A Systematic Review of Proactive Driver Support Systems and Underlying Technologies

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***Abstract*—Recently, there has been an incredible growth of recommender systems as well as proactive, context-oriented technologies, based on cloud services, ubiquitous computing and service-oriented architecture. This composition of techniques and technologies has made it possible to create intelligent support systems in areas with rapidly changing environment, like car driving. However, such systems are not yet widespread, and available prototypes, in most cases, are only useful for research trials, so their development remains an important issue. Thereby, this paper reviews the existing body of literature on recommender systems and related technologies in order to carry out their systematic analysis and draw the appropriate conclusions on the prospects for their development.**

I. INTRODUCTION

The 21st century is the century of information technology that touches all areas of human activity. Informatization, in addition to large enterprises and the financial sector, also affects ordinary human life. It has already become a common thing: e.g., nowadays, one can hardly be surprised by "smart homes"; in developed countries the "Internet of things" is gaining popularity, and people no longer need to ask specialists to find things suitable for them – they can simply use one of many recommender services [1]–[3].

Nevertheless, a huge amount of issues remains unresolved. One of them is the information support of the driver. The number of private vehicles in recent years has increased significantly and is continuing to grow steadily, which has already caused substantial problems, regardless of geographic location [4]. Big cities grapple with the annoying issue of gigantic traffic jams, lack of parking spaces is able to ruffle even the most balanced drivers. The growth of traffic on motorways has resulted in an increase in the number of accidents that could have been prevented by using driver condition analysis technology [5]–[7].

In addition to challenges and threats, the modern world also offers more possibilities due to globalization and wide opening borders what results in continuously increasing number of tourists [4]. Unfortunately, people are still forced to spend their time for routine tasks such as planning optimal routes, which are not supposed to be solved by humans but can be efficiently calculated by computers as mathematical tasks [1]. Often, the wrong planning in this case can lead to undesirable consequences – disruption of travel and waiting in traffic jams [4], [8].

In general, car traffic is one of the most dynamic and unpredictable processes, that imposes tremendous responsibility on the driver both for himself and for others. Therefore, the provision of accurate and relevant context information is a vital factor [6], [7].

Considering the mentioned facts, it becomes obvious that development of new intelligent solutions capable of providing various kinds of support to the driver in real-time is necessary to meet the described challenges of our time. The integrated implementation of such solutions is called “driver support system”. In most cases, these systems include several different technologies, the final composition of which is determined by the overall purpose of the system. Typical examples of such technologies are recommender technologies, driver state analysis techniques, or routing algorithms [9].

Proactive Driver Support System is a kind of driver support system that in general is able to solve the problem or make recommendations for its solution without a driver’s request. This became possible through the processing of contextual information and analysis of user (driver) history, preferences and conditions, which allows the system to compile a holistic picture of the current situation and even to predict further events [10]–[12]. This type of systems seems to be preferable due to limitations of possibilities for drivers to interact with the system while driving [5], [9].

Thus, this paper is aimed to review, analyze and systematize the current technological solutions and relevant algorithms in the field of proactive driver information support. It also focuses on identification of the most promising directions of research and development in this subject area.

The paper is structured as follows. Section II describes the literature search process and systematizes its results. Review of selected papers is presented in Section III. Section IV contains a comparison of discussed driver support systems and provides further analysis. Section V summarizes the results of the current study.

II. SETTING TARGETS AND LITERATURE SEARCH

In order to conduct a proper research, several preliminary steps had to be taken. The study objectives were formulated first. Then, the corresponding keywords were identified followed by the literature search with subsequent result structuring and filtering. Below, these steps are described in detail.

A. Research objectives

As mentioned above, the problem of the development of driver support systems, using proactive recommender technologies, is highly relevant at the moment, which makes it advantageous for the current study. It should be noted that the presented field of study is extremely broad, since it represents a collection of various technologies, innovations, methodologies, theoretical studies. Therefore, it seems appropriate to consider a wide range of literature on the issues raised. To achieve this goal, several specific objectives have been identified:

- determine the appropriate terminology for the topic;
- generate search queries based on selected keywords;
- search for related literature;
- undertake a review of the relevant literature;
- classify the reviewed literature by thematic signs;
- select key components of the driver support systems;
- compare described ready-made solutions;
- identify the most promising directions of research in the study area.

B. Choosing keywords

The subject area is located at the junction of various fields of research, therefore it includes concepts from a variety of disciplines. Hence, the search and selection of relevant literature is not an easy task. First, it is needed to choose the set of terms in such a way that it would fully and completely cover the potential areas of research, at the same time touching the minimum number of adjacent areas that are not included in the subject under consideration. Below is a list of selected keywords:

1) Related to vehicle and driving: driver, driver support, driver assistance, driver information support, route, tour, parking, tourism, traffic.

2) Related to recommender systems: recommendation system, recommender system, referees system, location, context, contextual, scenario, script, proactive system, service oriented architecture, collaborative filtering, information filtering system.

3) Additional tags: ontology, infomobility, smart space, semantic, real-time, active learning, taxonomy, heuristic.

C. Searching process

Required literature was found by using bibliographic databases, specifically ScienceDirect (http://www.sciencedirect.com/) and SpringerLink (http://www.springer.com/gp/computer-science/)

1) The first query: ("driver support") AND ("car" OR "vehicle" OR "automobile" OR "auto") AND ("system") AND ("information" OR "computer" OR "device") AND ("source" OR "script" OR "context").

Selected articles:

- A new scenario based approach for designing driver support systems applied to the design of a lane change support system [13];
- Designing and evaluating driver support systems with the user in mind [14];
- Interface design of eco-driving support systems – Truck drivers preferences and behavioural compliance [15];
- Iterative design of MOVE A situationally appropriate vehicle navigation system [16].

2) The second query: ("driver support") AND ("car" OR "vehicle" OR "automobile" OR "auto") AND ("information" OR "computer" OR "device") AND ("smart space" OR "service oriented architecture" OR "SOA" OR "infomobility" OR "proactive" OR "recommendation system" OR "recommender system").

