Cluster-Based Vehicle Routing on Road Segments in Dematerialised Traffic Infrastructures

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ABSTRACT

The structure and composition of the worldwide mobility infrastructure is growing exponentially and urgently needs to reduce the emission of carbon dioxide gas, to decrease the growing of traffic jam, to limit the over-abundancy of traffic signs, and to improve the interoperability of traffic sign between different countries. First, this paper proposes a new mobility paradigm to organize in a global way the mobility based on three arising technology characteristics: high-performance computing efficiency, geo-positioning accuracy, and 5G technology. Second, the paper proposes a cluster-based approach for managing the mobility of (autonomous-)vehicles in the frame of that new paradigm and propose a set of usage scenarios. Finally, some basic tools are presented in order to implement the machine learning-based clustering step of the approach.

KEYWORDS

Autonomous Car, Dematerialised Traffic Infrastructure, Future Mobility Paradigm, Traffic Management, Vehicles Routing

1. INTRODUCTION

The current structure and composition of our worldwide transportation system is extending exponentially and is a source of costs for all actors involved in it, should it be for the state that builds and maintains the roads and the road signs, or for the vehicle owners who buy expensive cars equipped with a lot of sophisticated devices. In that ecosystem, there is an emergent and urgent need to reduce the emission of carbon dioxide gas, to decrease the growing of traffic jam (Aridor et al, 2000), to limit the over-abundance of traffic signs, and to improve the interoperability of traffic sign between different countries (e.g. Japanese signs are often not understandable for European people), etc.

Aside from the technology exploited for driving (road marking, road signs, traffic rules, GPS, etc.) in the Existing Mobility Paradigm (EMP), new technologies also arise and offer new opportunities for the forthcoming years. Three of them are especially worth considering as they consist of the three concepts that support the funding of our paper. The first one is the high performance computing (HPC) (Byrnes et al., 2016) that allows aggregating computing power to generate exponentially more powerful systems able to solve large equations using deep learning techniques. The second one is the resolution of the geo-positioning satellite, which is already around a few centimeters[1]. This second element is to put in parallel with the development of street maps related to the infrastructure such as

the one provided by Open Street Map (OSM) (Ly et al., 2015). Finally, the last arising technology is the 5G technology that allows a big and fast exchange of information over time (Mitra et al., 2015). All three technologies putted together constitute the pillars of a Future Mobility Paradigm (FMP), an arising new driving paradigm

This new paradigm aims at organizing the traffic based on a global coordination of the driving parameters with the ineluctable support of the three new technologies. FMP uses parameters including constraints associated to roads segment or to legislation, but also features associated to vehicles, to drivers, and to the context (like the weather or the time of the day). It has the ambition to leverage the protection of the environment and of the people, and in the meantime to reduce the cost associated with the movement of the goods and the people. Considering this new paradigm, we propose in this paper a traffic management algorithm based (1) on the clustering of vehicles having one or more common feature(s), (2) on computing the optimal and the global movement of the vehicles and (3) on automatically driving the cluster from a point A to a point B, potentially, without the intervention of human.

This paper suggests a new approach for the future of mobility. It is based on observations of the existing situation and technologies and on common sense. FMP has recently been proposed and the cluster based mobility disclosed in a patent (Feltus, 2018).

The paper is structured as such: first we present the expected Future Mobility Paradigm, then we propose a new cluster based model running in this new paradigm, thirdly, based on that model, we introduce a four-steps cluster based mobility deployment. Afterwards we give an example of usage of this deployment, we present the first steps toward the deployment of the new paradigm and we conclude the paper.

2. RELATED WORKS

In the Existing Mobility Paradigm, vehicles are driven by drivers - or automatically - based on the recognition of road signs by visualization systems (driver's eyes, embedded camera, lidar, sensors (Bimbraw, 2005), based on driving rules know by the driver or the autonomous car, and based on the constraints on the road (e.g. highway code, position of the others cars)). This existing infrastructure and the nowadays way of driving constitute the EMP. This paradigm has reached its limits (in terms of environmental, mobility, price) and there is now a demand to switch to a more integrated and performance paradigm.

In parallel to the technological constraints, the EMP must also face a set of existing or arising problems like the driver responsibility, the security of the information exploited by the driver or the autonomous vehicle and the privacy of the personal driver's personal data. Regarding the responsibility, one important issue concerns who is to be held responsible in case of an accident. This issue of defining the responsibility has already been largely discussed in the field of IT (C. Feltus, (2014)) and more epically in the domain of autonomous vehicles (Hevelkeet al. (2015), Awad et al. (2018)). The second problem concerns the management of the security of the information managed by the vehicle's system. Wyglinski et al. (2013) explains that embedded computing and sensor systems are increasingly becoming an integral part of today's infrastructure, more especially with respect to autonomous systems such as unmanned ground vehicles that introduces new forms of vulnerability into this critical infrastructure. Risk analysis methods have been elaborated to mitigate the existing risk in information systems like in Mayer et al. (2015) and Mayer et al. (2019).

