Trends in Cognitive Mobility in 2022

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Abstract: Cognitive mobility framework has developed in the year 2022. The first international scientific congress (1st IEEE Cognitive Mobility at Bosch Budapest Innovation Center – CogMob Conference) was organised to create a space for sharing thoughts and starting conversations about the topic. This paper aims to summarise and evaluate the main tendencies of cognitive mobility. After reviewing the presented papers, there were evaluated according to essential elements of cognitive mobility, and statistical analysis was carried out to evaluate the papers. In our work, the five core topics of cognitive mobility in 2022 were defined and evaluated according to the essential elements. The similarity measure and proximity index-based evaluation of the abstracts and the keywords show that sustainability-related topics, energy sources, and their utilisation area are the most frequented. The tendency is expected to continue, but the international military situation could influence the weight of the topics.

Keywords: cognitive mobility; elements of cogmob; statistical evaluation

1 Introduction

This paper aims to provide an overview of the actual focal points of cognitive mobility based on the CogMob Conference 2022 key topics and evaluate the interdependence scientifically. The conference's papers covered broad research areas of mobility, from intelligent and sustainable mobility systems to the safety and security of ITS-related (ITS-Intelligent Transportation Systems) cognitive systems and advanced fuels and drivetrains.

Mobility is a crucial dimension of our society. The efficiency and sustainability of our life are heavily dependent on mobility and similar factors. *"Cognitive Mobility (CogMob) investigates the entangled combination of the research areas such as mobility, transportation, vehicle engineering, social sciences, artificial intelligence, and cognitive infocommunications. The key aim of CogMob is to provide a holistic view of how mobility, in a broader aspect, can be understood, described, and optimised as the blended combination of artificial and natural/human cognitive systems. It considers the whole combination as one inseparable CogMob system and investigates what kind of new cognitive capabilities of this CogMob system are emerging"* [1]. Mobility as one of the most important pillars of our society has several dimensions. Developing transportation sectors are merging with the increasing cognitivity level [2, 3] and cognitive mobility can be an enabler to make our cities more sustainable [4, 5, 6]. Deeper understanding of mobility with the help of cognitive approach [7] is the way to reduce the overall impact of mobility on the environment [8, 9, 10].

Based on its nature, one of the CogMob focus areas is engineering applications in the mobility domain.

This paper firstly summarises the relevant areas of cognitive mobility by analysing the papers presented at the conference. In the second part, these areas are related to the essential domains. The third chapter evaluates the fields of CogMob2022 in the elements of cognitive mobility and in the fourth part presents a statistical analysis to examine the interdependencies.

2 Trends in CogMob Area Analysis

The trends of cognitive mobility cover the connected cognitive vehicles, safety and security of ITS-relevant cognitive systems, cognitive aspects of orientation and navigation, advanced electric vehicles, and augmented conventional drives.

2.1 Cognitive Connected Vehicles

Raising the cognitive level of vehicles is one of the critical drivers of cognitive mobility. One direction is the development of methods to provide objective indicators for the complex tasks of road transport. One of the keys is to define an evaluation framework that can be applied in developing and evaluating new AI-based models. The aim is to define the metrics used in the development process and to facilitate the qualitative evaluation and comparison of algorithms. One of the proposed methods aims at broad applicability by choosing only metrics obtained from sensors already installed in vehicles [11].

With the proliferation of self-driving vehicles, motorcyclists, representing a vulnerable group of road users, require specific solutions. Their risk of severe injuries and fatalities is higher than the average and therefore requires the development of assistive systems to improve driving safety. Two promising methods are also being introduced, called sub-area and dynamic frame rate evaluation, to reduce the computational effort from raw video data to driver posture information [12].

One of the keys to the Traffic Sign Recognition and Detection System (TSDR) is its high-speed operation, which can be derived from the high-speed of vehicles. Through computer vision and human-machine communication, these systems help vehicles navigate. Improving and speeding up traffic sign recognition is one of the areas of development that will continue to drive future developments [13].