Selected articles:

- A Platform for Interactive Location-Based Services [17].

3) The third query: ("driver" OR "car" OR "vehicle "OR" automobile") AND ("recommendation" OR "recommender" OR "referees") AND "proactive".

Selected articles:

- Volvo intelligent news: A context aware multi modal proactive recommender system for in-vehicle use [9];
- Mobile recommender systems in tourism [18];
- Intelligent tourism recommender systems: A survey [19];
- User resistance to acceptance of In-Vehicle Infotainment (IVI) systems [20];
- A systematic review of scholar context-aware recommender systems [21];
- Enhancing driver situational awareness through crowd intelligence [7];
- Pull-based recommendations in mobile environments [2].

4) The fourth query: ("driver" OR "car" OR "vehicle" OR "automobile") AND ("recommendation" OR "recommender" OR "referees" OR "proactive") AND ("service oriented architecture" OR "SOA" OR "infomobility" OR "smart space" OR "context" OR "contextual") AND ("information" OR "scenario" OR "script" OR "method" OR "technique" OR "algorithm" OR "technology").

Selected articles:

- Towards latent context-aware recommendation systems [22];
- A Novel Approach Towards Context Based Recommendations Using Support Vector Machine [23];
- Driver-Vehicle-Environment monitoring for on-board driver support systems: Lessons learned from design and implementation [5].

Selected articles (SpringerLink):

- A proactive personalised mobile recommendation system using analytic hierarchy process and Bayesian network [10];
- Modeling context-aware and intention-aware in-car infotainment systems [12];
- Incorporating context into recommender systems: An empirical comparison of context-based approaches [24].

5) The fifth query: ("driver" OR "car" OR "vehicle" OR "automobile") AND ("recommendation" OR "recommender" OR "referees") AND ("location" OR "context" OR "contextual" OR "parking" OR "rote" OR "tour") AND ("infomobility" OR "smart space" OR "proactive" OR "collaborative filtering").

Selected articles:

- A survey of active learning in collaborative filtering recommender systems [25];
- A Hybrid Distributed Collaborative Filtering Recommender Engine Using Apache Spark Recommender systems survey [26];
- A mobile 3D-GIS hybrid recommender [8].

6) The sixth query: ("driver" OR "driver support" OR "driver assistance") AND ("car" OR "vehicle" OR "automobile") AND ("recommendation" OR "recommender" OR "referees") AND ("location" OR "context" OR "contextual" OR "proactive") AND ("parking" OR "rote" OR "tour" OR "traffic" OR "tourism" OR "trip" OR "ride" OR "journey") AND ("infomobility" OR "smart space" OR "collaborative filtering" OR "ontology").

Selected articles:

- A real-time personalized route recommendation system for self-drive tourists based on vehicle to vehicle communication [4];
- Learning semantically-annotated routes for context-aware recommendations on map navigation systems [11];
- Vehicle to Vehicle GeoNetworking using Wireless Sensor Networks [27].

D. Matching topics

Despite the similarity of subjects of the articles, a list of issues covered by them is extremely heterogeneous: some are focused on research of mostly theoretical issues about aspects of certain algorithms, while the others present the applied solutions, often focused on a purely graphical component, such as in MOVE.

This diversity reflects the complexity and depth of the topic, but the sample of articles was made on the basis of certain requirements, recorded in the search queries. Table I presents the correspondence between the topics of articles and selected issues (empty sell is for «the paper doesn't match this topic»).

As it can be seen from the table the following articles, despite interesting content, hardly match the subject area of the review:

- Vehicle to Vehicle GeoNetworking using Wireless Sensor Networks;
- User resistance to acceptance of In-Vehicle Infotainment (IVI);
- Intelligent tourism recommender systems: A survey;
- Interface design of eco-driving support systems – Truck drivers preferences and behavioural compliance.

TABLE I. ARTICLE COMPLIANCE WITH DISCUSSED TOPICS

Article reference	Driver support	Recommender system	Context-based	Recommender algorithm	Platform review
[2]		+	+	+	
[3]		+	+	+	
[4]	+	+	+	+	+
[5]	+		+		+
[7]	+	+	+		+
[8]	+	+	+		+
[9]	+	+	+		+
[10]		+	+	+	+
[11]	+	+	+	+	
[12]	+	+	+	+	
[13]	+	+-	+		+
[14]	+	+	+		
[15]	+-	+-	+-		
[16]	+	+-	+		+
[17]	+	+	+		+
[18]	+-	+-	+-		+
[19]	+-	+-	+-		
[20]		+-			
[21]		+	+	+	
[22]		+	+	+	
[23]		+	+	+	
[24]			+	+	
[25]		+	+	+	
[26]		+	+	+	+
[27]			+-		+-

Also, it should be noted that the following items are either comparative or review articles, so their further consideration in this paper does not make sense:

- Incorporating context into recommender systems an empirical comparison of context-based approaches;
- Recommender systems survey;
- A survey of active learning in collaborative filtering recommender systems;
- A systematic review of scholar context-aware recommender systems.

E. Distribution of publications by years

Fig. 1 presents the age composition of the selected literature. It can be noted that none of the publications reaches the age of 10 years. It can be also observed that the number of literature sources, at least according to the current selection, has been growing steadily, which confirms the relevance of the topic.

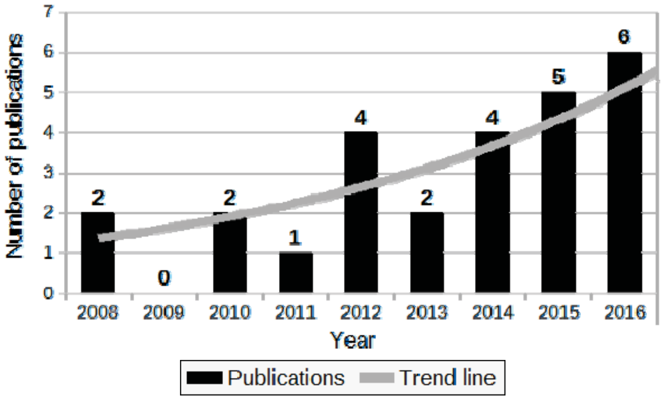

Fig. 1. Distribution of the publication by years

Total: 25 publications.

