) is reserved. The driver picks up the tourist(s) at the predefined time and follows the route loaded into the car's navigation system automatically via the car connectivity means.

Personal electronic devices (such as tablet PCs) could be used during the tour for narration, imagery and video synchronized with the vehicle's location and speed. The support is based on the ad-hoc "on-the-fly" combination of the available information pieces (pre-recorded narration, images, etc.) in the personalized context-aware manner.

The services involved into the proposed cyber-physical-human system and their interactions are shown in Figure 4.

The car location and speed are transferred to the car context service. The user (tourist) can use his/her personal device for adjusting / selecting tour parameters ("decisions"), change some car parameters (such as opening / closing windows, adjusting climate control, interior lights, etc.), communicate in some extent with the driver if he/she does not speak the person' language (e.g., ask for a stop near an attraction), and making changes in the profile. The personal schedule is also taken from the user's personal device.

All this information is formalized in accordance with the common ontology via corresponding services and together with information from other services (weather, attraction information, traffic, available narrations, images and video) is transferred to the recommendation service. The recommendation service is the core of the system. It incorporates the recommendation and proactivity engines that prepare the tour information and make recommendations on tour change in case of the changes in the current situation.

The tour route is transferred to the driver, and the tour guide is transferred to the tourist. As it was already mentioned, the system also provides for basic communication between the driver (Figure 5) and the tourist and may generate some tour recommendations that the user can accept or decline.

VI. Conclusion

The paper presents application of the cyber-physical human system concept to implementation of the connected car-based e-tourism system. Usage of the situational awareness and behavioral awareness technologies makes it possible to achieve personalized infomobile support of tourists. The system can adjust itself to the changing situation. Due to the usage of the connected car technologies the proposed system is not only capable of tour planning (taking into account tourist's preferences and schedule) as well as location-based customized visual information and audio guiding through personal smart device, but also can integrate with the car information system to automatically load the tour route to the car's navigation system and provide for basic communication with the driver.

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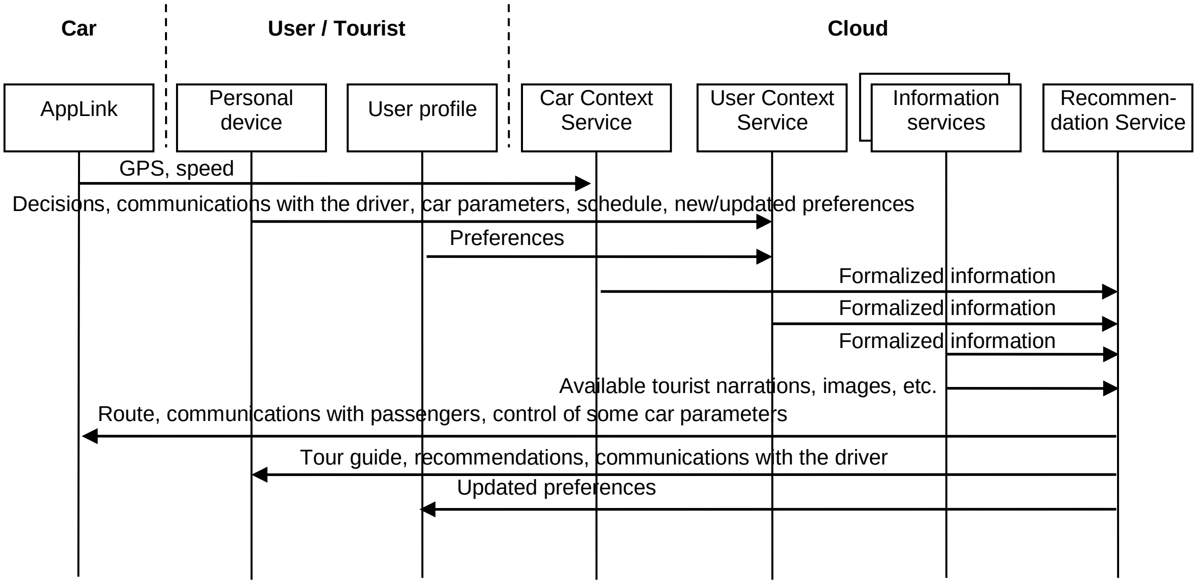

Fig. 4. Service interaction

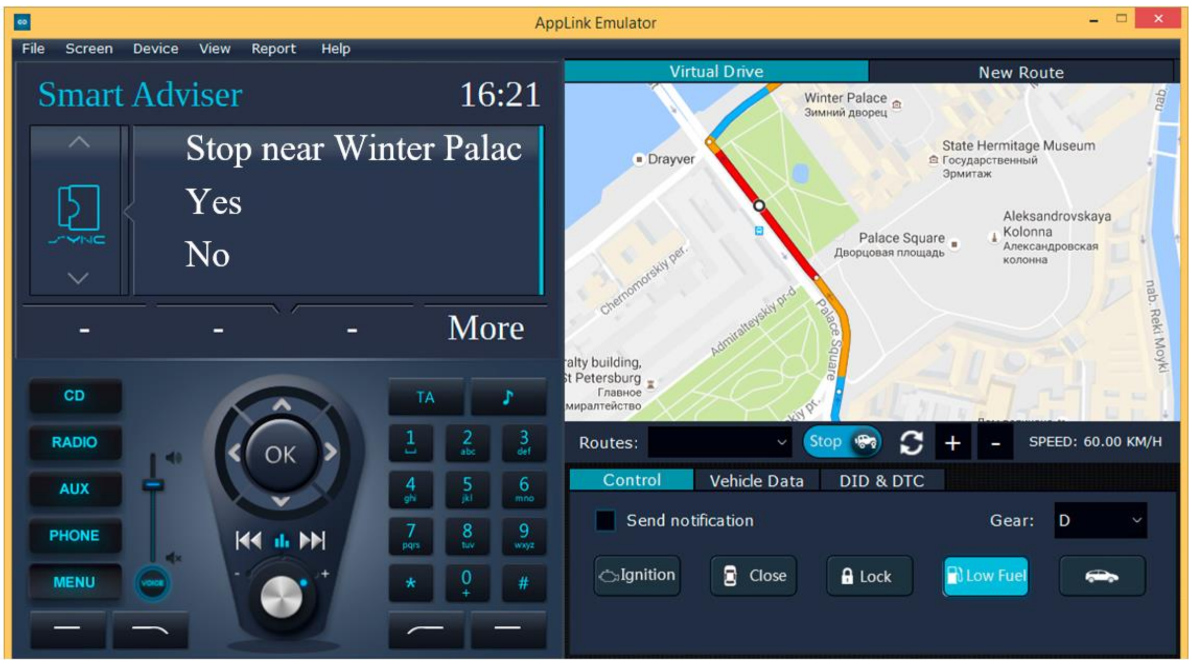

Fig. 5. The traveller asks the driver to stop near the Winter Palace (run in the emulator)

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