3. FIGURING OUT THE FUTURE MOBILITY PARADIGM

Nowadays, traffic management is dispatched to drivers who pilot their vehicles based on their own wants and in agreement with the external environment: road signals, traffic rules, traffic lights, road space available (size of the roads, available parking places, …), the other driver's movements and behavior, the perception of the environment and the highway code. Those drivers are helped and make use of embedded devices in the vehicles such as the speedometer, the GPS, the external temperature,

some alert indicators like the temperature below zero, or like the motor oil level. Commonly, the existing way of driving vehicles may be structured around four elements: (i) the existing road lanes delimited by road signs like the white or yellow colors line on the road, (ii) the road signals like the traffic light, the do-not-enter signs, the one-way sign, the traffic signs, etc., (iii) the driving law which constraints the speed limit, the allowance to overtake other vehicles, to park on road-sides or not, etc. and (iv) the own car equipment and other cars equipment (e.g., stop lights, flashers or the GPS system). In parallel, this "self-organization" of the traffic is coordinated based on existing traffic rules and road signals, and some complementary solutions, which also allow reducing the traffic jam, like embedded applications that suggest alternative roads to drivers. With the growing number of vehicles on the road and with the environmental demand for less pollution, this model appears nowadays obsolete and demonstrates to have reached its limits.

The new FMP proposed consists in guiding the vehicles on the roads no more from decisions made insight the vehicle (by the drive like in traditional driving or by the computer in case of autonomous driving) but by decisions taken by a vast management unit (MU) that has for purpose to act globally even if being distributed amongst many devices. The management unit will progressively consider the driver expectations, the context, the existing environmental constraints, and the expectation of the surrounding vehicles. The FMP formally defines a vehicle as an object that has a position (and/or surface/segment with or without some orientation like driving from A to B or from B to A) on the infrastructure (it may be for example a car, a bus, a truck, a robot, a group of people or animals, a group of workers on the road, a construction site. This vehicle has an identifier which should persist during one cycle of the system. The management unit communicates with the vehicle to assign him a specific identifier and to modify it if necessary. This MU is a (un)centralized system in charge of managing the usage of the infrastructure (e.g. road administration, town administration, decentralized urban transport network, a team of actors gathered in a war-room…) using a dedicated tool/platform (e.g. for monitoring, traffic management, optimizing, alerting, ruling, reservation management, parking management, etc.) and mostly composed of experts.

In this context, the new technologies developments offer new fundamental opportunities to support the realization of this paradigm, amongst which (i) an accurate geolocation ability (i.e.: using satellite and geolocation apparats, it is possible to locate the vehicle on the road with an accuracy of few centimeters. Moreover, knowing the size of the vehicles (length, width, height), likewise it is possible to deduce the space occupied by the latter on the road). FMP is also based on the knowledge that we have of the infrastructure (i.e.: the size and geo position of the roads is known and modeled with an accuracy of a few decades of centimeters and this accuracy will still be improved in the forthcoming months. These models are freely available in geo map like open street maps). (ii) the high calculation ability is paramount and is now available to calculate millions of millions of operations by seconds, and to optimize the results of those operations (e.g. by using deep learning algorithms). And (iii), the arising communication ability like 5G or other networks allows to communicate instantaneously big volume of data amongst vehicles and the central system (send information and collecting information)

4. CLUSTER BASED MOBILITY MODEL

Considering the new technologies, we propose an innovative space management model to administrate and organize the movements of the vehicles on the road and in the context of the FMP. This model (figure 1) includes core elements in blue (namely A1, A2, A3 and A4), known information elements in white, and optional elements in orange. The four core elements are the concepts that further compose the space management algorithm explained in section 4, respectively:

4.1 Clusters Definition

Clusters of vehicles with the same characteristics are determined. Based on the vehicles' characteristics, the first core element of the model consists of all possible clusters of vehicles (using AND OR NOT relations) conceivable based on the vehicle's characteristics. These clusters are for instance clusters

of trucks, clusters of buses running to an event, clusters of green cars, clusters of vehicles with a speed limit of 10 mph.

4.2 Blocs of Vehicles Definition

All possible blocs of vehicles are defined based on all clusters of vehicles, the road infrastructure and priority rules. E.g. trucks of dangerous goods are aligned (not one next to the other), trucks to Brussels are gathered on a road segment that covers the whole width of the road, two-wheeled vehicles are put in a rectangular shape, a cluster of heavy vehicles may not be composed of more than five vehicles to cross a bridge because of the bridge stability. An optional element associated with this core element concerns the management of the position of the vehicles in the bloc. For example, big trucks are positioned just after small cars. This core element requires knowing information related to the characteristics of the infrastructure and of the vehicles.