The average age of the publication: 3 years.

This topic can be considered significant also because the range of stakeholders is very broad and not limited to a narrowly focused business sector or territorial affiliation. Such technologies are investigated worldwide. This can be evidenced by Fig. 2, which shows the distribution of the reviewed articles by countries.

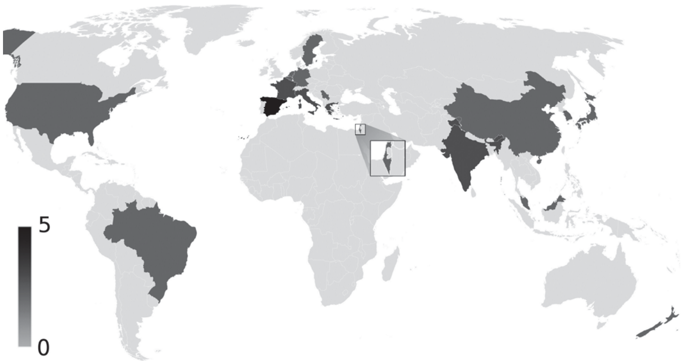

Fig. 2. Distribution of the article authors by countries

F. Paper classification explanation

Due to the heterogeneity of the issues considered in the publications found, the establishment of any general criteria for the analysis and comparison is a difficult task. For this reason, the articles will be divided into semantic units, and the comparisons will be held within them (Fig. 3).

1) Review of driver support systems section includes articles about the issue of creating such systems or description of the existing ones. They may be present as a demonstration of the algorithmic system kernel or as a specific technical solution, coupled with the impact analysis and compared to existing alternatives.

2) Review of frameworks section combines articles considering platforms that provide several recommender technology solutions. Such platforms are different from the single algorithms. Their main advantage is good integration between its constituent parts and the long list of issues covered. On the other hand, extensive functionality may not lead to less extensive restrictions.

3) Review of recommender system algorithms section contains articles describing various recommender algorithms, apart from the driver support systems. Such algorithms may have been justified in other activities. These articles make it possible to look at the problem of creating recommendations and analysis of user preferences abstracting from the automotive theme, allowing, thus, to bring something new.

4) Review articles on design experience section contains articles that set out not only the specific embodiments of systems and algorithms, but describe processes of creating such systems and aggregation of any other experience of this kind.

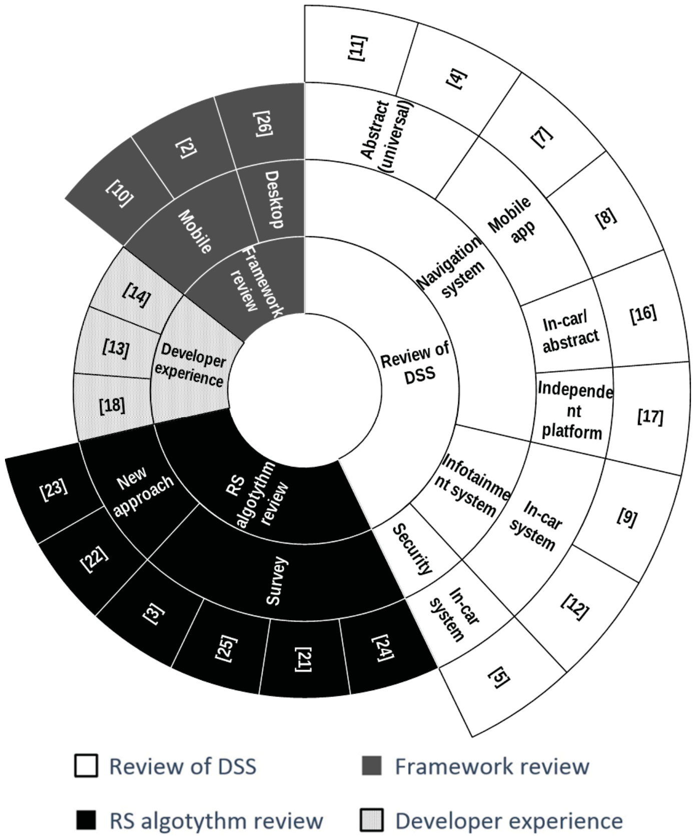

Fig. 3. Diagram of hierarchical classification of papers

III. Paper review

The review of selected papers is structured in accordance with the semantic units identified in the previous section. Though some of the approaches and frameworks presented in this section are not directly related to the driver support systems, they are considered as possibly useful for their subsequent integration into new ones.

A. Review of driver support systems

The paper *"Platform for Interactive Location-Based Services"* [17] sets out the functional features of the TransportML platform, it is an intermediary between various Location-based services (LBS) in accordance with the principles of service-oriented architecture (SOA). The article highlights three interacting entities: the client, the service broker and the service provider, communicating with each other via standardized XML language. Particular attention is paid to extensibility of the platform, providing maximum flexibility. Another important feature is the lack of predefined scenarios of services interaction, that, according to the authors, is a prerequisite for them to work together.

This technology was developed mainly for different kinds of emergency groups, but it can also be used for domestic purposes. The platform consists of the following components: Message gateway; Relay server that receives and sends messages; LibMobileCom library, which carries out the message formatting in accordance with a predetermined protocol. The format of the transmitted messages is called TMLDocument, it contains a number of XML-fields filled with the content at the time of interaction with the selected services.

It is alleged that the use of this platform can significantly reduce both time and distance of the final route, in addition, it provides a more uniform speed of movement.

The authors of the paper *"A mobile 3D-GIS hybrid recommender system for tourism"* [8] consider recommender systems as a kind of data array filter, which handles so huge volumes of information, that they can not be processed by a human. However, people sometimes are forced to interact with them, the most striking example is tourism. Therefore, the authors decided to develop a recommender system for e-tourism. Its features and architectural principles can potentially be applied to improve driver support technologies.

