

Introduction

Safe and accurate coordination of multi-robots systems is a field of research of high effervescence. Indeed, this kind of system of large potentialities makes possible to carry out for example tasks which are unfeasible for only one robot or improve certain criteria related to the velocity, the robustness or the flexibility of task to achieve. The applicative focus of the proposed PhD thesis corresponds to the field of **autonomous public transportation**.

In recent years, the development of fully autonomous vehicles for transportation tasks has received even more attention from different laboratories/companies through the world[1][2]. The focus of the proposed PhD subject is passengers' transportation in midtown(e.g., to cross an intersection) or in closed/dedicated areas. **Multi-vehicle navigation and coordination** is a complex task and **need very precise design and management of vehicle interaction**. The main scientific challenges related to this PhD subject deals with cooperative autonomous vehicles management and navigation in complex environments/situations(mainly in terms of cooperative scheduling, planning and control).

Safe, efficient and flexible coordination of a group of autonomous vehicles in dynamical environments requires taking into account both inter-connected aspects: high-level and low-level. The PhD thesis will elaborate on the architecture of control/management with the **modular** and **bottom-up** manner like Brooks[3]. Multi-vehicle system(MVS) are controlled either while adopting a centralized approach or while using a distributed approach that only uses local information of the environment. The works of this PhD thesis will obtain optimal or sub-optimal balance between centralized and distributed functionalities in order to enhance the overall efficiency of the MVS based on Hierarchical control structure mentioned above.

Methodology Adopted

The main research content of the doctoral thesis in the first year is to give a hybrid multi-controller architecture for the management/control of a group of vehicles(i.e., Multi-vehicle system, MVS) in constrained and dynamical environment.