4.3 Segments Association

Blocs of vehicles are associated to segments of the infrastructure based on priority rules and using algorithms. E.g.: trucks are aligned on a road segment between GPS coordinates xx-yy, car sharing is positioned in priority to "traditional car", and dangerous goods trucks are separated from scholar buses. This core element requires knowing characteristics of the vehicles, objectives of the system, contextual information, etc. It is achieved based on algorithms such as for instance the bin packing algorithm.

Figure 1. Space Management metamodel
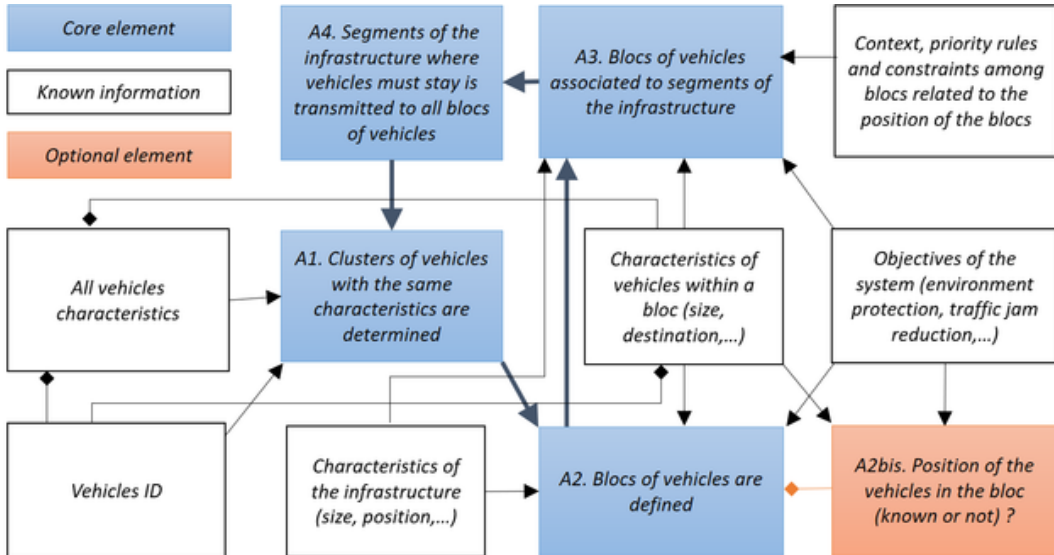
4.4 Information Transmission

Segments of infrastructure where blocks of vehicles must be are transmitted to each vehicle of the bloc, which have to move accordingly. This movement is done manually and instructions are displayed (e.g. using virtual reality, screen, smart phone, glasses,…) to the driver, or may be done automatically in the case of a vehicle without a driver.

5. CLUSTER BASED MOBILITY DEPLOYMENT

Based on the model explained in section 3, the four implementation steps are:

5.1 STEP 1. Collecting Information

Loading in memory information describing an initial allocation of vehicles engaged on the road segment. This information represents the position of the vehicles on the roads, including their allocations to groups of vehicles such as calculated in the previous allocation of vehicles to groups. It also comprises a set of features for each vehicle (type of energy used (electricity, fuel, gasoil,…), utility of the vehicles, shape of the vehicle, etc.), a set of features related to the driver and passengers (type of license of the driver, age of the driver, type of assurance, etc.), to information related to the context (weather forecast, local event, crash and emergency, official convoy, etc.). All of this data is collected from sensors on the road, from information platforms, from social media, from satellites, etc.)

5.2 STEP 2. Designing Clusters of Vehicles

Using data processing means, this step aims at populating the core element A1 of the SM metamodel by determining clusters of vehicles based on the collected information, wherein vehicles in the same cluster share at least one common feature. The system generates clusters of vehicles satisfying the rules (constraints, obligation, etc. for traffic safety, for traffic flow, for environmental concerns such as CO_2 emissions, etc.). These clusters can be defined using the vehicle ID, the characteristics associated with the vehicles, and the infrastructure characteristics.

For a MU that has to manage a large set of vehicles, a large set of rules and a big infrastructure (wide area), some speed-ups for computing that function are possible. One notable speed-up is using geographical/geometrical information found in vehicle characteristics, infrastructure characteristics and rules. Most of the rule applies on specific and limited areas (e.g. each instance of traffic light applies on a very limited area) and most of the vehicles have a position (and/or previous segment) at time t. So one can say that it may apply on different portions of the infrastructure, and in that case, for a determined portion of the infrastructure, the system knows the rules that apply in that portion, and in the sub-area and the area where the portion is located. The system could also extract a list of vehicle characteristics that occur in the rules and select only the rules that use those characteristics when defining the clusters.

