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What Humans Should Be Thinking While Driving: Method for Integration of Driver Cognitive Load Information with Map Data

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Abstract. The current navigation map data does not contain information regarding the cognitive load associated with the navigation related entities on the road (i.e., road segments, junctions, manoeuvers, etc.). The associated root cause as well as the optimum guidance information to address the cognitive load is not a part of the current navigation map data. There is no mechanism to create and store this as a part of the current navigation map data. Cognitive load /stress levels on different parts of navigation have a significant impact on road safety, but the navigation map data does not integrate this information to support these cases related to cognitive load while navigating, to reduce the stress associated with navigation. Routing based on cognitive load associated with the route is currently not possible. This paper demonstrates an effective method of integration of cognitive load levels to navigation map data using HERE map as well as technologies offered by HERE Technologies as a reference for creating the necessary infrastructure for the integration of human cognitive load to navigation map data.

Keywords: BeaCON · Navigation System · HMS · Cognitive Load · OEM · Machine Learning

1 Introduction

A car Navigation System (NS) highlights the current location on the navigation map and provides guidance information for the user to reach the target location [1]. NS itself is supposed to create only minimal driver interruptions while providing guidance information [2]. Driver distraction contributes to 5–10% of the crashes in Europe [3]. Also, it is identified that drivers are engaged in activities other than driving for half of the driving time [3]. This indicates that proper guidance should be given to the driver so that the necessary use of cognitive resources is ensured when needed. The creation of cognitive load information and integration into the navigation map to use for relevant use cases is a current gap in the navigation map. The research framework BeaCON (Behaviour and Context-based Optimal Navigation) enables conducting research on optimum integration between human and navigation systems, but the results from this

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framework and another similar mechanism are not integrated into the navigation map as well and there is no efficient method for this integration. To conduct research in this area, collecting the input needed to calculate the cognitive load associated with the route from different sources as well as associating the cognitive load with the navigation map data by enhancing the current data model to incorporate cognitive load is necessary.

The conventional navigation system is not a human-in-the-loop system but is a stand-alone system which considers only some static or hard-coded rules as shown in Fig. 1. This paper proposes an optimal method for creating the Human-in-the-loop navigation system by incorporating the cognitive load scenarios as well as the resolution for high cognitive load scenarios as shown in Fig. 1.

This paper is organized into multiple sections. Section 3 describes the integration of the cognitive load information to the map data in detail. This section also covers the cognitive load data processing component, which is responsible for collecting the preprocessed cognitive load information to the map data. Section 4 covers the representation of the cognitive load data in the navigation map. Section 5 covers the integration of cognitive load root cause and optimum guidance information to address the root cause in the navigation map data.

2 Related Work

[4] introduces a research framework that facilitates efficient analysis for generating optimal guidance information. But [4] does not provide any method for the consumption of the created optimal guidance information. [5] demonstrates the essential role of detailed human behaviour analysis in the development of intelligent navigation systems, but [5] does not contain a navigation map or any other methods for the integration of human behaviour data to reduce cognitive load. Even though [6] considers the human cognitive state for navigation systems, [6] does not consider real-world navigation entities as well as not providing any methods for the consumption of guidance information. In [7] a detailed analysis of driving attention by considering the subprocess of monitoring, control and decision-making is conducted, but in [7], the driving scenarios considered are very limited, as well as it does not integrate the results into any driving simulator framework or navigation map. [8] focuses on the situation awareness of driving contexts but not directly related to the cognitive load reduction or representation. [9] provides a cognitive model for navigation but does not conduct research related to cognitive load reduction or representation.

3 Integration of Cognitive Load Information to the Navigation Map Data

A block diagram indicating the method for integration of driver cognitive load with map data is shown in Fig. 2. The cognitive load data creation identifies the cognitive load associated with each road segment as well as for other navigation-relevant entities like junction manoeuvers, construction sites, etc. The collected cognitive load is also associated with other attributes like time, weather, traffic, etc. The cognitive load data creation algorithm has the following main tasks.