System design begins with a review of the existing theoretical framework and technologies. The paper distinguishes several types of recommender systems (RS): Demographic RS, content-based RS, collaborative filtering RS, knowledge based RS, utility based RS and hybrid RS. The developed system is based on collaborative filtering with its inherent disadvantages as grey sheep, historical data set and cold-start problems. In turn, the mobile application platform REJA acts as the main system basis. During the development, the following objectives were identified: ubiquity, location-awareness and 3D-interface.

The system allocates three types of knowledge: Users Knowledge, which are a set of user preferences that are used by collaborative filtering; Items knowledge, which provide the properties and characteristics of waypoints and locations used in the knowledge-based filtering (KBF); Context knowledge, which are obtained from third-party services by using the user location. The resulting recommendation is created by processing of all three types of knowledge. The entire system operates on the basis of three-tier client–server architecture, which consists of three software components, specifically of the recommender server, the GIS server and the mobile client application.

One of the main problems of modern tourism according to the authors of [4] "*A real-time personalized route recommendation system for tourists based on vehicle to vehicle communication*" is numerous traffic jams, caused, first of all, by the lack of awareness of drivers and any clear recommendations. This is especially critical in Points Of Interest (POI), which are the most desirable tourist destinations. Consequently, the development of the recommender system capable to update the information flows in real time and provide relevant recommendations is necessary for the successful maintaining of tourism activities. To achieve this, the authors discuss a number of existing navigation systems, such as V2V-navigation, personalized recommending systems, and systems that collect traffic information in real time.

As a result of the accumulation of all these data, the concept of real-time personalized route recommendation system for tourists has been created. It identifies three main logical steps needed to provide timely and accurate recommendations, specifically: data collection, evaluation of POIs and the generation of recommendations. In the developed system, each of these steps is represented by a separate software and hardware module. Data is provided from two sources: the driver and V2V communication. In the first case, it takes into account both explicit preferences of the driver and implicit preferences, which have been extracted by heuristic methods, taking into account the previous experience of driving. Each user preference is weighted corresponding to V2V readings updated in real time. The result is a traveling recommendation.

The article *"Driver–Vehicle–Environment monitoring for on-board driver support systems: Lessons learned from design and implementation"* [5] describes the experience on the development of ad hoc modules that can perform real-time monitoring and processing of related indications to the driver information support. Such monitoring modules called «DVE modules». These technical means can perform a wide range of observations: evaluation of road traffic; environmental assessment; evaluation of the driver's concentration, physical and mental state, and mood.

All of these modules are developed independently of each other, so it was important to unify their interfaces to interact within a single system. This system should take into account the dynamic interaction of three main components: the driver, the vehicle and the environment. Thus, DVE platform has been developed based on the data presented above and consisting of five modules:

- Traffic and Environment Risk Assessment (TERA) module evaluates the current likelihood of trouble, using external sensors, cameras and in-vehicle information.
- The Driver Characteristics (DC) module gathers information about the driver and his/her driving style, constantly calculates the number of indicators, such as the reaction time, time to replace the line, the time before the collision, and so on.
- The Driver Availability Estimator (DAE) evaluates the complexity of actions made by the driver and the amount of attention that it can be given to the interaction with the device.
- The Driver State Degradation (DSD) module monitors the physical and mental state of the driver to prevent falling asleep. It works closely with the DC.
- The Cockpit Activity Assessment (CAA) module evaluates the concentration of the driver on the road,

and calculates the percentage of time spent on secondary actions behind the wheel.

Each module is merely software unit designed for processing data. The data itself is read from the sensors and sent via CAN or TCP / IP to a specialized data pool (DVE pool of data), where several important processes occur, such as interaction between modules, collection the results of their work, the formation of the data array output.

Road traffic, without any doubt, is one of the most complex, unpredictable and unmanageable process. As a result, the person behind the wheel is forced not only to control the car, but also to analyze huge volume of information. This mission becomes impossible when one considers dynamics of the driving processes. The authors of [7] *“Enhancing driver situational awareness through crowd intelligence”* explain why it is so important to create a portable system that can analyze the situation and establish clear recommendations on the basis of relevant information in real time. However, all the car traffic is made up of independent people, whose behavior is difficult to predict, so updating of the information is a huge problem in the issue of these systems development, of course, if this information is not collected directly from the vehicles. Presented article offers such an approach

To begin with, the authors carry out a brief overview of related technologies, describe their advantages and disadvantages. The above materials serve as the foundation to create their own technologies. The first of these is the collection of information about traffic and road events using mobile phone accelerometers. This solution may seem strange, but it is motivated by the fact that not every car has a corresponding set of sensors and crowd sourcing requires a large amount of user feedback. In this regard, the mobile devices are more accessible than the embedded systems. The second advantage of the accelerometer, for example, compared to GPS is the maximum readout refresh rate. However, frequent updating entails an increase in the volume of information, proportional to the frequency of these updates. The authors conclude that the calculation capacity of today's mobile devices is sufficient to carry out real-time analysis of "raw" data and convert it to less capacious and more suitable data packets for further the transmission.

The authors has designed the resulting system based on client-server architecture principles. The client part is located on the user's mobile device. It consists of a user interface and a few processes running in the background to perform data collection. The backend uses PostGIS, a PostgreSQL extension, which allows the database to operate with geographic objects. Also, the pgRouting extension is used to build routes and search paths since it has perfectly proved itself in solving the traveling salesman problem. Besides, the openness of the source code has allowed the authors to revise it according to the needs of the project.

It is stated that the proposed approach can greatly reduce expenses for the message exchange between the client and the server as well as limit the number of calls to the GPS.

The article *“Iterative design of MOVE: A situationally appropriate vehicle navigation system”* [16] describes the process of MOVE system development, identifies its key goals and principles of functioning. When designing a system, the authors rely on specifics of interaction with the navigation device while driving, mainly on the fact that the driver is able to allocate very limited attention span on communication with the system. Consequently, the most important task is to optimize the information flow by enhancing its clarity and contextual relevance.

