SUSTAINABLE TRANSPORT AND MOBILITY:
A MULTIDISCIPLINARY ISSUE

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Abstract: Nowadays sustainable transports must achieve multiple challenges: energy, environment, safety and reliability. This paper gives some examples of research led at the University of Valenciennes (France) in the transport and mobility domain and of the research and development environment of our labs at the regional level as well as the French national and European levels. Illustrations focus on particularly critical issues linked to the presence of human being in the system, as passenger or as driver involved in the control loop. Related courses in that domain then transpose the research results for "licence" and master programs. An international syllabus dedicated to transport is also proposed in the course of an Engineering School.

INTRODUCTION

University of Valenciennes and Hainaut Cambresis (UVHC) was founded in 1964. It gathers about 10,000 students mainly involved in engineering and science but with 3 important colleges in literature and art, law and business. UVHC is a public research university, well known in the academic and industrial world for its specialty in the transport domains[1]. The University of Valenciennes and Hainaut-Cambrésishas been certified in 2007 by the Ministry of Higher Education and Research and labeled "Innovative Campus" for its policy in that domain and for the development consistency and the increasing visibility of its projects.

Two research labs are mainly involved in transport projects, LAMIH and TEMPO which gather 290 personnel, i.e., 110 facultymembers, 30 staff and 150 non-permanent engineers, PhD students, post-doctoral researchers.

LAMIH (Laboratoire d’Automatique de Mécanique et d’Informatique industrielles et Humaines) is both funded by the University of Valenciennes and CNRS. Its 4 teams develop very original multidisciplinary topics around complementary specialties involving technical systems as well as human beings: 1) ASHM team (Automation and Human Machine Systems) deals with control and supervision of industrial processes as well as human systems, 2) C2S team (Crash Comfort and Safety) studies mechanical processes and structures in terms of material as well as human biomechanics components, 3) DIM team (Decision Interaction and Mobility) aims at designing and simulating multi-agent interactive embedded
systems and decision support systems, and 4) DEMoH team (Decision Emotion and Human Movements) is involved in modeling human beings: as a moving body (for instance a passenger) through biomechanics theories on one hand and as decision-maker and controller (for instance a driver) through cognitive psychology on the other hand. Such a team gathering psychologists and physiologists, specialists of human science and working inside (and with) a lab of specialists in physical and engineering science is unusual in France, and gives a full originality to our practice of multi-disciplinarity.

TEMPO is a lab part of Carnot Institute ARTS more involved in technical issues and developing 3 themes. Two are mainly related to mechanical engineering, MSM (materials, surfaces and forming) and DF2T (Fluid Dynamics and Heat Transfer). The 3rd one PSI (Production Services Information) deals with control and structures of complex and nothierarchical organizations.

These two labs are the core of research in “Sustainable Transports and Mobility”, of related industrial developments and teaching programs for students in master degree and engineering school.

RESEARCH IN SUSTAINABLE TRANSPORT

The theme “Sustainable Transports and Mobility” is the research objective of LAMIH and TEMPO. It is on the dynamic setting up to cross-fertilize multidisciplinary actions from the engineering disciplines, Automation Science, Mechanical Engineering, Computer Science and Human science disciplines dealing with human modeling, biomechanics, physiology and psychology, Figure 1. This cross-fertilization, in line with the roadmaps of major French national and European transport institutions but also in line with our industrial partners, gives rise to many interactions between teams. These interactions aim to impact our three main strategic goals related to the three major societal challenges of “Sustainable Transports and Mobility”: Energy & Environment; Safety, Security & Reliability; Mobility & Logistics.

Several projects involve at least two disciplines:

In the field “energy and environment” dealing with emission and consumption reductions automation scientists, mechanical scientists both in structures and in fluids work on:

- Optimal engine management for future power trains [2],
- Heat transfer enhancement and control, heat exchangers [3],
- Near-wall turbulence, aerodynamics, control for drag reduction [4],
- Lightweight and ecofriendly safe structures [5].

In the field “safety security and reliability” involving human and transport means, automation scientists specialists in human engineering, psychologists, physiologists and specialists in biomechanics work together on:

- Human machine cooperative systems, diagnosis, human error and resilience (human in control) [6,7,8,9],
- Biomechanics, human trauma, ergonomics, handicap (human as a passenger) [10,11].