Demand Responsive Transport (DRT) services are gaining ground with the ability to configure mobility to individual needs. Alternatives to public transport systems and the increasingly popular shared mobility systems. Their development aims to improve their service quality further. One innovative form is the implementation of autonomous fleet systems. Research is investigating the challenges of deploying low-speed self-driving minibuses (tracking) in DRT and the primary tasks that must be carried out to prepare for the future introduction of such a service. A systematic process-oriented approach will be used to investigate the specific parameters, conditions and options for the vehicle and the operational options (for DRT). As a result, system interfaces will be identified, and the conditions for establishing such a service will be analysed [14].

Cognitive measures are increasingly necessary for all mobility modes, from motorbikes to urban buses. Different vehicle categories have different challenges, but using AI for prediction, environment perception data acquisition, improved human-machine interfaces, and system-level vehicle control offers cognitive mobility solutions [15].

2.2 Safety and Security of ITS-related Cognitive Systems

The mobility system's growing autonomy increasingly requires system security and cybersecurity improvements. Software development for modern vehicles is increasingly based on a service-oriented approach. Building software systems from software components add specific capabilities to the system and allow fine-tuning details. Methods are being developed to implement flexible software vehicle architectures based on adopting out-of-the-box software. One development direction follows the dynamic changes of the set parameters and provides easily extensible interfaces to new parameters or requirements. The concept further introduces a priority metric that describes the impact of services in the system and models how this metric is inherited through dependencies [16].

One area of understanding vehicle behaviour is accident investigation, where vehicle data is downloaded using target hardware and expert forensic software. Research is investigating the process of analysing the extracted data and the conclusions drawn based on a growing database of modern cognitive vehicles [17].

The relationship between vehicles and infrastructure is also at the forefront of cognitive mobility security research. Its impact on vehicle safety has implications for the further development of V2X-based (vehicle-to-everything) design processes. The research presents a novel methodological background for characterising the safety impact of network performance metrics on V2X-based automotive applications. The results are used to identify the safe operating range of a given V2X-based application [18].

Cognitive mobility system components are also increasingly becoming victims of cyberattacks. The application and implementation of Attack Graph, a commonly used IT security tool, is under way in vehicles. Cognitive mobility systems are based on autonomous decision making by the participants. To trust vehicles to make the right decisions, we need to make them immune to failures and malicious manipulation. A general model is proposed to automate the generation and analysis of attack paths in TARA. Several use cases of the model are discussed, including the enumeration of possible attack paths, the automatic assessment of the feasibility and risk of each path, and the construction of a protection diagram to ensure system security [19].

The fusional handling of safety and security aspects is a typical example of emerging cognitive mobility. An increasing number of sensors and activators is followed by intensive communication that, on the one side, is an opportunity to increase safety but, on the other hand, is a threat to security risks.

2.3 Cognitive Aspects of Orientation and Navigation

In the area of human-machine communication, CogMob co-manages human and machine capabilities in mobility, and in this regard, it should aim to help humans to preserve their spatial ability even when providing navigational aid [20].

GPS is a key element of current mobility systems. It is a human-machine interface that is mainly used to provide turn-by-turn navigational aid to human drivers. From one perspective, the user could save cognitive capacity by relying on this turn-by-turn navigational assist. Thus, they can pay more attention to the driving itself. On the other hand, frequent use of GPS (Global Positioning System) can erode human navigational abilities [21]. That is an often overlooked but crucial human skill in everyday life and special areas. Researchers provide design principles to support and not replace human cognitive skills. Such a method can raise awareness of the phenomenon [22], [23]. Another is to initiate active encoding as if the user has to deal with spatial information actively, it can achieve better knowledge [24]. A third possible way is to modify GPS software to encourage users to pay more attention to the environment by referring to landmarks in the instructions [25]. For more details, please be referred to [20].

2.4 Advanced Electric Vehicles

Electric vehicles are characterised by excellent energy efficiency and local zero CO_2 (carbon-dioxide) emissions, but overall it is necessary to assess production and reuse together with use. The growing amount of data that can be collected on vehicles will allow a more accurate understanding of the whole life cycle. A detailed analysis of these issues has been conducted to propose solutions to accelerate the path toward climate neutrality. Based on this extensive analysis, a forecast of future trends in electric vehicle technologies and beyond for other CO_2-neutral solutions will be made [26].

