



POLITECNICO DI MILANO



DIPARTIMENTO DI
ELETTRONICA,
INFORMAZIONE
E BIOINGEGNERIA



 POLITECNICO DI MILANO



e-Bikes: present and future of high-tech solutions

INTERNATIONAL LI-ION E-BIKE INDUSTRY SUMMIT

Shanghai, China, April 13th, 2014



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Time-slot: 20 minutes

Mittwoch, 30. April 2014



Introduction: speaker presentation





The "mOve" research group

#1 ranking in Italy in Engineering Research Universities



MOTOR VEHICLE control team

Home People Projects Network Publications Theses Initiatives

The mOve team is a group of researchers based at the Department of Electronics and Computer Science (DE), Department of Electronics and Information, Politecnico di Milano (Milan Technical University).

The activity of the mOve research team is focused on the design of control systems, the data-based identification of black-box models, the development of control-oriented dynamic models, and the control-oriented analysis and filtering of digital signals and detectors. These research areas are developed within the application realm of inter-vehicle and intra-vehicle electronic control systems.

Even if the research activities of the mOve team is mainly focused on road and off-road motor vehicles (cars, motorcycles, electric bicycles, agricultural tractors, trains, etc.), the interest and scope of the mOve team also include marine vehicles (surface ships and submarines). The intra-vehicle and inter-vehicle applications of the mOve team span over a broad range: chassis control (electronic suspension, braking and traction control, attitude and stability control, etc.), engine control, energy optimization, supervisory coordination and control of fleets of vehicles, etc. Such broad range of vehicles and applications covered by the mOve team activity represents a unique value of the research team, since it allows a quick and intense cross-fertilization of methods, ideas and technologies.

Another unique characteristic of the mOve team is its well-balanced mix of applied research on specific vehicular challenges, and theoretical research on new control theory and methods. In order to emphasize and foster the continuous cross-fertilization between theory and applications, most of the mOve team researchers are involved both in applied research projects and in basic research on new theory and methods.

The mOve team works in cooperation with world-class leading companies, on short and long-term research projects. While these industrial cooperation, the main goal of the mOve team is to develop state-of-the-art applied research, and to facilitate the transfer of theoretical research and innovative design methods into vehicle product innovation. Our goal is to increase the competitiveness of our industrial partners, while demonstrating the practical value of advanced theory and methods.

Even if the main research activity of the mOve team is in the field of Automation/Control, the mOve team benefits from being immersed in a large, world class, Electronics and Computer Science Department: this allows to carry out interdisciplinary research activity, thanks to the contact with other groups working in the fields of, e.g., Electronics Design, Software Engineering, Telecommunications, Optical and Electronic Measurements, etc.

40 faculty members;
150 people overall

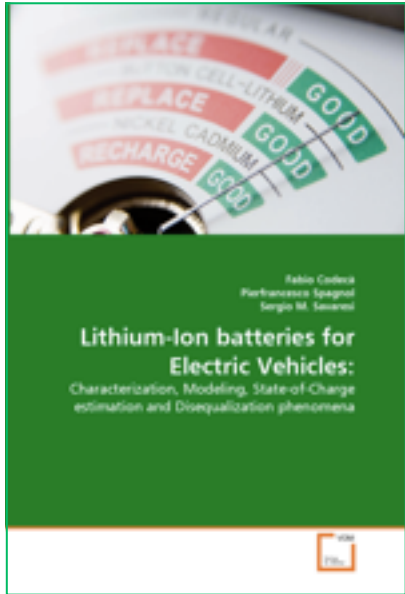
4 faculty members;
25 members overall
(PhD students,
research assistants)

One of the **biggest** EU academic research group focused on **vehicle control**

<http://move.dei.polimi.it>



Technology-Transfer examples: small electric vehicles



- Savaresi S.M. (2012). Automatic-control challenges in future urban vehicles: a blend of chassis, energy, and networking management. Oil & Gas Science and Technology - Revue d'IFP Energies Nouvelles, Vol. 67, No. 4, pp. 633-645.
- Dardanelli A., M. Tanelli, B. Picasso, S.M. Savaresi, O. di Tanna, M. Santucci (2012). A smartphone-in-the-loop active state-of-charge manager for electric vehicles. IEEE/ASME Transactions on Mechatronics, pp.454-463.
- Manenti A., A. Merati, A. Abba, A. Geraci, S.M. Savaresi (2011). A New BMS Architecture Based on Cell Redundancy. IEEE Transactions on Industrial Electronics, Vol.58, n.9, pp.4314-4322.
- Spagnol P., M. Corno, S.M. Savaresi (2013). Pedaling Torque Reconstruction for Half Pedaling Sensor. European Control Conference (ECC 2013), Zurich, Switzerland (to appear).
- Spagnol P., M. Corno, R. Mura, S.M. Savaresi (2013). Self-sustaining strategy for a Hybrid Electric Bike. American Control Conference, Washington, DC, USA (to appear).
- Corti A., V. Manzoni, Sergio M. Savaresi (2012). Vehicle's energy estimation using low frequency speed signal. 15th International IEEE Conference on Intelligent Transportation Systems, Anchorage, Alaska, USA, pp.626-631.
- Spagnol P., G. Alli, P. Lisanti, F. Todeschini, C. Spelta, S.M. Savaresi (2012). A full hybrid electric bike: how to increase human efficiency. American Control Conference, Montréal, Canada, pp.2761-2766.



