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Intelligent vehicles: integration and issues

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Résumé

Afin de construire des véhicules intelligents, scientifiques et constructeurs automobiles intègrent progressivement de nouveaux outils libérant les véhicules de l'action humaine. Cependant, à quel moment peut-on considérer un véhicule comme intelligent ? Dans cet article, nous parlons tout d'abord du fossé entre les domaines de la robotique et de l'intelligence artificielle (IA), l'IA étant le principalement utilisé comme boite à outils bas niveau. Finalement, nous détaillons quelques implémentations de l'équipe Rits pour concevoir une perception intelligente grâce à l'ajout d'un niveau de supervision, la gestion des incertitudes, l'utilisation des communications, ainsi que la gestion des ressources.

Mots Clef

Vehicule intelligent, supervision, incertitude, communication

Abstract

In the process of building more and more intelligent vehicles, scientists and car makers are progressively integrating new tools that make the vehicle more independent from human action. However, when can a vehicle be considered as intelligent? In this paper, we first point out the necessity of robotics and artificial intelligence (AI) to collaborate. Indeed, AI is mainly used as a tool in robotics for different tasks such as perception and control. Thus, we show the lack of a supervision level in current vehicles. Finally, we provide some implementations from Rits going towards more intelligent perception by adding a supervision level, dealing with the uncertainties, using communications and managing the resources.

Keywords

Intelligent vehicle, supervision, uncertainty, communication

1 Introduction

The concept of intelligent vehicle is delicate to define. If the first automated vehicles were created at the end of the 90's, then the denomination of 'intelligent vehicle' was first proposed in the 2000's and is legitimately subject to debate. At which moment, can be qualified an automate as an intelligent entity? Since the concept of cybercars [1], first vehicles designed as automated, to the emergence of a new on-demand automated transportation system (see the citymobil project [2]), including recent works and integration of fully automated driving on classical vehicles [3], the project team Rits (Robotics & Intelligent Transportation System), previously known as Imara, delivers in this article its thoughts about the goal and issues of perception to lead to real intelligent vehicles, pointing out the necessity for robotics and Artificial Intelligence (AI) to work together . Robotics is the science of perceiving and manipulating the physical world through computer-controlled mechanical devices [4]. On the other hand, is relevant to AI any computer program which would be said "intelligent" if the same observed behavior would be so qualified when performed by a human. This wording leads to the imitation game, or Turing test, in which a human has to determine to whom it communicates with through a computer interface: a machine or a human [5]. Stated as above, there seems to be a wide gap between the two scientific domains, except if we talk about *intelligent robots*, i.e., robots on one hand which would exhibit an intelligent behavior on the other hand. To push the idea to its extreme point, a test similar to the Turing's one could be defined for such intelligent robots: a human tester spends one hour with another human and one hour with an intelligent robot, in any order of appearance; And the human tester then has to determine who was the robot and who was the human. If he fails, then the robot is said to be intelligent. How far are we from this dream? To state on this question, the article is structured as follows: Sec. 2 analyses the relationship between AI and robotics. Sec. 3 describes our vision, whereas Sec. 4 illustrates it regarding concrete implementation of such ideas. Sec. 5 concludes and draws future perspectives.

2 AI as perceived from Robotics

The introduction of one of the most widely known textbooks on Robotics [4] starts this way: *"Robotics is the science of perceiving and manipulating the physical world through computer-controlled mechanical devices. Examples of successful robotic systems include mobile platforms for planetary exploration, robotics arms in assembly lines, cars that travel autonomously on highways, actuated arms that assist surgeons. Robotics systems have in common that they are situated in the physical world, perceive their environments through sensors, and manipulate their environment through things that move."* (excerpt from [4], page 3).

In planetary exploration, the environment is static and until now, there is no interaction with intelligent agents. Concerning industrial robots, they have a limited number of degrees of freedom and the environment is closed and designed to be safe. For lane keeping system, the problem is limited to lateral and longitudinal control, which is, even though complicated, really far away from what is called "autonomous driving". And finally, for assisted surgery, the robot is entirely controlled by humans: the robot does not take any decision. From these examples, it comes that this kind of robots are not confronted with changing environment and unpredictable intelligent agents: this is not the real world. It is a sub-part of what is called robotics, which has to deal with limited resources in term of energy, computational capacity, but, which cannot be considered as intelligent.

What do we call an intelligent robot? As any intelligent entity, its ultimate goal should be to ensure its survival in its environment. Developing this idea, an intelligent robot should be able to ensure its energy independence (know how to refill its energy resources). Then, it should be able to diagnose its own state and to evaluate its perception abilities (what can it do, what can't it do?). Towards survival, according to a mission (exploration, aid to individuals, *etc*), an intelligent robot should be able to react properly to an unknown/abnormal situation. Finally, it should be able to learn from experience. This list of goals is closed in spirit to classical models in Psychology, such as [6]: a pyramid of needs is proposed for explaining the behavior of humans along the following dimensions: physiological (most urgent), safety, affiliation, achievement and learning (least urgent). All this suggests that Robotics needs AI at a high level — such an intelligent robot would pass the extended Turing test (see Introduction section) on the long term.