The authors state that any road map in its essence is an abstraction. The process of data abstraction is called map generalization. It is divided into several independent steps, at least five of which are used in the system, namely: the selection, simplification, displacement, smoothing and enhancement. LineDrive system is a successful example of abstraction, but it doesn’t take the context into account.

In order to define the context, information about road segments, road signs, intersections, time of day, weather, infrastructure and current indicators of the vehicle are usually used. In turn, the geographic representation of the terrain consists of three types of knowledge: knowledge of orientation, knowledge of routes and overview knowledge. Also in this work, multiple additional aspects, such as accounting for user preferences and ways of describing the route by the users themselves, are considered.

During the map design process, it was decided to cut off all unnecessary information, leaving only the direct route, the surrounding roads and icons of roadside places, thereby concentrating the attention of the user. Symbols on the map were divided into semantic and symbolic group, where the first reflects the semantic essence of the object in form of numbers or text, and the last – associative, shown in the form of icons. As a result, of empirical experiments it was found that users most quickly navigate on the map when the basic information is displayed in a semantic manner, and the secondary in a symbolic form.

The authors raise the question of the dynamic display of information – on the road the driver has to focus on a single stretch of road at each point in time, with occasional estimation of the overall path. Naturally, manual focusing is not a valid option in the intense driving conditions, therefore several techniques of dynamic information display have been developed: Zoom in Context (ZC), Route scrolling (RS), combination of the two previous called ZC+RS that focuses on the context, coupled with the general route minimap (ZC+O). It was found that the most effective technologies are Zoom in Context and ZC + RS.

A series of experiments were set out that confirm the effectiveness of the presented system. Measurements were carried out based on three main criteria: total driver focus time, the number of views on the display and the average distance on the road. For each parameter, MOVE showed better results than LineDrive and systems with static displays.

The authors of [11]*"Learning semantically-annotated routes for context-aware recommendations on map navigation systems"* identify four stages of formation of navigation technologies: navigation in the complete absence of context (maps, etc.), navigation based on your current location, navigation with processing of entered user preferences and navigation with automatic accounting for the current context and user preferences.

The authors aim to make another step forward and implement the development of the fifth-generation technologies, namely semantically-oriented navigation, which should predict the most desirable routes, using the context, history and sentiment analysis.

A review of recent papers on this and related topics have identified key aspects of recommender systems, namely: the nature of the context, continuity of learning, availability of semantic search, prediction technique and type of object predicted. According to these parameters, the developed system (SACO) offers a fundamentally new method of designing recommender systems. The method uses the ant colony algorithm (ACO) as the prediction algorithm and a predefined ontology for context detection. Users can add their own ontologies in order to enlarge the level of customization.

During testing of the algorithm, a significant reduction in computational costs was recorded at the constant quality of the recommendations when compared to algorithms of tabu search and simulated annealing.

The work *"Modeling context-aware and intention-aware in-car infotainment systems"* [12] is aimed to create recommender system, whose key difference from the majority of existing systems is its ability to predict the user's intent. The presence of such a feature is dictated by the need to minimize the interaction between user and car while driving. Five requirements have been allocated for this purpose: confidence, multiplicity, context-awareness, adaption and obliviousness.

In pursuing their goals, the authors identified the most suitable methods for implementation. The process of predicting intentions uses Bayesian networks, which have proved themselves well in the creation of such predictions. The modeling of context information and its relationships is done using an ontology described in OWL.

The authors show the results obtained on the Intention-aware in-car Infotainment System (INIS) as an example. The system itself has worked well in general, but not without drawbacks, typical for this kind of systems and systems based on Bayesian networks. However, the theoretical solutions to these problems have been proposed. In conclusion, the authors stress that technology is undoubtedly requires some work, but this fact allows to assert that it has an untapped potential.

The authors of [9]*"Volvo intelligent news: A context aware multi modal proactive recommender system for in-vehicle use"* are concerned about the problem of driver interaction with the environment during operation of the vehicle. Drivers are often get distracted to answer a call, write a message, or even read the accumulated mail. At the same time, all these services are designed to accentuate a maximum attention to themselves while operating. It is obvious that such technology in driving conditions can cause serious consequences. The solution to this problem are numerous IVI-systems (In-Vehicle Infotainment). One of the main objectives of such systems is supplying information. In this regard, three main issues have been raised: what to present, when to present, and how to present. It also considered that the structure of the requests for information varies depending on the current context and circumstances such as the current time, weather, and so on.

The authors draw attention to the accounting for user preferences and suggest the use of technologies that are typical for recommender systems, like collaborative filtering and content-based filtering. Also, certain requirements to the recommender algorithm were put forward, namely: transparency, scrutability, trust, effectiveness, persuasiveness, efficiency and satisfaction. Equally important is the context, in which the formation of the recommendations is performed, such as the weather, location, time of day. The example is a prototype system, which displays the potential POIs near the filling point, when the amount of fuel is running out.

Another important parameter monitored is the state of the driver, which allows identifying sleepiness and inattention. In total, the system should use three groups of sensors to monitor the situation: driver sensors that aimed at the driver's face and body collecting information on its attention and emotions, vehicle sensors that monitor the current vehicle indicators and, finally, environment sensors.

All of the above indicators provide a holistic picture. This approach can be used to implement a galaxy of technologies, one of them is a measurement and evaluation of the driver's workload complexity technology, given as an example. This system can provide contextual information in the most appropriate moment, for instance, when idle or while driving in a straight highway; at contrast, in the most stressed areas requiring increased attention from the driver, the system is able to limit the flow of information and disable third-party technical devices, such as mobile phones to maximize the concentration of the driver on the road.