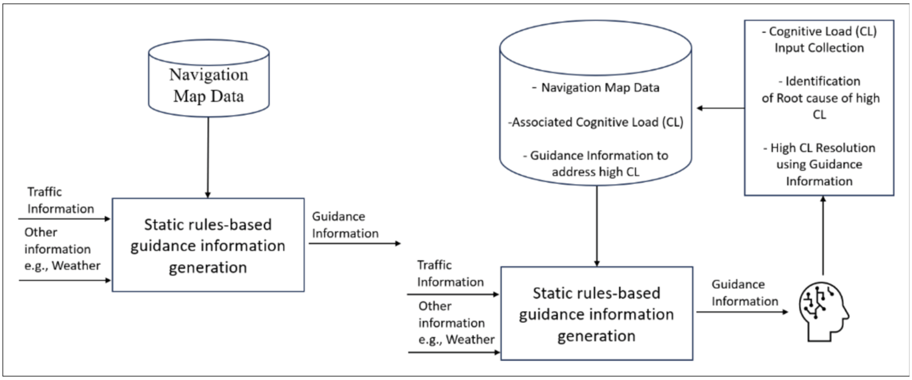

Fig. 1. Conventional navigation system (Left), Human-in-the-Loop Navigation System (Right)

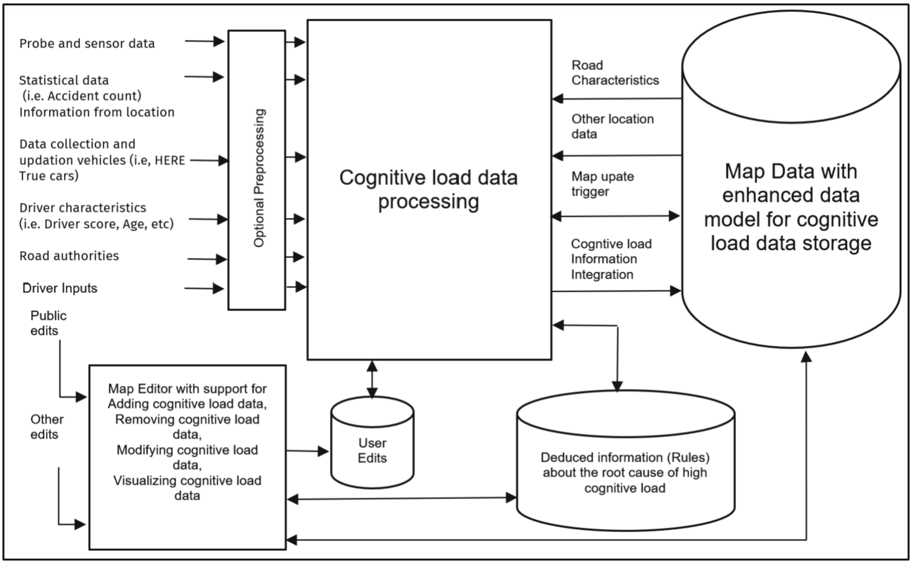

Fig. 2. Block diagram of method for integration of driver cognitive load with map data

- Collect the cognitive load at different locations from different sources.
- Perform initial validation.
- Map matches the data to road segments.
- Attach the cognitive load data with other necessary attributes to different road segments and other entities (i.e., deduced root cause).
- Deduce and publish information on the root cause as well as use these rules to provide cognitive load data for the road segments where direct information about the cognitive load data is not available from the sources.
- Storing the identified root cause.

Two of the main components of the system are.

- Input data collection and processing.
- Cognitive data processing.