One of the electric vehicle powertrain's fundamental dynamics and sustainability aspects is the analysis of inverters and their power transistors. There is an exciting transition in the type of circuit breakers used in inverters. In addition to technical and safety aspects, including lifetime, reliability and possible failure modes, other aspects, such as cost, market needs and availability, are also considered. [27]

Accurate battery temperature prediction in electric vehicles is critical for efficient thermal management of the battery system. The research uses a nonlinear autoregressive exogenous network to model the complex thermal behaviour of the battery cell. Using conventional driving data, the model is trained, and its accuracy is proven over a wide temperature range, demonstrating the approach's simple, general and robust applicability. [28]

Synchronous reluctance motors are becoming an increasingly important player in electric mobility due to the growing need to reduce the amount of rare-earth metals in electric vehicle components. Novel post-processing methods are being developed based on differential inductances of finite element analysis inductance tensor maps. A force method based on the number of rotor displacement rises coupled with the coefficient of coercivity determines the required inductance map resolution. Reduction of nonlinear effects by modifying the current profiles through motor control can only be achieved with a well-defined tensor mapping method. An adequately defined motor model, together with an appropriate control compensation method, can further improve the efficiency of synchronous reluctance motors and provide the required performance in the low speed and part load range where the real operating points of an average used vehicle are found [29].

A critical dimension of e-mobility is the battery and its degradation during use. Considering the typical use of electric vehicles, a test track has been designed from which detailed data can be collected from highly sensorised vehicles. Results showed that batteries lose 4% of their capacity over 10 000 km and almost 14% over 45 000 km [30].

Hybrid propulsion technology is one of the most critical research areas today, as these technologies can improve fuel consumption through energy recovery. Laboratory measurements of the drives are carried out on test benches in the first development phase to keep the parameters constant. In addition to the conventional combustion engine-electric drive hybrid systems, other combined systems are also being developed, such as an electric motor and a hydraulic pump/motor unit (HPM). The experimental hybrid power source is designed to achieve the highest efficiency during vehicle starting, acceleration and regenerative braking [31].

Electric vehicles have different noise, vibration and harshness (NVH) characteristics than conventional powertrain vehicles. Increasingly accurate data collection and evaluation requiring high computational power allow complex tests. In a comparative study of electric drive cars, vibration and noise have been measured at different speeds at several locations on the driveline and in the passenger compartment. The results show that vibration intensity and noise primarily depend on vehicle speed [32]. During the acceleration phase, the gear shift commands dominating the vehicle exterior were almost inaudible [33].

The market launch of electric vehicles is one of the answers to the improved demand for sustainable mobility. Electric drives standalone, multiplied or used with a combination of internal combustion engines are more accessible to control and could enable a more complex optimisation field during the control. Its elements, such as the battery, inverters, and electric motors, are the developments' focus. Connected to this, the noise and vibration questions are also heavily investigated.

2.5 Augmented Conventional Vehicle Drives

The electrification of mobility is one of the significant trends, but the technological and supply constraints mean that conventional powertrains have a long future ahead of them. Extended conventional powertrains are and will be part of mobility in the coming decades. On the one hand, diesel powertrains are branded as the enemy of the environment, and on the other hand, there is still no alternative in some application areas.

One of the main objectives of diesel engine development is to keep overall emissions and fuel consumption low. The complexity of turbocharged diesel engines with low and high-pressure exhaust gas recirculation poses a technical control challenge, requiring multiple determinations of the recirculated exhaust gas mass flow. This is only possible through complex system monitoring, data collection and a complex control system. Experimental methods are being developed to estimate the recirculated exhaust mass flow in high and low-pressure systems [34].

Other research included a numerical study on integrating a gas-air mixer into the heating mantle housing to reduce fuel consumption. In this method, a heating mantle was fixed to the outer wall of the gas-air mixer. The gas-air mixture and the heating medium used a reverse flow method. Water at constant temperature and with different flow rates depending on the engine speed was used as the heating fluid. The results of the CFD analysis confirm a significant increase in the temperature of the gas-air mixture at the outlet of the mixer. Therefore, the new integrated preheater-mixer design can be used in internal combustion engines for gas-air mixture and temperature control [35].