Thus, the main limitation for the development of the system is the amount of attention that the driver can spend. Therefore, the cornerstone in described task is the technology of interaction with the driver. There were several candidates for this role: TextToSpeech technology (TTS) Heads-Up Display (HUD), Heads-Down Display and Center stack Display (CSD). To identify the best candidate, a special driving simulator was designed. It showed that HUD was less distracting than the CSD, however, CSD was easier to ignore.

The resulting system was based on the principles of loose coupling for maximum flexibility and interchangeability of conjugated services. As a result, the answers to the questions posed at the beginning of the article have been found: (i) a set of sensors determines when information can be supplied; RSS-feeds, social networks, and user preferences determine what information is provided for the user; finally, HUDText and

Google Voice answer the question "how" this information can be presented.

In conclusion, the authors summarize the results of tests, which showed a significant reduction in the average deviation from the road compared to other IVI-systems. They also focus attention on the necessity of further development of recommender algorithms that, with high probability, is the most promising direction in the development of driver support systems.

B. Review of frameworks

The paper *"A Hybrid Distributed Collaborative Filtering Recommender Engine Using Apache Spark"* [26] deals with the development of recommender system built around a collaborative filtration algorithm, based on Apache Spark. Apache Spark is an open source framework designed for reading, analyzing, and processing of big data. It uses distributed computing, cluster analysis and machine learning technologies.

According to the article, collaborative filtering has been and remains one of the most popular methods of the recommendations generation, however, it is not without flaws. The most significant are: cold start, sparsity and scalability. Currently there are several solutions, including combined, applied to nullify or at least reduce the negative impact of these factors, however, their complete elimination is hardly possible. An example of the combined solution is Hadoop's MapReduce, which, despite the use of optimization technologies, has insufficient time and cost efficiency.

Apache Spark is presented as a better alternative to MapReduce. It uses both clustering method and dimension reduction method. The cold start problem is solved by the introduction of additional functionality, such as tags. Apache Spark uses a Resilient Distributed Dataset concept (RDD), which significantly increases the speed of calculations. Also, an important role is played by the so-called "lazy evaluation", allowing to postpone the execution of operations until the results are demanded. Alternating Least Square method (ALS) is the only algorithm that deals directly with collaborative filtering within Apache Spark.

The target model has gone through several tests processing 1 million, 10 million and 20 million user preferences. It was found that the effectiveness of Apache spark increases as the number of users grows. Disadvantages include increased demand for memory, which greatly increases the cost of the operation, causing a necessity to revise ALS and cluster system. Nevertheless, despite imperfections, use of Apache Spark achieves higher efficiency compared with conventional algorithms.

The article *"A proactive personalised mobile recommendation system using analytic hierarchy process and Bayesian network"* [10] describes the JHPeer framework. It is a modern framework that focuses on the interaction with mobile applications using a number of innovative technologies for the recommender systems, such as P2P-communication, analytic hierarchy process based multi-criteria ranking approach (AHP-MCR) and Bayesian network technology.

The authors start with a discussion of previous generations of recommender systems and algorithms they use. It is alleged that most of the currently available recommender systems have significant drawbacks, the authors identify two main ones: a limited number of types of information processed and the inability of recommendation services to interact with each other. The authors also see the shortcomings in the standard collaborative filtering algorithm: in addition to the obvious problem of a cold start, it poorly copes with processing of multi-criteria user ratings.

However, these disadvantages can be eliminated by using hybrid and P2P technologies implemented in the JHPeer framework. Currently, the framework consists of a plurality of technologies and services that operate within its three-tier architecture. The lowest layer is called "Network layer" and is responsible for the physical interaction of mobile devices, such as transmitting TCP/IP protocol messages. On the second level, there are internal services of the framework, its filtering algorithms and third-party services. Also, at this level, the program communicates via high-level JHPeer messages. The third level is the level of applications.

As mentioned above, the system information is exchanged in accordance with P2P principles. However, the P2P system is implemented unconventionally: it is divided into super-peers and mobile-peers, while in the classic P2P interaction all peers are equal.

As for recommending algorithms, there are already several technologies implemented, capable of collecting and processing dynamic real-time contextual data, which are subsequently used to create recommendations. The data is collected by a so-called Context service, then, it is stored by a caching/indexing component. To process loosely coupled data the AHP-MCR approach is used. It is a multi-criteria decision making method, which allows to rate recommendations. It weighs the criteria by pairwise comparisons, using geometric mean method and predetermined hierarchical structure. This approach worked well in comparison with standard collaborative filtering technique. The cold start problem impact is reduced by the use of Bayesian networks technology. On the basis of this approach, a Proactive Personalised News recommender system PPNews was developed. It takes full advantage of the JHPee platform. However, the developers were not able to achieve a significant increase in the accuracy of the recommendations.

In conclusion, the authors stated that they still had open issues to work on. In the future, they would develop an improved API allowing to transfer video and audio by system means. They were also going to enhance the privacy by introducing registration features.

C. Review of recommender system algorithms

According to [23] (*"A Novel Approach Towards Context Based Recommendations Using Support Vector Machine Methodology"*), all recommender systems can be divided into two groups: context-dependent and context-independent (aspectual). Systems from the last group are primarily focused on the data mining and an overall evaluation of a particular entity. However, according to the authors, this approach does not work in the least satisfactory results, and the user often receives absolutely not what expected.

The authors consider the context as a restriction provided by the user, so the context converts the value of the considered aspects. After reviewing a number of existing recommender systems, the authors conclude, that the support vector machine (SVM) is the optimal method for the development of recommender systems. It handles both aspect and context-oriented information and is able to automatically find the connection between them. Data classification and generation of prediction vector based on the input vector are key objectives for these kinds of systems. Thus, this method represents a linear classifier.

Data processing in the present system is carried out in several stages: first input stream is filtered to eliminate information trash, then, some parts are extracted and spitted into tuples. Finally, context-independent preferences are identified using the method of linear regression and the context is determined. The resulting data can be used as the input vector for further training.

During the tests, it was found that recommender systems based on collaborative filtering integrated with the SVM, give much more accurate predictions, committing fewer errors, what proves the advisability of using this method for the construction of such systems.