During input data collection and processing, different input data is collected from different sources. The strategies applied for different input data are given in Table 1. Cognitive load data processing correlates the cognitive load with different location attributes as well and the correlation rules of this correlation can be stored in a database. These rules can be used to deduce the cognitive load of the locations where direct input about the cognitive load data is not available. The rules created by identifying the correlation can make use of machine learning algorithms. A brief overview of the data processing sequence is shown in Fig. 3.

Table 1. Strategies applied for different input data

SN	Input	Description
1	Probe and sensor data	Basic cleaning as well as standardization. This data shall be collected and provided by different OEMs (Original Equipment Manufacturers)
2	Statistical information	Information from statistical reports that identify or correlate the cognitive load associated with a route. The preprocessing of the statistical information can include standardization. Statistical data can also be contributed as deduced or assumed cognitive load data information. For example, if a particular road segment has a higher number of accidents, an assumption that this part of the road induces higher cognitive load to the user is possible
3	Data collecting and updating vehicles	Probe and sensor as well as other information from the test vehicles. Test vehicles can be used for map-making as well as for collecting other location-related information by driving along the route. The preprocessing can include standardization
4	Driver characteristics	Information related to correlating the driver characteristics with cognitive load information. The preprocessing of this can include standardization
5	Road authorities	Information or reports from the road authorities identify or correlate the cognitive load associated with a route. The preprocessing of the road authority data can include standardization

(*continued*)

Table 1. (*continued*)

SN	Input	Description
6	Driver inputs	The input from the driver correlates the road with cognitive load data. The preprocessing of this can include using a human language interpretation model to convert driver inputs to a standard format where a standard format correlates the cognitive load with location characteristics
7	Map edits	The user can add, modify, and delete the cognitive load values for road segments as well as other entities like junction, manoeuver, etc. The reason for the cognitive load can also be entered. The newly added data shall be integrated into the map after the necessary verification and validation steps

4 Representation of Cognitive Data in the Navigation Map

The data model for cognitive load integration shall enable the following.

- Calculate cognitive load for the road segments.
- Calculate cognitive load for point locations as well as for the road segments.
- Calculate cognitive load for entities like junctions, manoeuvers, etc.
- Enable calculation of total cognitive load by using the cognitive load associated with road and other entities.
- Identify the root cause of cognitive load associated with roads and other entities, which can be used for cognitive load reduction (For example by providing navigation information as per the root cause).
- Integration of the guidance information, which is needed as per the identified, calculated, and assumed cognitive load where the guidance information can contain the following.

– Necessary guidance information which is needed to reduce cognitive load.
– Guidance information in user-preferred language if necessary

- Time-dependent cognitive load information associated with road and other entities.
- Weather-dependent cognitive load associated with road and other entities.

Generally, standard attributes like the speed limit are uniformly spread across the navigation entities, for example, a road segment. Also, the reason why a specific speed limit is applied to a road segment is not of interest to the driver. But these characteristics are different when it comes to the cognitive load associated with road entities.

The way the driver cognitive load is represented in the navigation map data is driven by its purpose, which is reducing the cognitive load associated with road entities. Also, the representation shall be suitable to include different cognitive load analysis standards without significant changes in the data model. The HERE map data model for the Advanced Navigation Attributes layer [10] is taken as a reference data model. The geographic area is divided into multiple partitions. An example of partition data is shown in Fig. 4. The lines showing the topology segments in the partition as well as the properties corresponding to each topology segment are also shown in Fig. 4. The cognitive load analysis result can be attached to the road topology layer by using segment anchors [11] wherever needed, like the other attributes. The specific data model for cognitive load representation in a map data layer is shown in Fig. 5. The mechanism of the cognitive load measurement result representation varies depending on the specific method used [12]. The data model is not limited to the methods specified in the data model in Fig. 5. For example, the advanced steering entropy method used by BeaCON [4] is another efficient method which can be used to identify high cognitive load areas.