The development of new advanced fuels requires more efficient cost-reduction methods. Artificial neural networks can be used in fuel design, but creating data sets can be costly. A new line of research aims to create high-precision, multi-layer, perceptron-like artificial neural network models for predicting the combustion and emission characteristics of a medium-performance commercial diesel engine. It was found that the high-resolution dataset resulted in truly accurate models that can be used to pursue cost optimisation research [36].

Lubricants play a crucial role in the energy loss of an engine. Several technical solutions exist to reduce friction and wear losses caused by lubricants. With the proliferation of low-friction engine oils such as 0W-20 and below, the importance of tribological lubricant additives is increasing. This research investigates the tribological potential of selected nano-scale ceramic particles (zirconia, copper oxide and yttria) as lubricant additives and compares them in terms of their financial impact. The results show that additives with the best tribological properties are not always the best for mass-produced lubricants [37].

The physical and chemical condition of the lubricant also plays a crucial role in the long-term performance of engineering systems. Knowledge of the lubricant condition allows optimisation of condition-based oil changes, which can help reduce wastage by extending the life of engine oils. A study presents a methodology for processing FT-IR data that simplifies decision making on the extended shelf life of used engine oil. The presented methodology can be implemented as a planned maintenance step during scheduled service in the workshop and during regular inspections by fleet operators [38].

The cognitive mobility approach enables traditional drive developments, finer control, and more efficient utilisation. Developments like EGR control solutions or alternative fuels could support further diesel technology in areas where the current battery electric technology cannot offer real advantages. Research in the lubricant domain helps to decrease fuel consumption, i.e., overall energy demand.

3 Evaluation according to Cogmob's Basic Elements

Basic elements of cognitive mobility were first described with the following five dimensions [15]: triggering necessity, decision, tool/vehicle/quality, infrastructure/resources and human-machine interface. This chapter evaluates the five CogMob areas according to these five dimensions.

The "Cognitive connected vehicles" area involves nearly all the areas. Triggering the necessity of mobility is not a heavy aspect here, but the other four play a role with a centre of gravity in decision assistance and human-machine interfaces.

Safety and security of ITS-related cognitive systems affect the tool/vehicle/quality dimension as the safety and security demand higher complexity of the systems. It is closely connected with triggering necessity, as safety aspects could increase entry limits, thus postponing or even canceling mobility.

Cognitive aspects of orientation and navigation are heavily connected with decision and HMI, as they improve the environment perception capabilities.

Advanced electric vehicles and augmented conventional vehicle drives focus on the vehicle itself, but secondarily, they affect the resources through fuel economy and alternative energy sources.

Table 1

Evaluation of 2022 key areas according to Cogmob basic elements

	triggering necessity	decision	tool/vehicle/ quality	infrastructure/ resources	human-machine interface
cognitive connected vehicles		focal area	linked	linked	focal area
Safety and security of ITS-related cognitive systems	focal area		focal area		
cognitive aspects of orientation and navigation		focal area			focal area
advanced electric vehicles			focal area	linked	
augmented conventional vehicle drives			focal area	linked	

4 Statistical Evaluation

The aim of the statistical evaluation of the presented papers of Cogmob2022 was to understand deeper the interdependencies between the domains. The analysis was carried out with the WosViewer software. VOSviewer uses a similarity measure known as association strength [39, 40]. This similarity measure is sometimes referred to as the proximity index [41] or the probabilistic affinity index [42]. Using the association strength, the similarity s_{ij} is calculated between two words *i* and *j* as (1):

$$s_{i,j} = cij(wi, wj)^{-1} \quad (1)$$

where c_{ij} denotes the number of co-occurrences of items *i* and *j* and where w_i and w_j denote either the total number of occurrences of items *i* and *j* or the total number of co-occurrences of these items. It can be shown that the similarity between items *i* and *j* calculated using (1) is proportional to the ratio between, on the one hand, the observed number of co-occurrences of words *i* and *j* and, on the other hand, the expected number of co-occurrences of words *i* and *j* under the assumption that occurrences of items *i* and *j* are statistically independent.