The ruleset is supposed to be "preventive". The ruleset considers all possible cases, including rules to reach a safe stable state. The technology used for that purpose is e.g.: kmeans algorithm (Zahra et al., 2015), *Kohonen* maps (Singh et al., 2015), or elastic-net (You et al., 2016).
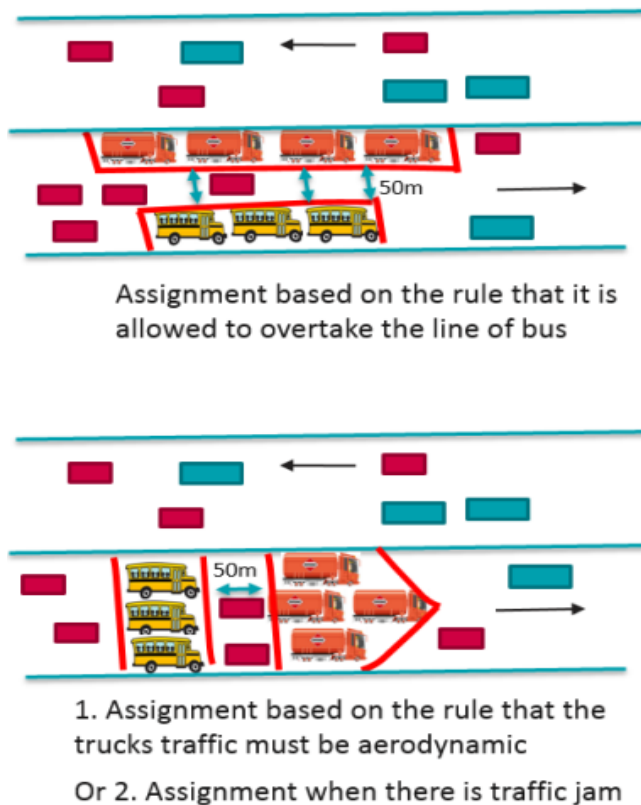
Figure 2. Creation of clusters of vehicles based on the vehicle's features, based on the context, based on the road segment concerned.
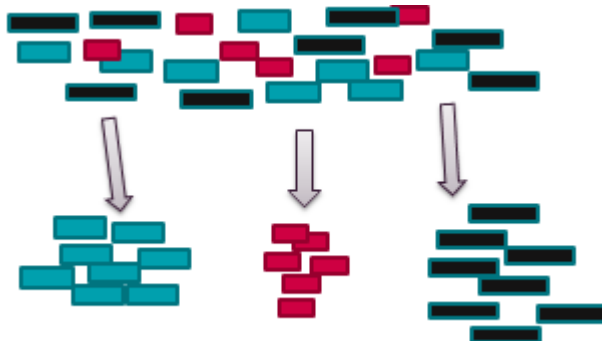
5.3 STEP 3. Associating the Cluster of Vehicles to Portion of the Road

After the clusters defined by the MU, the optimal allocation of each cluster to a shape on the road segment is calculated. Therefore, HPC systems are required to (i) associate at least one shape with each cluster of vehicles, wherein the shapes are chosen so that the aggregate surface of the shapes covers the aggregate surface occupied by all the vehicles of said cluster. This association corresponds to the population of the core element A2 described in figure 1. (ii) the shapes are allocated, including the vehicles associated with each shape, to portions of the road segment; wherein the shapes and the allocation are such that they satisfy a set of constraints, comprising the dimensions of said road segment. That corresponds to the population of the core element A3.

Figure 3. Association of clusters of vehicles to shapes on the road.

Assignment based on the rule that it is allowed to overtake the line of bus

1. Assignment based on the rule that the trucks traffic must be aerodynamic

Or 2. Assignment when there is traffic jam

To perform that step, the system uses as input a set of fixed and well-defined parameterized geometric shapes, of different sizes. With each cluster previously defined the system associates one or more geometric shapes with 0, 1 or more refinements of the parameter constraints. The shapes selected and the refinement depend on the characteristics of vehicles, the number of vehicles in the cluster, the geometry of the infrastructure, the context (type of traffic, weather,…) (e.g. environment protection, traffic jam reduction …). E.g. trucks are aligned, two-wheeled vehicles are put in a rectangular shape, a vehicle driven by a driver having already made one or more accidents is constrained to be

in a dedicated cluster, a vehicle driven by a driver with a special status (e.g. driving license type) is allowed to be in any cluster it wishes.

Each geometric shape associated to a cluster of vehicles is assigned to a segment of the infrastructure based on specific rules (e.g. trucks to Brussels are gathered on a road segment that covers the whole width of the road), based on priority rules, based on the others blocs, based on the context (e.g. state of the infrastructure no bloc may be associated to a flooded road, potholes,…), based on constraints among blocs. This is performed using algorithms (e.g. Bin packing algorithm (Delorme et al (2016))).