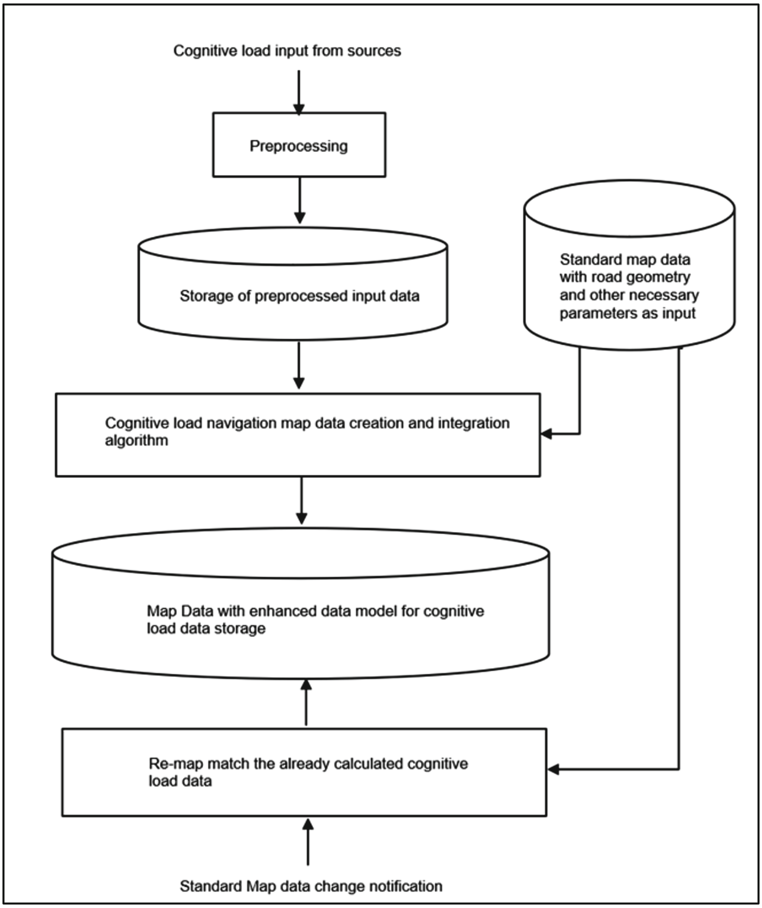

Fig. 3. Data processing for the method for integration of driver cognitive load with map data

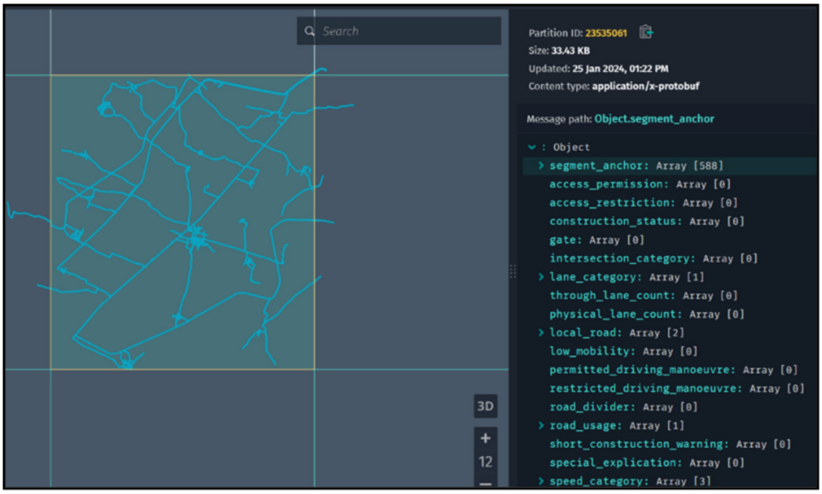

Fig. 4. An example of partition data

5 Creation and Integration of Optimum Guidance Information

To create the optimum guidance information, not only the information about the cognitive load values but also the root cause of guidance information is necessary. The principles generated by the research framework BeaCON can be used to identify the optimum guidance information from the cognitive load data as well as from the context information. Currently, BeaCON supports the following.