In the field “mobility and logistics” automation scientists dealing with manufacturing management and logistics and computer scientists specialists in multiagent systems, human computer interaction, operational research and optimization deal with:

- Mobile and embedded systems, cooperative diagnosis architecture and life cycle [12],
- Operational research and decision making, human-machine interactive systems, multimodal chains and transport networks, for instance stigmergic robust control for autonomous vehicle routing [13],
- An emergent theme related to the assistance to mobility of disabled persons is transversal with the second field. [14,15].

INDUSTRIAL ENVIRONMENT AND RESEARCH NETWORKS

LAMIH and TEMPO are strongly involved in the ground transportation domain (Railways, metro, cars, trucks) and are the core of a huge development of R&D projects at regional, French national and European levels:
- CISIT (acronym for International Campus on Safety and Inter-modality in Transportation) is a big project of R&D funded by the French Ministry of research, the Regional Council of Nord Pas de Calais, and the European Union (FEDER). CISIT is a project of 46 million euros for 7 years, leaded by LAMIH and gathering 350 researchers and PhD students. CISIT manages post-doctoral and PhD student grants provided by the Regional Council[22].

LAMIH and TEMPO are active members of several networks:
- GIS 3SGS is a French “Groupement d’Intérêts Scientifiques” devoted to Supervisory control, safety and security of large systems in several fields such as transportation, energy, manufacturing, networks … This GIS facilitates setting up industrial and academic partnerships for creating new research projects for French national programs such as ANR (French research funding program) or European programs[23].
- European GDR HAMASYT (Human MAchineSYstems in Transportation and industry) is supported by CNRS and leaded by a member of LAMIH. This group is dedicated to Human aspects and gathers European partners: TU Delft, TU Berlin, TU Copenhagen, Polytechnico de Milano and French Universities: UT Compiégne, University of Reims.
- Networks have been built along European projects of the FP5, 6, and 7 in the fields of human modeling and resilience in Urban Guided Transportation Systems (UGTMS 2002-2004, MODURBAN 2005-2007), and more generally ground transport driver modeling (ITERATE 2009-2011).

UVHC is member of the cluster i-Trans fostering partnerships between labs and companies. We are also members of the huge international project called RAILENIUM, an International testing Center for rail infrastructure created end 2011 around the University of Valenciennes and railways manufacturers like ALSTOM (fast trains) and Bombardier (metros and tramways) in association with other Universities of the Region Nord Pas de Calais. The budget is 550 million euros over 10 years. Topics related to our competences concern 1)
“intelligent” interactions between vehicles and 2) infrastructure and virtual prototyping. CISIT, i-Trans and RAILENIUM will be settled in the new technology park TRANSALLEY (innovative and sustainable mobility) currently under development close to UVHC main campus.

TEST BENCHES, SIMULATORS AND DEMONSTRATORS

Dedicated test benches and demonstrators have been developed for experimental purposes.

In the field “energy and environment” an example of study deals with hybrid car motorization, Figure 2. The structure is a double hybrid: mechanical hybrid (splitting the torque between electric machine and IC engine) and electrical hybrid (splitting the current between the super-capacitor and the electric machine). In this context, an optimal control problem formulated in discrete time allows to compute at each instant the repartition of current and of torque. The considered criterion is the fuel consumption.

Figure 2: Electrical machine for light hybrid and Demo car

In the field “safety security and reliability” involving human and transport means several topics are studied with several full scale simulators with human in the loop performing near-real activities. In the car driving domain we assess the human state through measurement of workload, vigilance or attention and the efficiency of decision-based or action-based support systems, Figure 3a, [8]. A more innovative research deals with the shared control between human car driver and an automated tool in low speed, Figure 3b, [16].

Another domain studied by LAMIH for several decades is the dynamic task allocation between automated systems and human operators in order to study the impact of the degree of automation on the air traffic control, Figure 4a. That led first to a theory of dynamic task allocation between human and machine aiming at optimizing the controlled system performance (here the air traffic) while regulating human Traffic controllers workload [17]. Further works led to a theory of human machine cooperation [18, 19, 20, 21].