A. Robust and Generic Hybrid Multi-Controller Architecture (MCA)

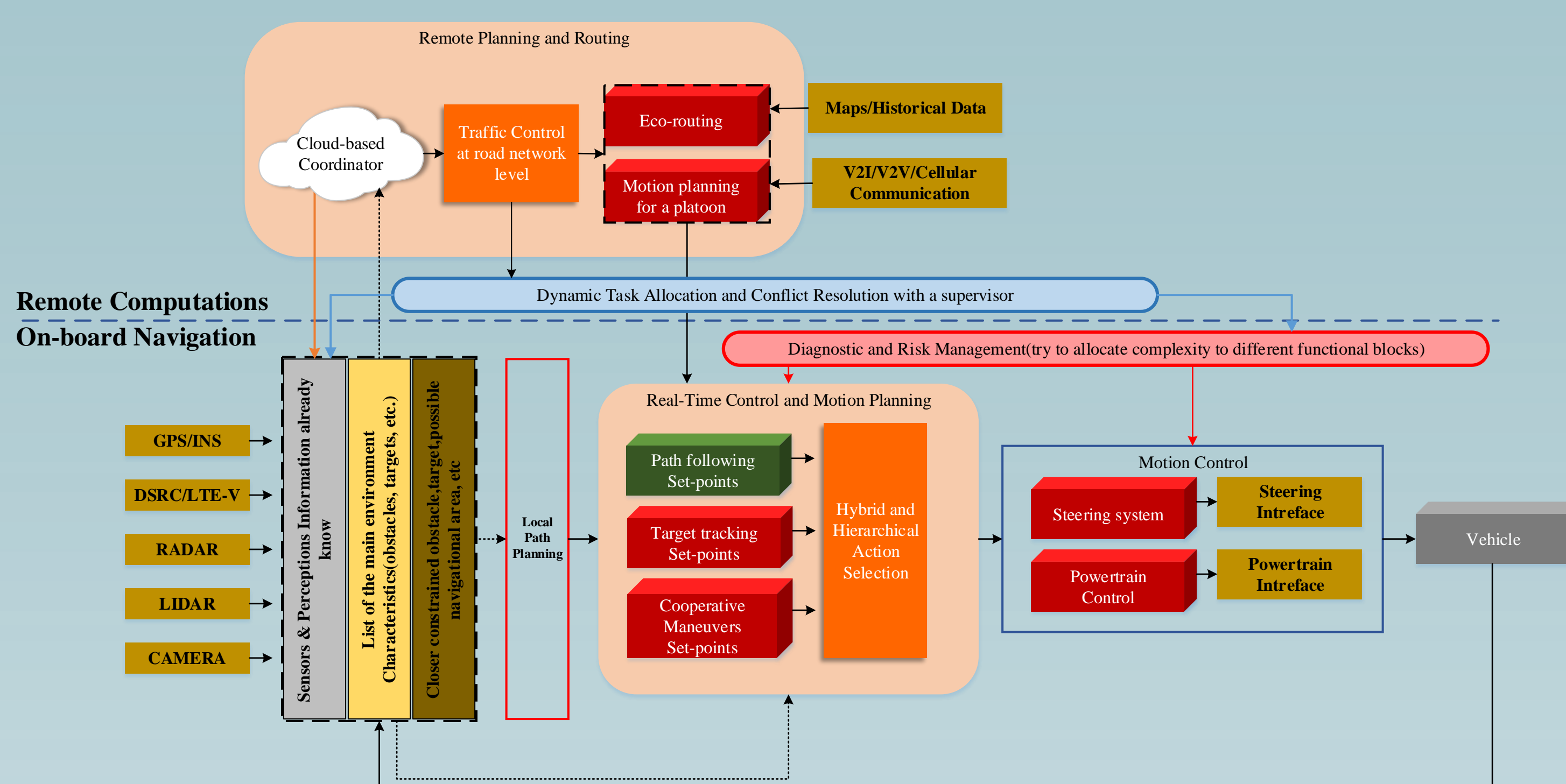


Figure 1. Examples of multi-controller architecture which could be used to manage with reliable way the coordination of autonomous multi-vehicle systems

As show in Figure. 1, a successful multi-vehicle system(MVS) in an intelligent transportation system depends both on the on-board instrumentation and on the surrounding environment, i.e. the road infrastructure and the cloud infrastructure which could supply to MVS static and dynamic road maps. Historical databases, and remote computational power.

B. Cooperative multi-vehicle navigation

The challenge consists of guaranteeing the stability and the safety of the MVS at the critic time of the **transitions between shape configurations**. This will make possible to change online the spatio-temporal configuration of the MVS according to the context of navigation. The developed concepts should be enough generic in order to be applied for **complex intersection/roundabout navigation**.

Results of Optimization-based Coordination of MVS

In the first doctoral year, the optimization problems involve MVS of variable size and these applications are at the border of traffic control(road network level).

- A pictorial classification of these applications is given

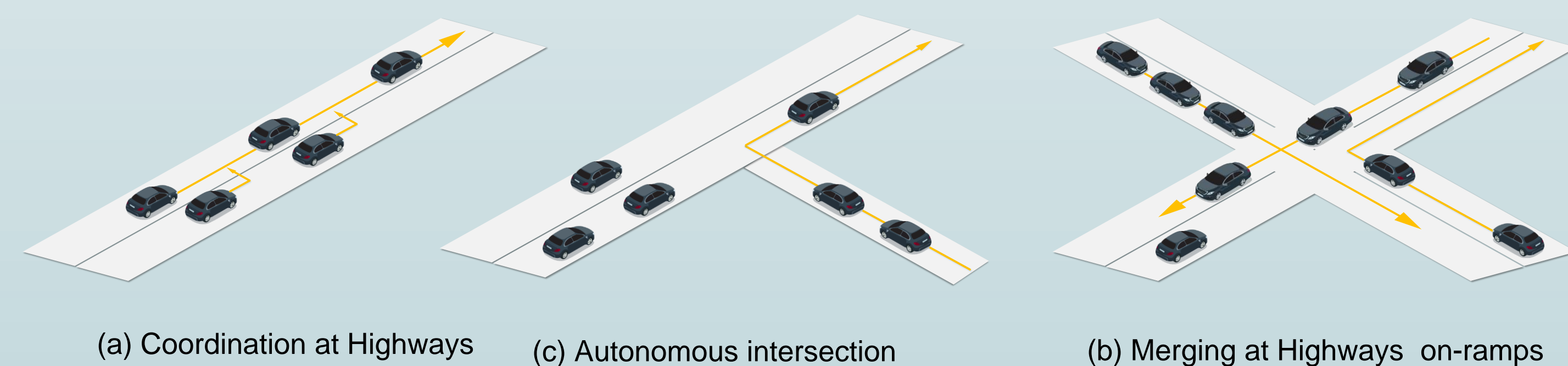


Figure 2. Coordination problems for multi-vehicle systems(MVS)

- Example: Motion planning for a platoon in Highways/Autonomous Intersection

- ① A problem of multi-vehicle coordination that arises in Highways is Proactive Speed Harmonization. If for example for each vehicle i , when it enter a control zone within time $\forall t \in [t_i^0, t_i^m]$, define the set $Y_i(t)$ (W.R.T. a state equation $\dot{x}_i = f(t, x_i, u_i)$) as