5.4 STEP 4. Transmit Position

Steps 1 to 3 happen instantaneously, based on the vehicles' positions. Step 4 corresponds to the population of the core element A4 and consists in exploiting the information first to simulate where the cluster defined aims to be in the future and/or secondly to force the vehicle to move to this position. E.g. truck clusters move from A to B, bus must park at reserved parking, trucks are on the right and cars on the left, a classical vehicle may become an emergency vehicle and change of cluster. This information is transmitted using 5G technology, using VANET (Pathan, 2016) technology, using RSU (Mehar et al., 2015) technology, etc.

6 EXAMPLE OF ADVANTAGES

Having described the cluster based mobility deployment in section 4, this section illustrates some advantages of this new paradigm and list a set of other advantages foresee.

## 6.1 Traffic Organized Based on the Real Traffic Needs

This advantage means that the system continuously looks for the most efficient schema for vehicles to circulate on the road considering the constraints explained earlier. For instance, in the morning, most of the vehicles travel from the home to workplaces although nearly nobody circulates from work to home (fig 4).

Figure 4. Example of traditional one way traffic jam
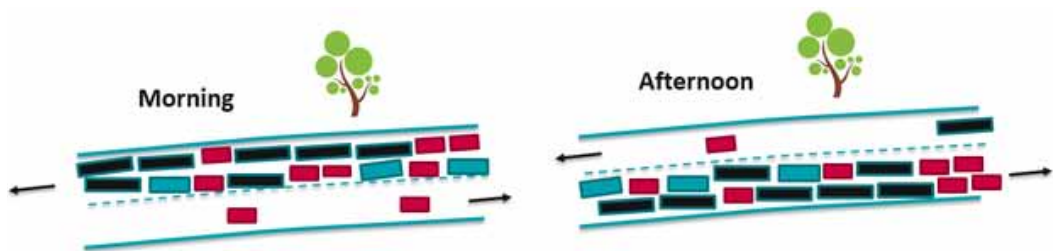
Considering driving with the new paradigm, the system is able to understand the necessity, in the morning, to allocate more space to clusters of vehicles traveling to work and the opposite in the evening (fig 5). This is an important advantage compared to the existing paradigm that cannot avoid traffic jam the morning to enter the city.
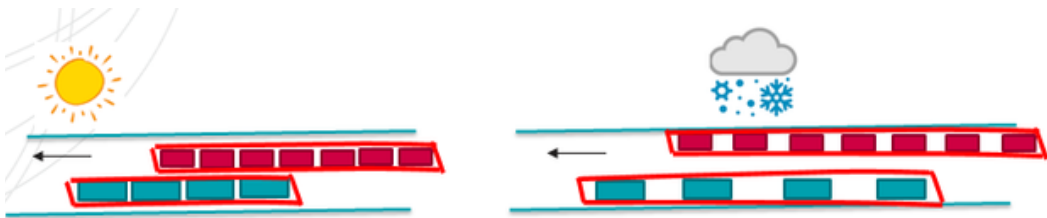
Figure 5. Example of different association of clusters of vehicles to shapes on the road based on the destination of the vehicles.
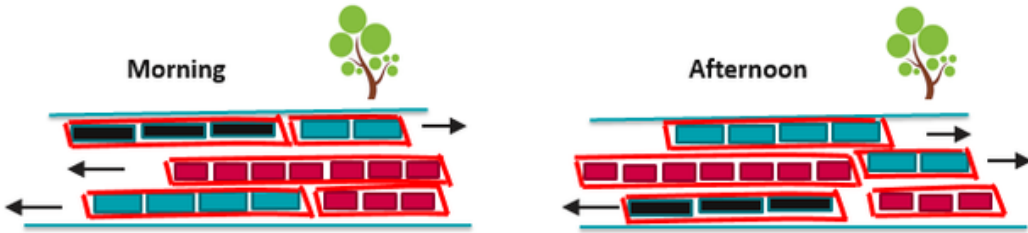
6.2 Traffic Organized in Function of the Weather

This advantage means that depending on the weather conditions, the system may decide to adopt a more secure circulation behavior in that it may decide, for instance, to allocate more space in between the vehicles in a cluster or amongst two clusters (fig 6). This would improve this linear adaptation of the space between vehicles could also potentially be enriched with a reduction of the vehicle's speeds.

Figure 6. Example of different association of cluster of vehicles to shapes on the road based on the real-time weather
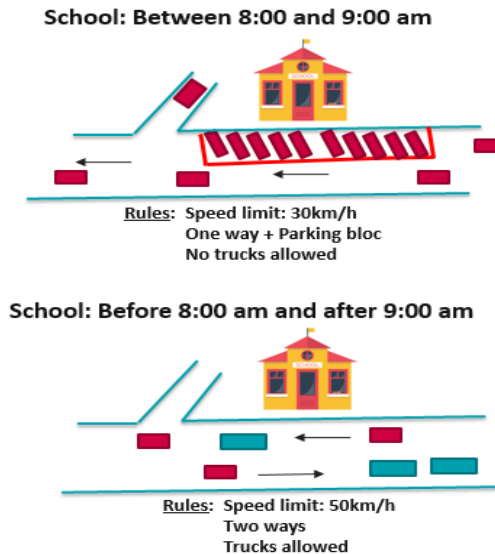

6.3 Traffic Organized in Function of the Time

Around a school, the traffic is limited to one lane with many parking places in the morning during 8:00 and 9:00 PM and shifts in two lanes the rest of the time. Moreover, it is possible to consider that only cars are allowed and that some space is allocated to parking space (fig 7).

