Research Statement

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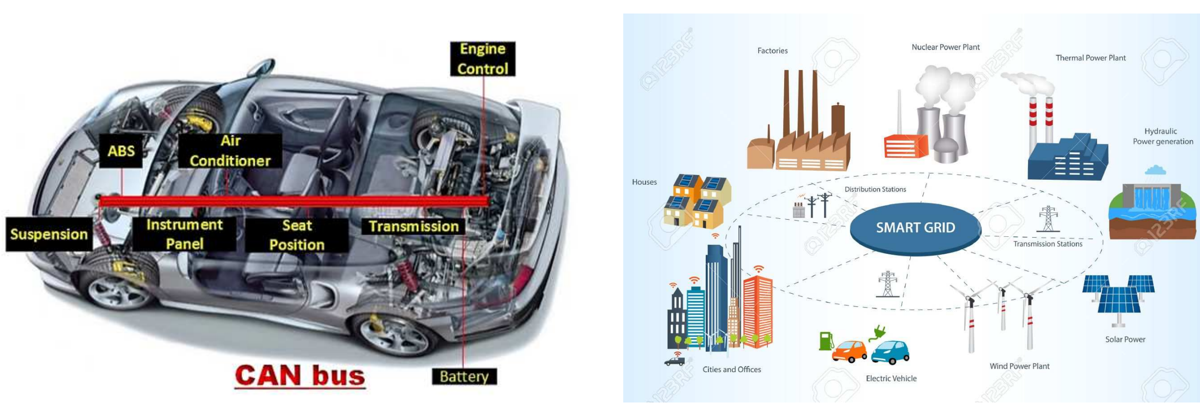
My research is in the general area of mechatronics, analysis of dynamical systems, control design, and applied mathematics. My research program reflects and highlights the applicability of these subjects to a diverse and varied domains and fields. My research approach emphasizes exploiting physical insights in a mathematically rigorous manner, and experimental verification of our theories. My main research thrust in the past few years can be categorized into the following groupings with some overlap:

1) Networked-control systems
2) Hybrid dynamical systems
3) Multi-agent systems
4) Robotics

1. Networked-control systems

A major research focus of mine is the design and the implementation of control techniques for networked control systems (NCS) in which the plant and the controller communicate with each other over a shared communication network [1]. The utilization of NCS offers attractive



Application of NCS in automotive systems and smart grids

benets in terms of flexibility, reduced complexity in wiring connections, lower cost and ease of maintenance. Due to these advantages, the incorporation of a network in the feedback loop is becoming more and more popular in a wide range of applications. Examples include chemical processes, refineries, power plants, air-planes, water transportation networks, industrial factories, energy collection networks (such as wind farms), environmental monitoring, battlefield and supervision. However, the insertion of a network in the feedback loop induces communication constraints (variable transmission intervals, quantization errors, delays, packet dropouts, and scheduling) which may seriously affect the control objectives [2]. A significant challenge in NCS is therefore to achieve the control objectives (in terms of stability and performance) despite these limitations. I have focused during my research on the synthesis of control techniques that cope with variable transmission intervals and quantization errors in NCS. In this regard, I have proposed novel implementation strategies that guarantee the closed-loop stability in the presence of these issue and also to efficiently reduce the amount of communications between the plant and the controller, which is essential for NCS [3], [4], [5], [6], [7], [8].

2. Hybrid Dynamical Systems

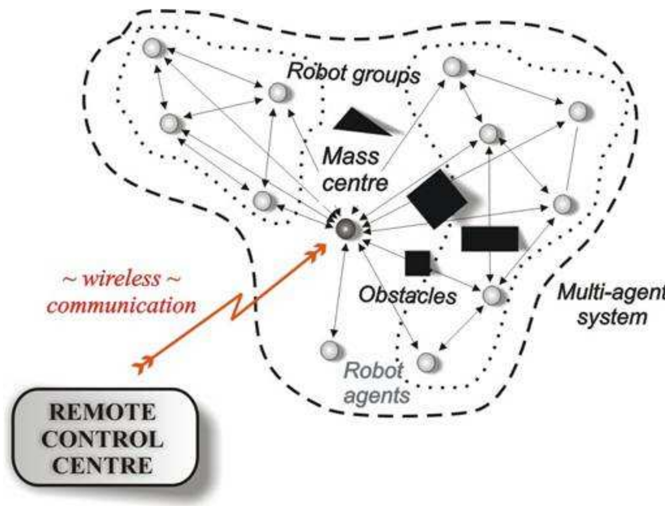
Hybrid systems are dynamical systems exhibiting both continuous and discrete dynamic behaviour [9]. Such systems arise in many real contexts, including automotive systems, chemical processes, communication networks, biological processes, and supply chain management. For instance, a supply chain, whose goal is to transform ideas and raw materials into delivered products and services, is an example of a heterogeneous interconnection between continuous dynamics (inventory levels, material flows, etc.) and discrete dynamics (connection graphs, precedences, priorities, etc.) [10]. Another example is biological processes that undergo both abrupt changes (cell divisions, gene activation, etc.) and continuous evolution (e.g., change in concentrations of proteins and other chemicals) [11]. Hybrid systems research in engineering has contributed to many advances in engineered systems, for example, robotics and autonomous systems. More recently, hybrid systems have found applications in cyber-physical systems, which refer to a new generation of engineered systems that have both physical and computational entities.