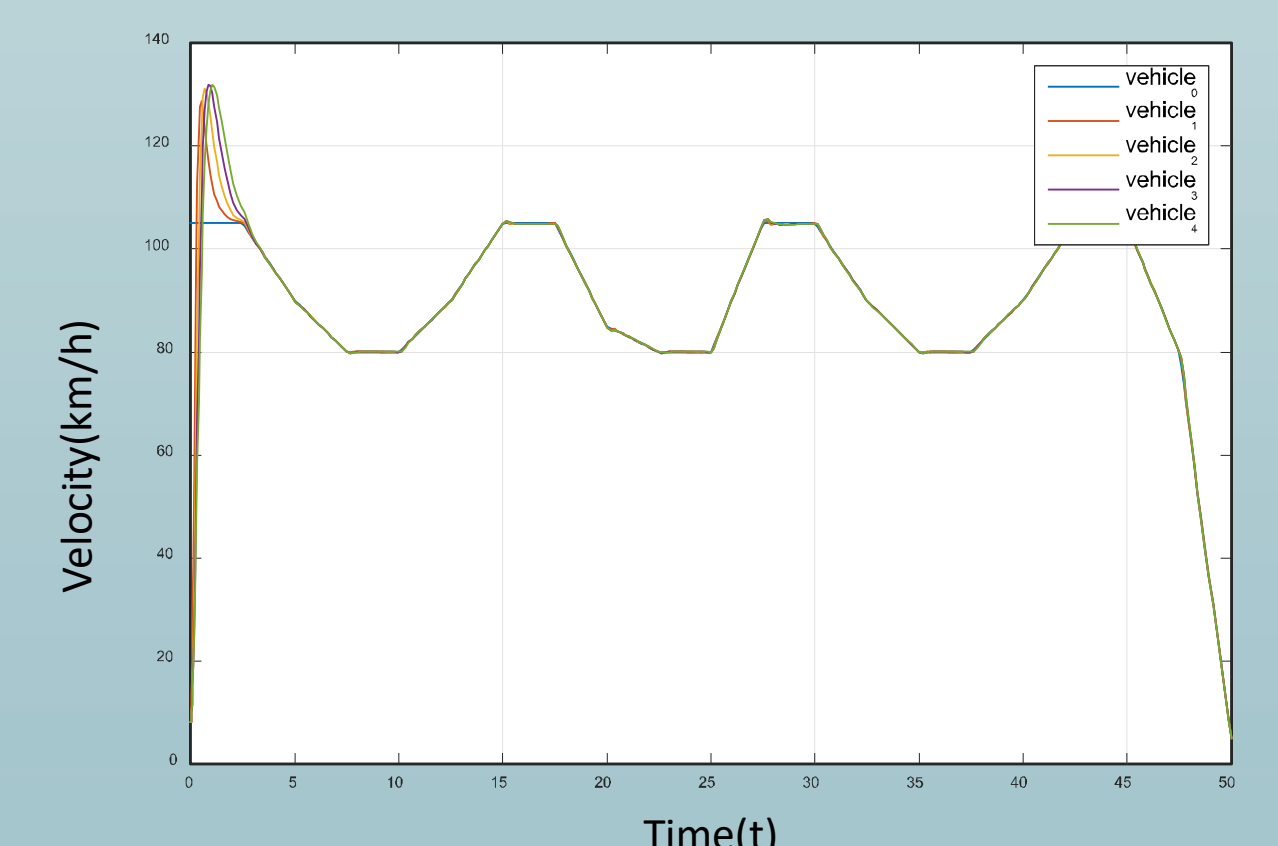
$$Y_i(t) \{p_i(t), v_i(t), t_i^m\}, \forall t \in [t_i^0, t_i^m]$$

