Polytech network form for PhD Research Grants from the China Scholarship Council

This document describes the PhD subject and supervisor proposed by the French Polytech network of 14 university engineering schools. Please contact the PhD supervisor by email or Skype for further information regarding your application.

Supervisor information	
Family name	ADOUANE
First name	Lounis
Email	Lounis.Adouane@uca.fr
Web reference	http://lounisadouane.online.fr/
Lab name	Institut Pascal
Lab web site	http://www.institutpascal.uca.fr/index.php/en/
Polytech name	Polytech Clermont-Ferrand
University name	Université Clermont Auvergne
Country	France

PhD information	
Title	**Sub-optimal Energy Management Architecture based on Stochastic Decision Process for Intelligent Hybrid Electric Vehicles**
Main topics regards to CSC list (3 topics at maximum)	I-17. Control theory and technique V-4. New technology of high-performance energy economics VI-4. Intelligent construction

Required skills in science and engineering	Automatic science, Mechanical engineering and Computer science

Subject description (two pages maximum)

Please cf. enclosed PhD subject of two pages.

PhD Thesis subject

Sub-optimal Energy Management Architecture based on Stochastic Decision Process for Intelligent Hybrid Electric Vehicles

Institut Pascal, IMobS3, Clermont-Ferrand, France
Supervision: Lounis ADOUANE, Associate Professor, Habilitated to lead research (HDR)

I. Introduction and Context

Growing environmental concerns coupled to the decreasing of fossil fuel energy sources stimulate highly research on new vehicle technologies. Hybrid Electric Vehicles (HEV) appears to be one of the most promising technologies for reducing fuel consumption and pollutant emissions [German 03] [Kamal 18b]. During the last decades several firms/industries and laboratories throughout the world are thus more and more interested on the multi-disciplinary domains linked to HEV.

The opened PhD position aims to enhance the energetic performance of HEV while optimizing the powertrain control strategy to deal with HEV which could have until three possible modes of actuations (Tri-Hybrid: Electric, Hydraulic and Thermic). This PhD thesis will be achieved within MACCS[1] team of Institut Pascal[2] Laboratory (Clermont-Ferrand, France) with close interaction with Safra[3] Company (Albi, France), the company who designed and produced the hybrid bus BUSINOVA Evolution[4] (cf. Figure 1(a)), which is among the possible experimental platform to use in this PhD Thesis.

Keywords: Tri-actuated hybrid vehicle (Electric, Hydraulic and Thermic); Optimal Powertrain Control; Online and offline optimal control; Hybrid control architecture (continuous-discrete); Artificial Intelligence (Dynamic programming, MDP, Fuzzy logic, etc.).

II. Approach and main objectives

Among the challenging multi-disciplinary domains linked to HEV, the one linked to Hybrid Powertrain Control (HPC) is of first importance. Indeed, the control of hybrid powertrains is much more complex than control of classic engine [German 03]. Indeed, the control laws have to deal closely with the state of charge of the battery and with the variable efficiency of each element of the powertrain [Kamal 18a, 18b]. Optimization of energy management strategies on given driving cycles is often used to derive sub-optimal control laws to apply on the HEV. Therefore, the efficiency of the used HPC affects highly the fuel economy, battery lifespan and vehicle's performances.

In addition, it is important to highlight the fact that mainly in dense urban navigation, vehicles have the characteristics of frequent starts/stops. Thus, significant amounts of energy (mainly due to its high inertial dynamics) need to be optimized/saved during these two important phases. The idea in this PhD thesis is to find the most efficient way to switch/merge between the different actuations to cope notably with the peak of power demanded during the starting phase [Hui 11] and to store the high power flow during the stop phase, without affecting the performance of the HEV [Kim 08]. Furthermore, it is important to optimize also the velocity of the HEV during these phases [Dahmane 18].

In the literature, mainly two categories of techniques are used to deal with energy management using efficient HPC, the first is called Rules based (Fuzzy logic, State machine, etc.) and the second is based on offline/online optimization/control (dynamic programming, Lyapunov control, etc.) [Abdrakhmanov 17] [Ouddah 18]. The aim of the proposed PhD thesis is minimizing energy consumption of the overall system while taking into account the available online (current level of battery, vehicle's need of torque, etc.) and offline (based on standard identified vehicles cycles in real situation, profile of the road, etc.) system dynamic knowledge.