1. Conduct tests on the selected test route in the virtual environment.
2. Create cognitive load information from the probe data.
3. Data mining uses the data analytics framework provided by BeaCON to generate insight into the cognitive load data as well as to generate principles to address the high cognitive load.
4. Create optimum guidance information.

After step 3 from above, BeaCON shall contain the identification of the root cause as well as the principles to address the root cause. The principles from the virtual test route in BeaCON can be applied to the navigation map data where the navigation context is similar to the corresponding test environment. From the principles identified from the BeaCON framework or by using other methods, static rules shall be deduced. These rules can be used to identify and address the navigation scenarios by integrating the cognitive load values, root cause and the guidance information into the navigation map. Creation and integration of optimum guidance information using BeaCON is shown in Fig. 6.

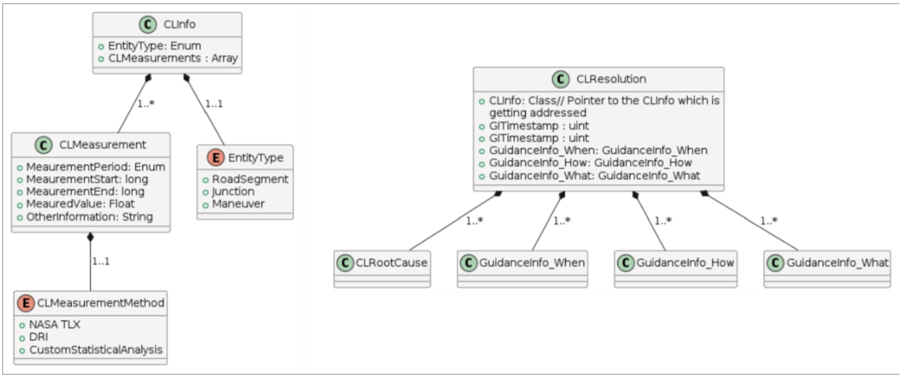

Fig. 5. Data model for cognitive load analysis and representation in a map data layer

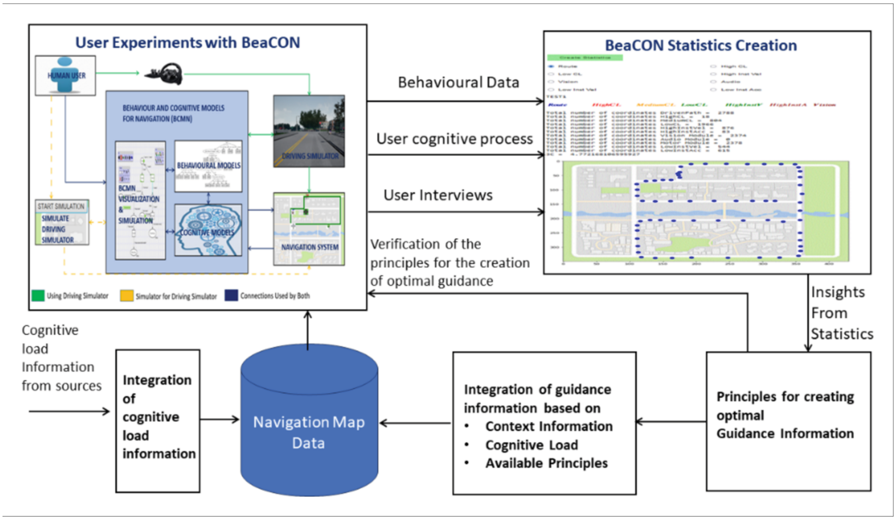

Fig. 6. Creation and integration of optimum guidance information using BeaCON

6 Representation of Cognitive Load Root Cause and Optimum Guidance Information into the Navigation Map

The BeaCON framework or any other methods (i.e., user interviews, information from road authority etc.) for cognitive load analysis shall provide the following for reducing the cognitive load associated with navigation.