Unfortunately, AI is often only considered as a library of algorithms, in which Robotics researchers dig as necessary when their algorithms are not good enough for the tasks they plan to do. Many examples can be exhibited that follow this idea: The A* algorithm is a very good illustration of such an idea.

3 Our vision

From the proposed definition of an intelligent robot (Sec. 2), the most advanced work in progress for intelligent robots seems to be for autonomous driving, *i.e.*, intelligent terrestrial vehicles in the ITS scientific domain due to the necessity to face the real world. An autonomous car is a very complex robot (Fig. 2) driving in a urban jungle. It is equipped with many sensors: Proprioceptive sensors (acceloremeter, gyrometer, odometers, *etc.*) provide information about the vehicle itself such as its velocity or lateral acceleration. On the other hand, exteroceptive sensors, such as video camera, laser or GPS devices, provide information about the environment surrounding the vehicle or its location. In addition, intelligent vehicles are connected to the other vehicles as well as with the infrastructure through communication: V2V (vehicle to vehicle), V2I (vehicle to infrastructure) and even Vehicle to Pedestrian. Additionally, even though really specific to driving applications, for legal reasons, it has to take into account the human will into the decision loop and to interact with the driver.

Perception tasks can be defined as the situation assessment in the area of interest of the vehicle regarding four hierarchical layers (Fig. 1). First, the geometry of the road must be calculated, this includes the lane estimation problem and the intersection detection. In the infrastructure layer, relevant elements of the infrastructure such as buildings or guard rails must be detected. The traffic layer is related to the obstacle detection and tracking, whereas the priority rules consists in estimating the element of highway code (road sign units, traffic lights,*etc.*).

At each robotic level, AI techniques are used if it is not too time consuming for the limited robot resources. For example, Li *et al.* import genetic algorithms (a whole subfield of AI) for merging maps [7]: given one grid map of some environment, how to translate/rotate a second grid map so as to maximize the number of pixels that match between these two maps?

Robotics researchers import AI algorithms when needed by their current application. AI is considered as a library of algorithms into which Robotics researchers dig to improve one element of the behavior of their robotic it is not too time consuming. But our point is clearly to say that this way to use I.A. inside intelligent vehicles is limited. A

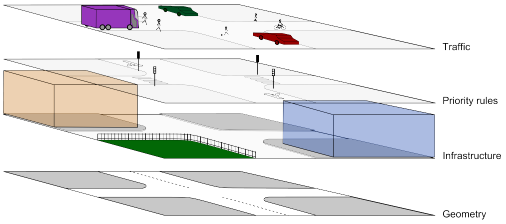

Figure 1: Situation assessment with 4 hierarchical layers

supervision layer is necessary to allow the system to adapt its algorithm to the context (see Fig. 1).

This missing supervision layer is provided by the notion of software architecture of a robotic agent. We define a software architecture as a structure to organize the various algorithms inside a robotic agent. It should encompass very fast loops at the perception module or the control module, and potentially slow (eventually very slow) reasoning algorithms.

An other major issue is now to accept that the robot must take decision according to a level of uncertainty.

4 Implementation

4.1 Supervision through Software Architectures: a unified framework

Through these examples, it appears that AI techniques can be relevant to solve low level robotics problem concerning one element of the perception, planning or control loop.

However, our claim is that AI techniques can/must be used at a higher level, which is called "Supervision" (see Fig. 2) in order to bring intelligence into the decision process. For example, reaching a full autonomous driving mode in all situations seems difficult in practice due to weather conditions and sensor limitations for instance. To guaranty safety, it is absolutely needed to assess what the vehicle ”knows” and to adapt the driving behavior to the perception uncertainties. An autonomous car, in addition to perceiving its environment, should also self-assess its own perception abilities, in order to give the control partially back to the driver or to stop if safety is not guaranteed due to sensor/condition limitations. In [8], two ontologies are used: one to represent the automation spectrum and the other to define situation assessment. Then, inference rules are used (integrating the uncertainty on the considered situation element estimation) in order to determine the maximum automation level allowed by the system abilities. This symbolic reasoning aims at what we call "intelligence" or a behavior which will allow the robot to better survive in its environment.