In terms of online energy optimization, this proposed thesis will focus on methods related to hybrid systems control (continuous-discrete) to find the optimal way to switch / merge between the electric, hydraulic and thermic operating modes of the vehicle to achieve its displacement in urban environment. Indeed, to guarantee the energy efficiency using the control architecture, it is planned to investigate further

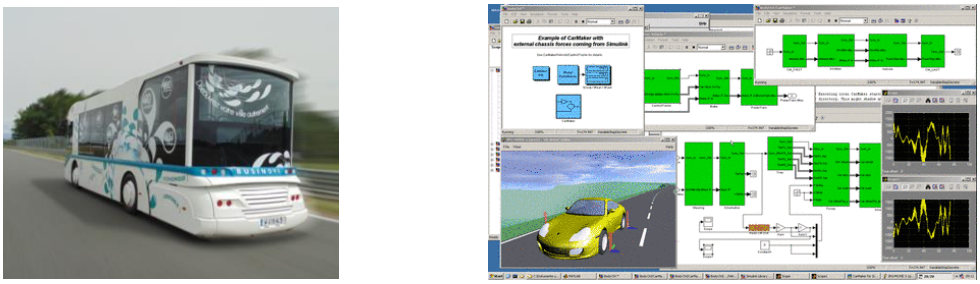
[1] Modeling, Autonomy and Control in Complex Systems
[2] http://www.institutpascal.uca.fr
[3] http://www.safra.fr/
[4] http://www.businova.com/

the potentialities of hybrid controllers [Žefran 98] which allow controlling continuous systems in the presence of discrete events. Each dedicated controller will be applied to control the identified model of the system corresponding to one mode or a merge of them. These kinds of hybrid controllers and the theory liked to it, permit to obtain, in addition to the stabilization of the system, a rigorous analysis of the control performances.

In addition, it is not sufficient to have optimal multi-source management/control of vehicle's actuation (energy needed for operational performance) it is also important to satisfy other criteria, linked for instance to passenger comfort, durability/life of used mechanical/electrical systems (economic performance), reduction of pollution and emissions of greenhouse gases and noise (environmental performance) [German 03]. This multi-criteria optimization will be mainly managed according to an offline optimization, using notably Artificial Intelligence techniques (fuzzy logic, neuro-fuzzy, Markovian Decision Process) which permit to master the inherent complexity to this kind of systems [Dahmane 18]. The main objective here is optimizing the energy consumption of the HEV, while taking into account the vehicle's road profile (given for instance from a topographic map combined with a GPS) as well as the current traffic on the road, and obviously while taking full advantages of the actuation possibilities of the studied HEV.

III. Simulation Experimental platform

The modelling and the control of the overall system will be done first using Matlab/Simulink and while using dedicated software for this kind of system like CarMaker available at Institut Pascal. Thereafter, effective implementations in C++ will be done on an actual HEV system.



(a) BUSINOVA **(b)** IPG-TruckMaker

Figure 1

PhD candidate expected background: Good mathematical background. Basic knowledge on automatic control and/or artificial Intelligence methodologies (Fuzzy logic, Neural network, etc.) would be appreciated.

Candidacy and contacts: The candidates should send ASAP, a CV, a motivation letter, letter of recommendation, a list of referees and the Master results for: Lounis ADOUANE: Lounis.Adouane@uca.fr

References:

[Abdrakhmanov 17], R. Abdrakhmanov and **L. Adouane**, *Energy Management and Powersplit in Hybrid Electric Bus via DP-based Optimal Profiles Database*, **VPPC'17**, IEEE Vehicle Power and Propulsion Conference, Belfort-France, 11-14 December 2017.

[Dahmane 18], Y. Dahmane, R. Abdrakhmanov and **L. Adouane**, *Stochastic MPC for Optimal Energy Management Strategy of Hybrid Vehicle performing ACC with Stop&Go maneuvers*, 15th IFAC Symposium on Control in Transportation Systems (CTS 2018), Genova – Italy, 6-8 June 2018.

[German 03], German J.M. (2003) Hybrid powered vehicles. Society of Automotive Engineers.

[Kamal 18a], E. Kamal and **L. Adouane**, *Intelligent Energy Management Strategy based on Artificial Neural Fuzzy for Hybrid Vehicle*, IEEE Transactions on Intelligent Vehicles (T-IV), volume 3, issue 1, pages 1-14, March 2018, DOI: 10.1109/TIV.2017.2788185.

[Kamal 18b], E. Kamal and **L. Adouane**, *Hierarchical Energy Optimization Strategy and its Integrated Reliable Battery Fault Management for Hybrid Hydraulic-Electric Vehicle*, IEEE Transactions on Vehicular Technology (T-VT), Available online February 2018. doi: 10.1109/TVT.2018.2805353.

[Kim 08], Kim YJ. Integrated modeling and hardware-in-the-loop study for systematic evaluation of hydraulic hybrid propulsion options. PhD, Univ. Michigan 2008:1–16.

[Ouddah 18], N. Ouddah, **L. Adouane** and R. Abdrakhmanov, *From Offline to Adaptive Online Energy Management Strategy of Hybrid Vehicle Using Pontryagin's Minimum Principle*, International Journal of Automotive Technology (IJAT), Accepted on Jan. 2018.

[Hui 11], Sun Hui, Yang Lifu, Jing Junqing, Luo Yanling, Control strategy of hydraulic/electric synergy system in heavy hybrid vehicles, Energy Conversion and Management, Volume 52, Issue 1, Pages 668-674. January 2011.

[Žefran 98], M. Žefran and J. W. Burdick, Design of switching controllers for systems with changing dynamics. IEEE Conference on Decision and Control CDC'98, Tampa, FL, pp. 2113-2118, 1998.