- What guidance information shall be provided.
- When to provide the guidance information.
- How the guidance information shall be provided

Each of this information shall be represented as a part of navigation data, so the navigation system using this can act effectively to reduce the cognitive load. A class diagram shown in Fig. 5 can be used for this purpose. The segment anchors can be used in this case in order to attach information related to the reduction of cognitive load. In this case, the segment anchors may not be the same as those of the segment anchors used to store the measured cognitive load. The cognitive data layer can be a separate layer similar to the arrangement of topology geometry and road attributes as shown in Fig. 7. The cognitive load values associated with the road elements can be in a separate layer in order to provide the decoupling of the cognitive load root cause and solution. For example, if a user wants to retrieve only the measured cognitive values without the resolution, the data model shall support it accordingly.

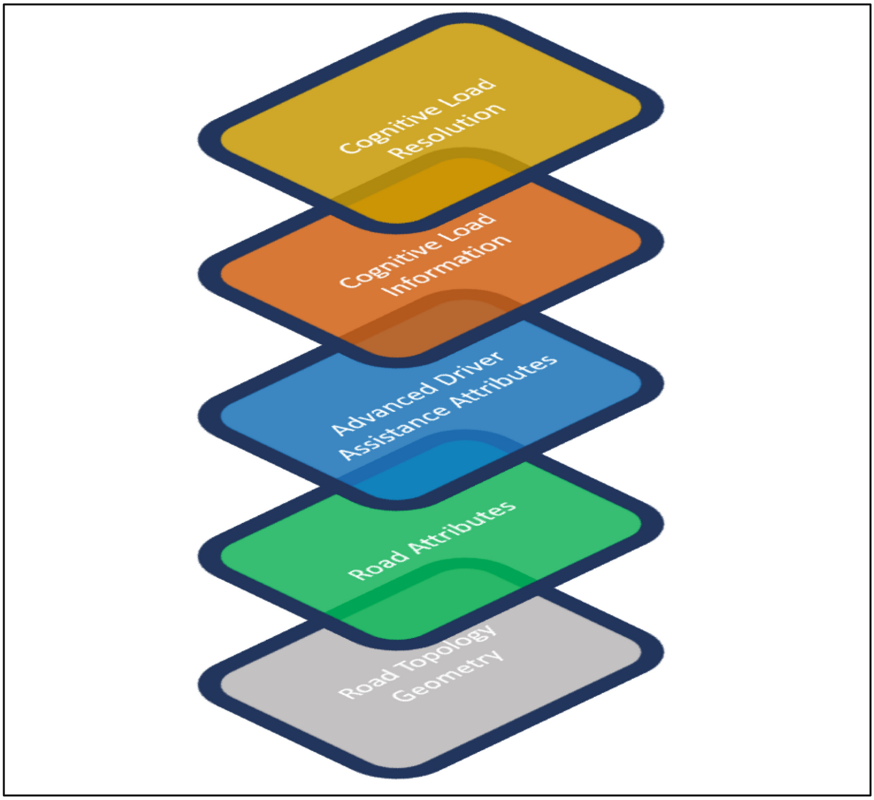

Fig. 7. Cognitive data layer along with other navigation map data layers

7 Conclusion and Future Work

The method for integration of the human cognitive load data is presented. Related works on the same topic are described. Comparison with the state of the art in this field is covered. Different categories of input data which is needed to enable the cognitive load calculation are briefly covered in a tabular form. Cognitive data processing as well as the representation of the cognitive data by using an optimum data model is described in detail. Integration of optimum guidance information to address the high cognitive load situations is also presented. Enhanced input data collection as well as the cognitive load data generation based on this enhanced data collection can be considered for the road map. More traffic situations can be integrated into the BeaCON framework so that the optimum guidance information to reduce cognitive load for a wide range of traffic situations can be identified.

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