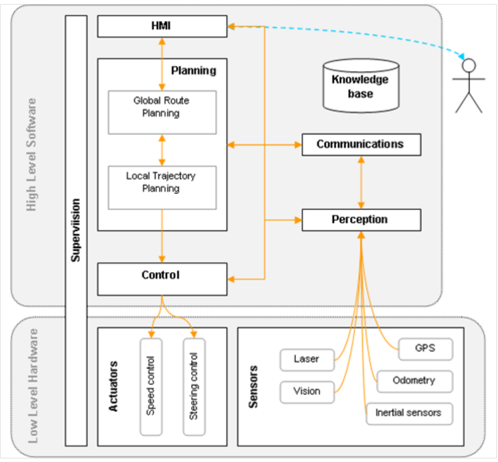

Figure 2: Automation loop for ITS

In the robotics subdomain of ITS, Pollard et al. propose an intermediate approach towards full autonomy based on control layers, and self-assessment of the sensor states, both being based on dedicated ontologies [8]. This way, every algorithm running on an automated vehicle can be described by a concept of such ontology, and reasoning over these concepts can take place (through SWRL inference rules, in this example) — a minimal reasoning encoding supervision is hence represented with a minimal computation cost.

4.2 Dealing with uncertainty

The second main issue leading to intelligent vehicles is the way to deal with uncertainty. In an ideal world with infinite computational resources, the entire world could be modeled with uncertainty. However, this is not possible and crucial choices must be done concerning the knowledge representation and random variables that are used. Concerning the knowledge representation, several options are offered, from classical probabilities [4] to more time consuming ones such as Dempster-Shafer representation or Transferable Belief Model (TBM), which allows to deal with unknown and conflicted situations, and also to manage sensor reliability.

To assure a proper uncertainty representation with a calibrated resource consumption, aiming at unifying perception algorithms in a same framework is assumed necessary. Such a perception system would indeed enables a quick overlook on lacks of information and could guide a supervision module on regions which need thinner resolution or require a special focus.

As a small step in this direction, [9] proposes to track both pose and status of a traffic light in the same process. The proposed algorithm then enable a complete support to fully describe a traffic light state and help the decision.

A step further, Trehard *et al.* [10] push the idea of using TBM to unify navigation and mobile object detection in the same representation. Their solution takes the most of TBM framework to build a surrounding map of the vehicle and model its occupant in the same process.

Even with a proper uncertainty representation, unknown correlations between sources can give inconsistent results. In the context of intelligent vehicles, it is a major problem as various information are available (ego-localization, detection of moving objects...). In [11], the authors propose an architecture based on the Split Covariance Intersection Filter-Information Matrix Filter (SCIF-IMF) to combine properly data from multiple sensors. For localization tasks, the authors of [12] introduce a drift model, coupled with a dedicated architecture, which can prevent the inconsistency of the Extended Kalman Filter (EKF).

Robotics aims at dealing with uncertainty data to take the best decision as possible (even it is not always used in practice). As opposed to AI, which often assumes that things are known, *i.e.* reasons at a symbolic level.

4.3 Increase the perception using communication

Vehicle perception is limited to the sensors and the computational power available. When local perception is not enough, an intelligent vehicle should be able to act accordingly. One solution that has emerged over the last few years is the use of communications. Wireless data exchange, using the 802.11p standard, opens up new possibilities regarding perception.

Vehicle To Infrastructure (V2I) or Vehicle To Vehicle (V2V) communications provide a new mean to foresee otherwise undetectable situations. For instance, an obstacle is detected by one vehicle and the information is communicated to others which can then adapt their speed and reach a consensus on which vehicle should first avoid the obstacle. Using communications for perception, Li *et al.* propose a solution to see-through vehicles by sharing images [13]. Vehicles detected in the image can thus be replaced by what is seen from them and is therefore detecting locally invisible pedestrians crossing the road.

This extended perception also involves to be cautious about how data are fused. Bresson *et al.* in [14] propose a multi-vehicle localization framework in which data incest is avoided. In this article, the authors show that it is possible to take advantage of maps which are currently being built by other vehicles in order to localize each other more accurately.

4.4 Limit the combination explosion

A robot has limited resources in term of calculation power and internal memory. It has to ensure that these limitations will not make crash the whole system. This is a particularly true for our SLAM (Simultaneous Localization And Mapping) implementation, based on a stretching compacted grid map. This idea follows the same principle as mip-mapping in video games. We load in memory only the local neighbourhood map slots, when we conserve the rest of the map on the hard disc. In addition we use a coding technique to compact and save the old or non-used far slots (one slot cover a 800x800 m^2 saved on about 100kb). This new implementation is dedicated to "open" outdoor environments.

5 Conclusion and perspectives

What we present in this article is unfortunately not yet a unified solution to solve the problem of bringing intelligence into a vehicle. However, it tries to highlight the efforts made in the RITS-Inria team to make progress towards a unified solution. These efforts are articulated around four axes: the need to bring intelligence into a supervisor able to manage resources and to self-assess the state of the automate, the way to deal with uncertainty, the necessity to collect missing data using communication if necessary and finally, the confrontation to real implementations which implies a real worry about the way to deal with calculation power and internal memory.

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