The abstract analysis results are presented in Fig 1. It shows that energy sources, environmental effects, artificial intelligence, and ADAS elements are the primary nodes, and further peripheral areas are also linked.

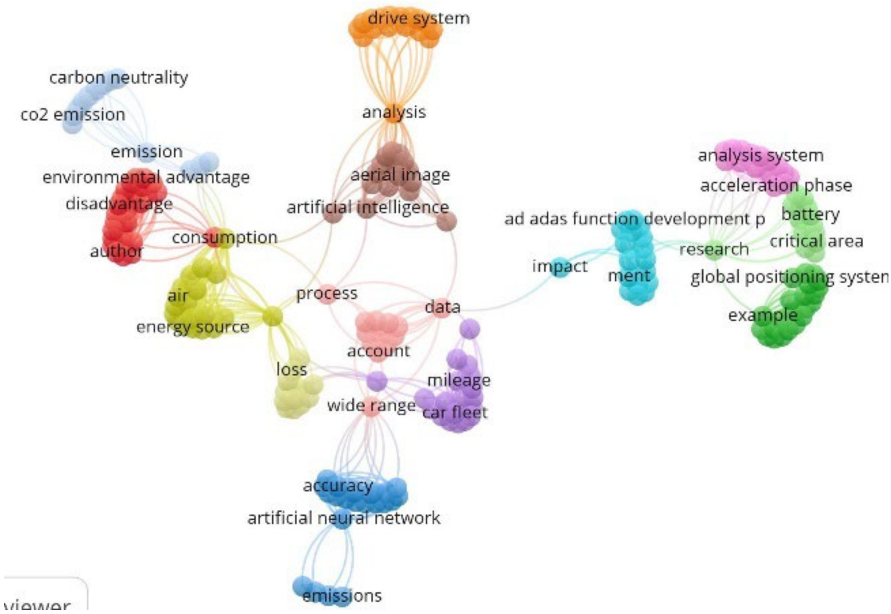

Figure 1
Analysis of the abstracts of CogMob2022

Keywords analysis is presented in Fig. 2. According to this ecological footprint, electric vehicles, electric mobility, NVH, and e-drives are the most important intersection points.

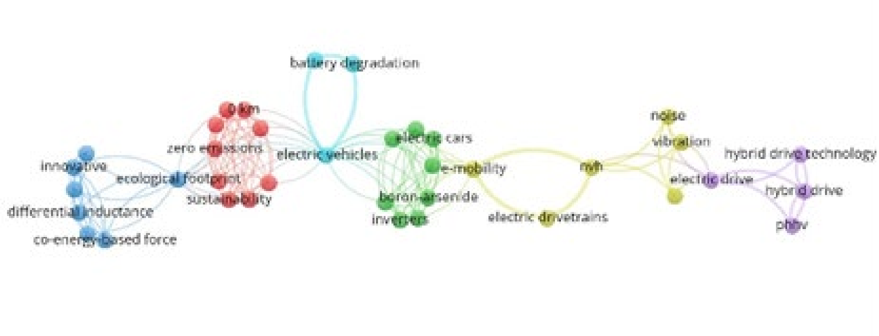

Figure 2

Analysis of the keywords of CogMob2022

If the two analysis results are compared, the outcomes are the following: sustainability aspects of mobility appear in both evaluations (environmental effects and ecological footprint). As this is one of the strongest driving force of mobility development nowadays, its shortage would have been unexpected. The elements of Fig 2. mainly could be incorporated into the energy sources node. The other nodes related to autonomous mobility do not appear within the keyword analysis's focal points.

Conclusions

Cognitive mobility is one of the emerging domains of the 21st Century. Analysing the themes, the following can be summarised: The topics of the papers cover five domains: connected cognitive vehicles, safety and security of ITS-related cognitive systems, cognitive aspects of orientation and navigation, advanced electric vehicles, and augmented conventional vehicle drives. Four elements of cognitive mobility are in the focal area, and the fifth is linked, as presented in Table 1. The similarity measure and proximity index-based evaluation of the abstracts and the keywords show that sustainability-related topics, energy sources, and their utilisation area are the most frequented. It is expected that it will be continued, and as a function of the military situation, the defence-related domain's role increase is expected.

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