Figure 7. Example of different association of cluster of vehicles to shapes on the road based on time of the day

Traffic organized in function of the time potentially generates new identity and privacy issues. Solutions exist for dealing with the passenger identity and for provisioning him with the appropriate access right (Gateau et al. (2008)) and for the granting personal driver data privacy (Feltus et al. (2017))

## 6.4 Other Examples of Clusters-based Mobility in the SMP

Other examples of clusters-based mobility in the SMP are:

- Payment of assurance premium based on the type of cluster the user has optionally willing to be associated with. For instance, if a driver wishes to go as fast as possible from point A to point B, the system will allocate him to a cluster that goes fast. Consequently, in this case, the insurance company may use this information to charge the driver with an expensive rate. On the other hand, the driver is willing to have very secure behavior and to go slowly from A to B will have a low assurance rate. In the same vein, the characteristics of an assurance taken by a driver (e.g. Omnium,…) could be considered as a vehicle's feature and the latter could be used as a parameter for the elaboration of the clusters of vehicles by the system.
- Mobility without road signs (e.g. drawing of the lanes on the road or pedestrian crossing). Being independent of road signs means less driving risk in case of the hidden signals (e.g. by the rain or by the snow) and hence, a better safety for the drivers and the pedestrians.
- Having the road information centralized and being dispatched to the driver within the vehicle allows avoiding semantic issues related to the understanding signal. For instance, a European driver could easily drive in the center of Tokyo without worrying about the meaning of the road signs (which are obviously different from eastern countries).
- Provided that the road space is managed by a central authority, it is foreseeable to reserve access on specific road space. For instance it is possible, by means of dedicated interfaces (like a web platform, a dedicated device or a smartphone) to book a specific static space on the road for instance, to park a car or to maintain the road, or to book dynamic space to have a guarantee of better road traffic for a special purpose (like for instance de reservation of a dynamic space for the emergency vehicles).

7. DEPLOYMENT AND DISCUSSION

The deployment of the new paradigm requires a plethora of technologies including those associated with HPS, 5G and geo-positioning. It also requires a dedicated infrastructure including connected vehicles, millions of probes and sensors, computing capabilities, access to satellites, etc. In this context, deploying a fully complete and integrated infrastructure is utopian at the time being. However, in order to illustrate the feasibility of the new paradigm, some initial analyses have been conducted in order to demonstrate the achievability of section IV. An example of the analysis concerns the clustering of vehicle on a road segment based on three vehicle's features: the position of the vehicle on the road, the type and priority associated to those vehicles (i.e. car, school bus, truck, green car and emergency vehicle), and their expected speed (ranging from 40 to 90 mph). Based on these features, a set of 30 vehicles has been randomly generated and positioned on the road like illustrated on fig. 8

Figure 8. Position of the vehicles on the road based on the vehicle's features (icon's color corresponding to vehicle type).
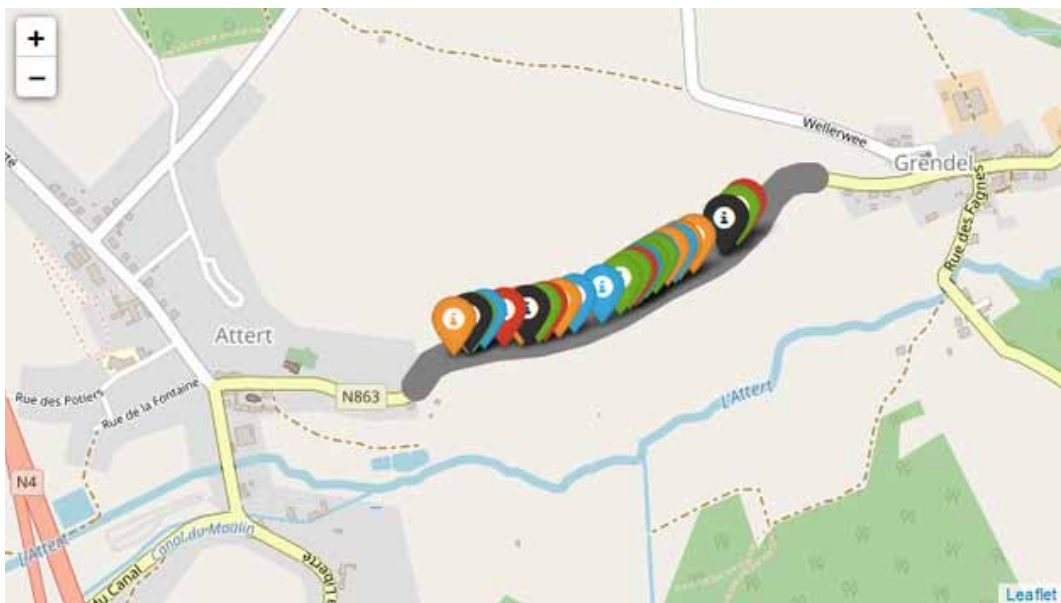
The set of clusters being generated, the second step consisted in grouping the vehicles on the road according to these features. Therefore, we used SKLearn Library (https://scikit-learn.org/stable/) and Python 3.7. Scikit-learn is a machine learning simple and efficient tool for data mining and data analysis, accessible to everybody, and reusable in various contexts. Using this library, we achieved unsupervised learning. More especially, we achieve clustering of the vehicles using the KMeans algorithm that has purpose to cluster data by trying to separate samples in n groups of equal variance, minimizing a criterion known as the inertia or within-cluster sum-of-squares. Kmeans requires the number of clusters to be specified. Accordingly, in our case, we decide to split the vehicles in three clusters.