The article *“Towards latent context-aware recommendation systems”* [22] describes the prerequisites for the development of recommender systems and their further transformation into the context recommender systems. The authors describe their operating principles, advantages and disadvantages, as well as potential areas of application. It is alleged that the improvement of the context modeling algorithms increases the complexity of the data, this translates into an increase in the number of dimensions of the contexts and the exponential growth of relationships between them. The authors suggest that the issue can be resolved by extracting hidden context, i.e. by identifying a scenario resulting in the processing of a number of disconnected readings of different sensors.

To achieve this goal, a multi-stage model of the data processing has been developed. The first step is the collection of raw data, then its primary analysis, formation of statistics and subsequent extraction of hidden context. At the same time, the explicit user ratings for the recommended entities (“user-item data”) are collected. The output consists of a latent context, an explicit context and user preferences, which are then inputted into the valuation model. The valuation model uses an improved version of the collaborative filtering method that focused on accounting the contextual circumstances.

The article also describes algorithms of latent context extraction and several related algorithms. So, the system uses the principal component analysis (PCA) method, which helps to reduce the dimensionality of the data, and this was one of the main objectives in this study. Also, the system uses a neural network and deep learning algorithms, allowing to associate remote parts of the data sets and to identify the hidden context on their basis.

The authors combine algorithms in different variations thus offering some recommender system operation methods, all of which show a significant improvement in the quality of recommendations as compared with standard prediction techniques based on the explicit context.

D. Review articles on design experience

The topic of the paper *“Designing and evaluating driver support systems with the user in mind”* [14] is the design and evaluation of driver support system (DSS) in the context of human-computer interaction. This article describes the background for their creation and draws parallel between the DSS and other human-computer technologies. On this basis, specific requirements were set out such as high security, ease of use and intelligent supply-limited amount of information in the conditions of deficiency of attention from the driver. Another important factor, according to the article, is the simple pleasure of driving, allowing the end user to adapt to this type of technology.

In summary, the results of experiments were set out for the implementation and operation of some of the technical solutions that contribute to the resolution of the aforementioned problems. The first experiment describes the experience of HUD-display implementation, signaling the changes of the traffic light colors and upcoming intersections. It was found that young drivers are more likely to pay attention to the HUD, than the old ones, but in both cases, it was possible to reduce the speed of the driver at intersections.

Further, the problem of driving cars equipped with systems that cancel vestibular information was described. A side effect is the inability of the driver to estimate correctly lateral acceleration of the vehicle in bends. The solution is the transformation of the tactile sensations into the graphical ones by deformation of the visual field of the driver from rectangular to trapezoid during turning.

Another visual manipulation technology is manipulation with the light of tail lights, brightness of which can vary depending on the speed and distance to the car, moving behind, thus avoiding potential collisions.

Throughout a number of reported studies the dependence of the solutions efficiency on the context, in which they are used, is clearly observed. It is also alleged that the important factor is the nature of technology testing, namely, compliance of the test conditions to real conditions.

Summing up the results, the authors conclude that this issue is extremely multifaceted both in subject matter and in research methods, making this field of knowledge more difficult to study, but also allows to extract more benefits from this diversity.

From the very beginning of the article, the authors of [13] *“A new scenario based approach for designing driver support systems applied to the design of a lane change support system”* focus on the complexity and diversity of the issue of developing driver support system. At this stage, the reader faces a variety of different, sometimes opposing, stakeholder requirements, which are guided by different goals and speak completely different languages. Therefore, one of the main tasks of the developer is to identify or even anticipate customer expectations on a number of key parameters, often interrelated.

Based on the above, the authors conclude, that during the development of driver assistance systems, the correct identification of preferences is not just desirable, but imperative. By the example of the lane change support system development project, the new approach is demonstrated. It is based on the direct interaction with the user and uses virtual reality, gaming principles, user scenarios. The results are surprising. It turns out that the lane change support system should be composed of independent asymmetric modules. This approach allows obtaining a much greater volume of feedback, as well as determining the user's reaction to other changes in real time. As part of larger projects, this process can be formalized and is divided into logical steps.

In addition to the advantages of a closer relationship with a potential customer and quick adaptation to changing requirements, significantly reduced the risks of an unsuccessful launch of the product to the market. Everything mentioned above compensates the high cost of such technologies, demonstrating their practical effectiveness.

The article *"Mobile recommender systems in tourism"* [18] begins with a description of the history of recommender systems as such. The authors argue that with the development of location-based services (LBS), these systems began to be used in tourism.

Further, it provides a brief overview of the existing forms of recommender systems. Generally, their construction is based on one of the six basic algorithms: collaborative filtering, content-based filtering, knowledge-based filtering, demographic filtering, matrix factorization or hybrid technology.

The authors state that functionality of almost any recommender system for tourism comes down to process and analyze the characteristics of different POI and tourist services, and sometimes it deals with route construction, of course, taking user preferences into account.

Then, the paper gives a classification of recommender systems by various criteria. According to the architectural approach, they are divided into: (i) Web-based, (ii) stand-alone, and (iii) Web-to-mobile; according to the user involvement in the creation of recommendations: (i) pull-based, (ii) reactive, and (iii) proactive; according to the data processing criteria: (i) context-aware (CARS), (ii) critique-based (CBRS), (iii) user constraints-based (UCRS), and (iv) pure location-aware (LARS).

The table of these criteria was constructed for comparison of travel systems, but the optimal solution has not been found, and therefore the authors conclude that the potential of such technologies is not yet disclosed. As potential research issues, the development of smart interface, reducing consumption of a user attention when creating recommendations, greater use of feedback, and privacy of user data were offered.

IV. Discussion

The discussion is comprised on identifying key features of the driver support systems under consideration, subsequent comparison based on above mentioned features and further analysis of the performed state-of-the-art review, resulting in the identification of promising areas of development in this subject area.