A third example concerns the railway domain. The objective is to analyze and assess the resilience of a human-machine system in order to develop learning devices based on the management of well-known or unknown situations, Figure 4b[7].
In the field *mobility and logistics* and the particular emergent topic related to assistance to mobility of disabled and elderly persons we built several platforms. An example of platform purpose is to study the motion of upper limbs of disabled drivers during a driving task at low speed. It offers a visual output and a force-feedback instrumented steering wheel equipped with 3 dynamometers for measuring simultaneous forces and torques applied by both hands on the steering wheel, Figure 5a and Figure 5b. The extension of the study aims to implement an auto adaptive assistance tool into the steering wheel regarding the disabled person needs [14, 15].
COURSES IN TRANSPORT

Two colleges propose courses in transport: ISTV (College of Science) with a master degree and ENSIAME (Engineering School in Computer Science, Automation and Mechanics) with an international autumn semester taught in English.

ISTV Master degree in Transportation Science:
The Master course is based on a License degree in Engineering Science (SPI) which teaches the background in Electronics, Automation Science and Real-Time Computing along a three years course (electronic, electricity, components, electromagnetism, linear system control, C-language programming, robotic, logics). Four skills gathering several modules are available for obtaining the Master degree in Transportation Science in two more years: automatic control (discrete time systems, control of complex systems, supervision, industrial LAN, flexible workshop), real-time computing (micro-processors, multi-task programming, real-time, DBMS), human-machine systems (Human Centered Design, Human Reliability Assessment, Human Machine Cooperation, dedicated Support Systems: ADAS, Decision Support Systems) Automobile and hybrid motors, (security, safety, hardware in the loop, electrical hybrid and heat vehicle, hybrid motorization, communication from Vehicle to Vehicle and Vehicle to Infrastructure). The research platforms described above are available for student stays and projects in Master courses.

ENSIAME international syllabus on transportation:
The syllabus runs during the first semester (early September till end February) of the ENSIAME final year. All courses are given in English. Lectures, case-studies, practical and hands-on computer training are used to transfer the necessary knowledge for Automotive, Railway and Aeronautic Industrial Applications. Six main modules are developed in 280 hours: Design and Process (Computer Aided Design/PLM, Virtual reality) Production Technology (Production Systems, Production Scheduling, Management Engineering Support Tools), Safety (Active & Passive, Signaling, Structure analysis), Comfort & Ergonomics (Acoustics/ Vibrations, Ergonomics, Postural comfort- Accessibility, Thermal comfort - Air quality, Human-Machine System analysis) Energy & Environmental Issues (Energy & Environmental Issues, Energy usable for transportation, Ecological “Green” Transportation), Reliability Engineering and System Safety (Reliability, Systems Integration, Smart Transportation Systems). The modules are completed by projects, case studies and visits of companies, all allowing 35 ECTS. Application procedure is available at [24].

CONCLUSION

This paper has drawn a short description of researches and related courses in the domain of Sustainable Transports at the University of Valenciennes. These activities lie on two main lab working on multidisciplinary topics dealing with technical as well as human issues and gathering specialists in engineering science (automation, mechanics, computer science, biomechanics) and in human science (psychology, physiology).

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[22] see: http://www.cisit.org/
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УСТОЙЧИВ ТРАНСПОРТ И МОБИЛНОСТ:
МУЛТИДИСЦИПЛИНАРЕН ВЪПРОС

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Ключови думи: Устойчив транспорт, енергия, безопасност, надежност, човешки фактор, сътрудничество човек-машина, хора с увреждания, среда на изследователска и развойна дейност, курсове.

Резюме: В днешни дни устойчивият транспорт трябва да се справи с множество предизвикателства: енергия, околна среда, безопасност и надежност. Статията дава някои примери за изследвания, проведени в Университета във Валансиен (Франция) в областта на транспорта и мобилността и за средата на изследователската и развойна дейност на нашите лаборатории на регионално, национално и европейско равнище. Илюстрациите са фокусирани върху особено важни въпроси, свързани с присъствието на човека в системата като пътник или водач. Курсове в тази област преобразуват изследователските резултати в „лицензи” и магистърски програми. Предложена е международна учебна програма за инженерно училище, посветена на транспорта.