Figure 9. Position of the vehicles on the road based on the vehicle's features.

The result of applying the Kmeans algorithm was the definition of three clusters: cluster 1 (position 52.2 miles from start, speed 56.2 mph), cluster 2 (52.9 miles, 71.2 mph) and cluster 3 (93.1 miles, 60.9 mph). It demonstrates the feasibility of the clustering approach (Step 1 of the paradigm).

8. CONCLUSION AND FUTURE WORKS

The position paper presents the expected new mobility paradigm to organize the mobility based on three arising technology' characteristics, to know: high-performance computing efficiency (Byrne et al., 2016), geo-positioning accuracy (Ly et al., 2015) and 5G technology (Mitra et al., 2015). In the frame of that new paradigm a cluster based approach for managing the mobility of (autonomous-) vehicles and a set of usage scenarios have been proposed for illustration.

By relying on that approach, the importance for a static road-signaling infrastructure is lessened, and static signaling may even be rendered obsolete. The allocation of vehicles inherently accounts for all constraints that should be respected at the time of computation, including vehicle features, road infrastructure constraints, and traffic rules. By clustering vehicles having common features together, macroscopic traffic features become usable by the proposed algorithm, which are difficult to take into account using known systems. As the allocation provides a distribution of vehicles on a road segment that takes into account common features of vehicles and/or their users, such as for example common destinations, the fluidity of the traffic is generally improved, and congestions are avoided, as less lane changes will be required by the vehicles in order to get to their destination. Moreover, the constraints and rules may change in time or per policy, resulting in a different traffic routing pattern, while relying on the same underlying computation method. For example, the method may be used to route vehicles so as to minimize the time spent on the road, to minimize the CO_2 emissions, to minimize the size of the infrastructure used, or to minimize the cost of the moving.

The existing driving paradigm is based on old technologies and old systems supported by big companies that keep this paradigm "alive" to make profits. However, new technologies exist and are ready to support the shift from a material-based driving toward a space-management based driving approach. Moreover, ecological concerns keep growing and are in favor of material reduction.

As future works, we foresee to develop and to test additional and complementary modules. More especially, we are analyzing and developing new tools to determine dynamic shapes associated with the road segments and the corresponding tool to automatically dispatch the clusters to the optimal shapes on the road. Moreover, the new FMP proposed constitutes an innovative domain model to be fully protected. Accordingly, one approach therefore could consist in considering the new FMP as a specific architecture model to be protected as explained in Feltus et al. (2012), Grandry et al. (2013) and Band et al. (2015). This work requires a new domain model transformation as explained in Rhazali et al. (2015) and Rhazali et al. (2016).

FUNDING AGENCY

REFERENCES

Aridor, , & Hannan, L. A. (2000). Traffic jam: A compendium of human diseases that affect intracellular transport processes. *Traffic (Copenhagen, Denmark)*, *1*(11), 836–851. doi:10.1034/j.1600-0854.2000.011104.x PMID:11208074

Awad, E., & Levline, S. (2018). *Blaming humans in autonomous vehicle accidents: Shared responsibility across levels of automation*. arXiv preprint arXiv:1803.07170.

Band, I., Engelsman, W., Feltus, C., Paredes, S. G., & Diligens, D. (2015). *Modeling enterprise risk management and security with the archimate*. Language, The Open Group.

Bimbraw, K. (2015). Autonomous cars: Past, present and future a review of the developments in the last century, the present scenario and the expected future of autonomous vehicle technology. In *ICINCO, 12th International Conference on* (Vol. 1, pp. 191-198). IEEE.