A. Comparison of driver support system publications

Obviously, the first and biggest semantic unit including papers on driver support systems is the closest in meaning to the subject under consideration. It represents the greatest interest for comparison and analysis. As a result of the systematic review with the papers of this unit, several distinctive features have been highlighted that determine their functional basis and are common to the driver support systems:

1) Platform: framework, or a set of tools and interfaces, based on which the system is built.

2) Communication between components: information transmission method and the corresponding interfaces that enables interaction between remote parts of the system.

3) Algorithms used: mathematical models that reflect the principles of the internal functioning of the system, and representing its software part.

4) Analysis of user preferences: approach to account for user preferences, that affect the relevance of submitted and processed data for a specific person, also determines system customization level.

5) Analysis of contextual information: if the previous parameter is responsible for the system's ability to adapt to a particular user, this one ensures adaptability to changes of the environmental conditions, which allows to give information relevant to the current location, time and other circumstances.

6) Architecture: selected style of hardware and software design, which defines the principles of construction and operation of key structures of the system, and their interaction as a result.

Table II represents the comparison of different solutions based on the selected key features («-» is for «this feature is not appropriate»; «?» is for «there is no available information on this feature»).

B. Analysis of the results

As it can be seen from the table, various researchers focus on different, very narrow sections of the selected issues. Some focus on the use of any new, perhaps unexpected for a given domain algorithms, some seek to get the maximum benefit from the interaction of independent services, based on the principles of service-oriented architecture, others exploit the advantages of the increasingly popular crowd-sourcing.

In this case, it is possible to conclude that there is no uniquely optimal solution, which might be claimed as "gold standard" [13]. At the same time, almost each of the reviewed articles offers new opportunities, whose potential is yet to be

TABLE II. COMPARATIVE TABLE OF DRIVER SUPPORT SYSTEMS

Article name	Platform	Communication between components	Algorithms used	Analysis of user preferences	Analysis of contextual information	Architecture
A mobile 3D-GIS hybrid..[8]	REJA	TCP/IP	Collaborative filtering	Collaborative filtering	GPS, Location-aware knowledge filtering	Three-tier client–server architecture
A Platform for Interactive...[17]	Transport ML	XML via TCP/IP, TMLDocuments	-	?	Based of related services	Service-oriented architecture
A real-time personalized route recommendation system...[4]	-	TCP/IP	Fuzzy rote scoring	POI, Restrictive Conditions, V2V preferences, explicit requirements	Rote V2V attributes, rote history collected via V2V	V2V communication, interaction with hot-spots
Driver–Vehicle–Environment..[5]	DVE	CAN, TCP/IP	-	Explicit requirements, sensor data	Car sensors, cameras. Data is processed by five modules	Embedded system
Enhancing driver situational..[7]	PostGIS, PgRouting extention	HTTP, JSON coded messages.	Collaborative filtering, crowd wisdom	?	Accelerometer data, data from other users	Client-server architecture
Iterative design of MOVE A situationally...[16]	MOVE	-	Map generalization (5 steps)	-	Based on current location, Zoom in Context	-
Learning semantically-annotated… [11]	SACO	?	Ant colony optimization, semantic distance evaluation	Domain-specific ontology	?	?
Modeling context-aware and intention..[12]	-	-	Bayesian networks	Explicit POI preferences, user history	Customized ontology, car sensors	Embedded system
Volvo intelligent news - A context..[9]	?	TCP/IP	Collaborative filtering	Driver conditions collected from sensors	Location-based services,	Embedded, service-oriented architecture for external features

discovered. Coupled with the extensive demand for navigation and recommendation systems individually, it can be argued that a successful combination of them, based on concepts and technologies described above, will be a real breakthrough in intelligent driver support issue.

However, as noted above, the development of such a solution is hardly limited to the choice of a single technology as each of them have their own advantages and disadvantages, which are often hard-to-eliminate. For example, collaborative filtering, in most cases copes with intelligent search of user preferences, but when it comes to specific cases defined by a predetermined context, the effectiveness of this technology is rapidly falling, even in cooperation with corrective techniques [8], [10], [21], [23], [25], [26].

Ant colony algorithm is a smart choice for fast, resource-efficient search of the shortest paths, but is heavily dependent on user feedback and the number of the participating agents in the system, and therefore absolutely useless in areas with low attendance [11]. The same applies to almost any artificial networks that need training [25]. Some hybrid solutions reviewed in this paper were quite effective in overcoming the partial set of problems, while creating new ones, albeit less significant.

Besides, how reasonable is to refuse the proposed diversity of technologies, practices, decisions, considering that their scope is as wide and versatile? In some studies, it was decided to abandon the internal calculations and data collection, using third-party services, while others are focused on gathering readings only from their own sensors, building thus completely autonomous system. And, most importantly, both decisions were absolutely correct in the context of presented situations.

Thus, the main problem at the moment, is not the lack of technology and solutions as such. Actually, they abound. The real problem lies in the lack of interoperability due to poor uniformity of their interfaces [10]. This fact was also touched on in [17], where it was suggested that a decent solution is the use of service-oriented architecture. This method requires a plurality of independent, unified, and therefore, interchangeable services, which constitute the functional blocks of unified system. This approach ensures maximum product flexibility and less dependence on certain of its elements, allowing to adapt the final configuration to a specific task.

V. CONCLUSION

This article provides a review of the most recent literature on the subject of intellectual driver support and related fields of knowledge. Judging by the number of articles found and the dynamics of their growth, it is possible to conclude that this issue is actively developing due to the efforts of the scientific community and finds support among stakeholders.

Despite having very different approaches to the development of driver support systems, which have been the described in the reviewed articles, as well as the diversity of tasks to be solved by designing rather heterogeneous technologies, this article was able to organize the above-mentioned knowledge, and to consider it in the framework of a single paradigm. It leads to the conclusion that the creation of intelligent driver support systems is a holistic, independent branch of modern scientific perspective.

All aforesaid makes the problem of developing driver support system highly relevant. At the same time, in the course of the present work the most promising vector of development in this area has been identified as the unification of services and technologies for the implementation of the final solution based on a service-oriented architecture.

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