Whilst hybrid systems offer a fundamentally more flexible framework and a wide range of tools for modelling, analysing, and designing complex dynamical systems, the interaction of continuous- and discrete-time dynamics in a hybrid system often leads to very rich dynamical behaviour and phenomena that are never encountered in purely continuous- or discrete-time systems.

During my research, I have employed the framework of hybrid dynamical systems [9] in the modeling and the analysis of networked control systems, which truly describe the dynamical behaviour of the interacting continuous- and discrete-time dynamics [3], [4], [12].

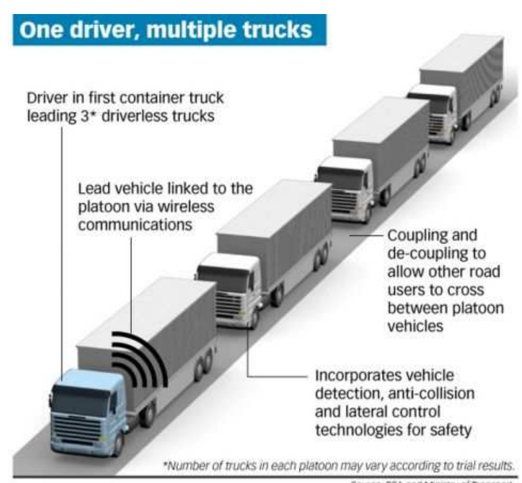
3. Multi-agent systems

A Multi-Agent System (MAS) is a collection of agents co-operating or competing with each other in order to fulfill common or individual goals. Multi-agent systems can solve problems that are difficult or impossible for an individual agent to solve. The major advantages of using multi-agent technologies include: (1) individuals take into account the application-specific nature and environment; (2) local interactions between individuals can be modeled and investigated; and (3) difficulties in modeling and computation are organized as sublayers and/or components. Therefore, MASs provide a good solution to distributed control as a computational paradigm. In addition, artificial intelligence (AI) techniques can be utilized.



Application of MAS in robotic systems

MAS have been applied to various problems, including market simulation, monitoring, system diagnosis, and remedial actions. For instance, in urban public transportation systems, MAS technique can be used to model and analyse the dynamical behaviour of vehicle platoons, in which a set of vehicles move together while keeping a particular geometrical configuration without any material coupling. Hence, in platoon multi-agent system, each agent is corresponding to a vehicle.



Application of MAS in vehicle platooning

The recent research results in distributed multi-agent coordination are roughly categorized as consensus, distributed formation control, distributed optimization, distributed task assignment, distributed estimation and control, and intelligent coordination.

During my research, I have focused on the study of the consensus problem for the so-called "open multi-agent systems", in which the set of agents are not constant but new agents can join and/or existing agents can leave the network at any time instant [13].

4. Robotics

Robots and manipulators can be programmed to perform dangerous, dirty and/or repetitive tasks with consistent precision and accuracy. Therefore robot manipulators are increasingly used in a variety of industries and applications. Typical applications of robots include welding, painting, assembly, pick and place for printed circuit boards, packaging and labeling, palletizing, product inspection, and testing; all accomplished with high endurance, speed, and precision. They can assist in material handling. In both production and handling applications, a robot utilizes an end effector or end of arm tooling attachment to hold and manipulate either the tool performing the process, or the piece upon which a process is being performed.

My graduation project at the end of BSc. program was dedicated to design a smart robot gripper that can pick and place objects while prevents the slipping of the object with the minimum gripping force. Hence, the end-effector should be able to move a fragile object, such as an egg for instance, without slipping it with the minimum force that does not destroy the egg. My MSc. work was concerned with the application of different control techniques to a two degrees-of-freedom robotic arm. The applied control strategies include PID control, Fuzzy control, Computed torque, and Sliding mode control [14]. During my post-doc position in the Technical University of Eindhoven in Netherlands, I have participated in the supervision of a master student whose work was dedicated to the real-time path planning and collision avoidance for robotic manipulators using A^* and simplex algorithm [15].

Future research plan

My future research will include the application of the techniques and tools from the control theory on energy systems, water distribution networks and medical applications. Moreover, I strive to apply the technique of multi-agent systems in relevant domains of interest such distributed dynamical systems, supply chain management, and biological systems.

Sincerely Yours,

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