$$\min \frac{1}{2} \int_{t_i^0}^{t_i^m} u_i^2(t) dt, \text{ subject to}$$

$$\dot{p}_i = v_i(t), \text{ and } 0 \leq v_{\min} \leq v_i(t) \leq v_{\max}$$

$$\dot{v}_i = u_i(t), \text{ and } u_{\min} \leq u_i(t) \leq u_{\max}$$

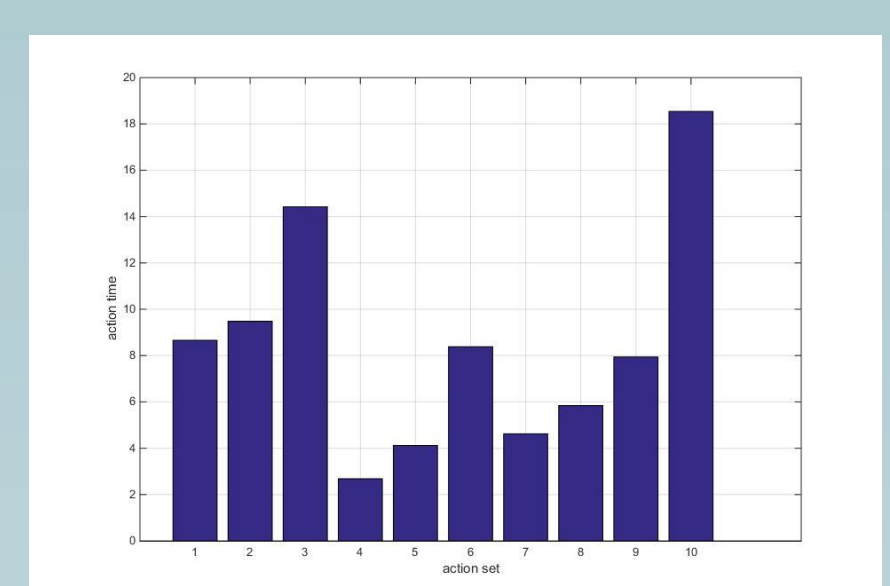
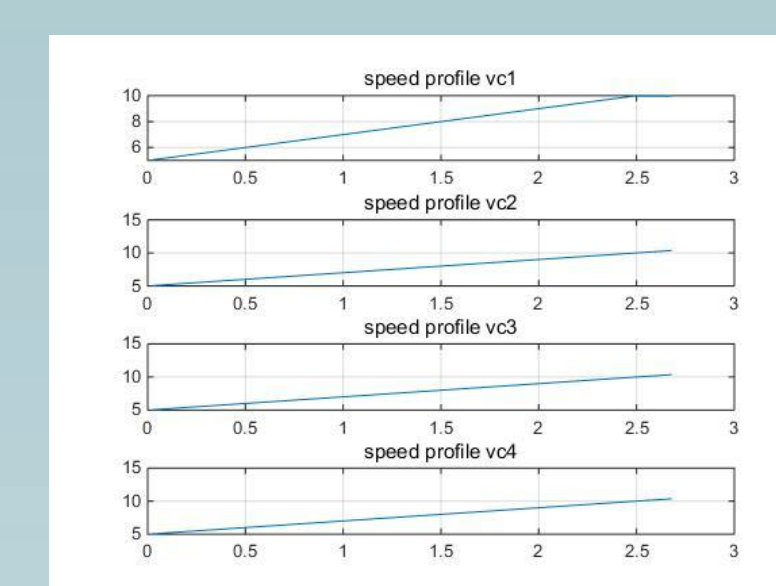
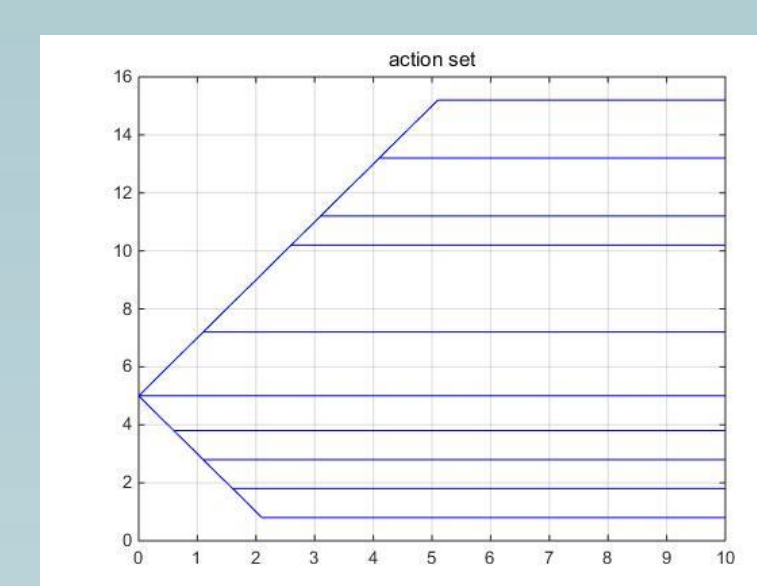
$$p_i(t) \leq p_k(t) - \delta$$



- ② A multi-vehicle probabilistic optimization algorithm is applied to the problem of multi-vehicle coordination in an intersection.

$$J(X) = W_{sep} \sum_{i \neq l} \sum_{k=1}^{k_{max}} \frac{1}{d_k(i_v, i_{self})^2} + W_{speed} (v_{max} - v_{avg})^2 + W_{control} \sum_{k=1}^{k_{max}} |v_{i_{self}}(k) - v_{i_{self}}(0)|$$

$$q^i(X^i) = \min \left(\sum_{k=1}^N q^i(X_k^i) E(J(X_k^i)) - TS(q^i(X^i)) \right)$$



what the next step of work?

- Research the motion driving planning for MVS in global road network maps;
- Integrate the multi-controller architecture from remote computations modular to on-board Navigation modular;
- Develop a Multi-level Bayesian Decision Making Network(MBDMN) for robust and reliable Decision–Action process under high level of uncertainties.

Bibliography

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