Byrne, G., Ahearne, E., Cotterell, M., Mullany, B., O'Donnell, G. E., & Sammler, F. (2016). High Performance Cutting (HPC) in the New Era of Digital Manufacturing–A Roadmap. *Procedia CIRP*, *46*, 1–6. doi:10.1016/j.procir.2016.05.038

Delorme, M., Iori, M., & Martello, S. (2016). Bin packing and cutting stock problems: Mathematical models and exact algorithms. *European Journal of Operational Research*, *255*(1), 1–20.

Feltus, C. (2014). *Aligning access rights to governance needs with the responsability MetaModel (ReMMo) in the frame of enterprise architecture. Prom*, Petit, Michaël.

Feltus, C. (2018). Method and System for Vehicles Routing on Road Segment. Office for Intellectual Property (OPI), reference LU101055.

Feltus, C., Dubois, E., Proper, E., & Band, I. (2012, October). Enhancing the ArchiMate® standard with a responsibility modeling language for access rights management. In *Proceedings of the Fifth International Conference on Security of Information and Networks* (pp. 12-19). ACM.

Feltus, C., Grandry, E., Kupper, T., & Colin, J. N. (2017). Model-driven Approach for Privacy Management in Business Ecosystem. In MODELSWARD (pp. 392-400). Academic Press.

Gateau, B., Feltus, C., Aubert, J., & Incoul, C. (2008, June). An agent-based framework for identity management: The unsuspected relation with ISO/IEC 15504. In *2008 Second International Conference on Research Challenges in Information Science* (pp. 35-44). IEEE.

Grandry, E., Feltus, C., & Dubois, D. (2013, September). Conceptual integration of enterprise architecture management and security risk management. In *2013 17th IEEE International Enterprise Distributed Object Computing Conference Workshops* (pp. 114-123). IEEE.

Hevelke, A., & Nida-Rümelin, J. (2015). Responsibility for crashes of autonomous vehicles: An ethical analysis. *Science and Engineering Ethics*, *21*(3), 619–630.

Li, X., Ge, M., Dai, X., Ren, X., Fritsche, M., Wickert, J., & Schuh, H. (2015). Accuracy and reliability of multi-GNSS real-time precise positioning: GPS, GLONASS, BeiDou, and Galileo. *Journal of Geodesy*, *89*(6), 607–635. doi:10.1007/s00190-015-0802-8

Mayer, N., Aubert, J., Grandry, E., Feltus, C., Goettelmann, E., & Wieringa, R. (2019). An integrated conceptual model for information system security risk management supported by enterprise architecture management. *Software & Systems Modeling*, *18*(3), 2285–2312.

Mayer, N., Grandry, E., & Feltus, C. (2015, June). Towards the ENTRI framework: security risk management enhanced by the use of enterprise architectures. In *International Conference on Advanced Information Systems Engineering* (pp. 459-469). Springer.

Mehar, S., Senouci, S. M., Kies, A., & Zoulikha, M. M. (2015). An optimized roadside units (rsu) placement for delay-sensitive applications in vehicular networks. In *Consumer Communications and Networking Conference (CCNC)* (pp. 121-127). IEEE.

Mitra, R. N., & Agrawal, D. P. (2015). 5G mobile technology: A survey. *ICT Express*, *1*(3), 132–137. doi:10.1016/j.icte.2016.01.003

Pathan, A. S. K. (2016). *Security of self-organizing networks: MANET, WSN, WMN, VANET*. CRC Press.

Rhazali, Y., Hadi, Y., & Mouloudi, A. (2015). A methodology for transforming CIM to PIM through UML: From business view to information system view. *Third World Conference on Complex Systems (WCCS)*, 1-6.

Rhazali, Y., Hadi, Y., & Mouloudi, A. (2016). Model Transformation with ATL into MDA from CIM to PIM Structured through MVC. *Procedia Computer Science*, *83*, 1096–1101.

Singh, N., Javeed, A., Chhabra, S., & Kumar, P. (2015). Missing value imputation with unsupervised kohonen self organizing map. In *Emerging Research in Computing, Information, Communication and Applications* (pp. 61–76). Springer.

Wyglinski, A. M., Huang, X., Padir, T., Lai, L., Eisenbarth, T. R., & Venkatasubramanian, K. (2013). Security of autonomous systems employing embedded computing and sensors. *IEEE Micro*, *33*(1), 80–86.

You, C., Li, C. G., Robinson, D. P., & Vidal, R. (2016), Oracle based active set algorithm for scalable elastic net subspace clustering. In *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition* (pp. 3928-3937). IEEE.

Zahra, S., Ghazanfar, M. A., Khalid, A., Azam, M. A., Naeem, U., & Prugel-Bennett, A. (2015). A. Novel centroid selection approaches for KMeans-clustering based recommender systems. *Information Sciences*, *320*, 156–189.

ENDNOTE

[1]   https://en.wikipedia.org/wiki/Galileo_(satellite_navigation)

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