PCT/IB2012/050492 - WO 2012/104810 (2012). Electrically pedal-assisted bicycle. SEMS S.r.l., Politecnico di Milano, FNM S.p.A. (Sergio M. Savaresi, Giovanni Alli, Cristiano Spelta, Pierfrancesco Spagnol, Massimo Vanzulli, Giuseppe Biesuz). Filed on 2/2/2012; published on 9/8/2012.

•MI2012A000260 (2012). Bicicletta a pedalata assistita e metodo per il controllo di una bicicletta a pedalata assistita. Politecnico di Milano, Università degli Studi di Bergamo (Previdi F., S.M. Savaresi, M. Corno, M. Tanelli, G. Alli, P. Lisanti, P. Spagnol, I. Boniolo, C. Spelta). Filed on 22/02/2012.

MI2011A000393 (2011). "Metodo e sistema elettronico per la gestione automatica dell'autonomia energetica di un veicolo, particolarmente in veicoli elettrici". Piaggio & C. S.P.A. e Politecnico di Milano (S.M. Savaresi, A. Dardanelli, M. Tanelli, B. Picasso, O. Di Tanna, M. Santucci). Filed on 11/03/2011.

MI2011A000150. Bicicletta a pedalata assistita elettricamente. Politecnico di Milano, SEMS srl, FNM spa (Sergio M. Savaresi, Giovanni Alli, Cristiano Spelta, Pierfrancesco Spagnol, Massimo Vanzulli, Giuseppe Biesuz). Filed on 3/2/2011.

MI2010A002408 (2010). Sistema e metodo di assistenza alla guida in tempo reale. Piaggio & C. S.P.A. e Politecnico di Milano (Mario Donato Santucci, Onorino Di Tanna, Sergio Savaresi, Andrea Corti, Vincenzo Manzoni). Filed on 27/12/2010.



Basic research (book, papers)



R&D Industrial cooperations



Spin-off company

E-Bikes: classification, with a glance on the future





Lesson learnt from cars...



ICE (classic)



Parallel Hybrid



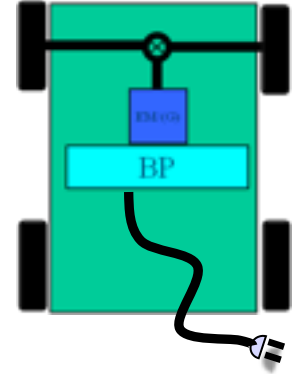
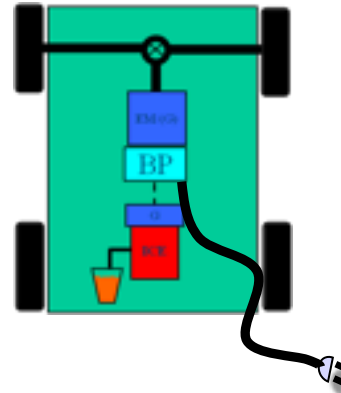
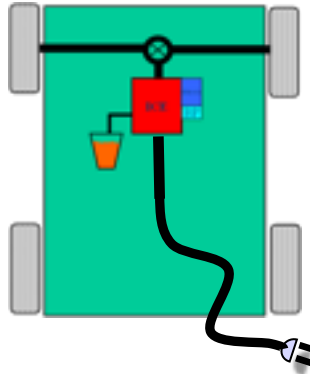
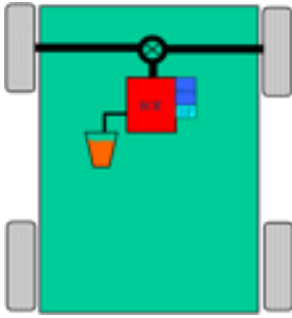
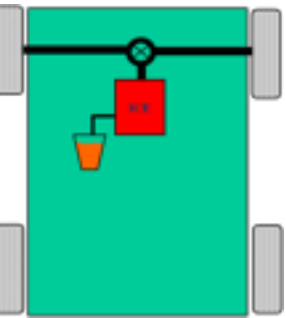
Parallel Hybrid Plug-IN



Serial Hybrid Plug-IN



Electric Plug-IN



Internal Combustion Engine (ICE)



Carbon-based-(fossil) fuel



Electric machine (motor/generator)



Battery-pack



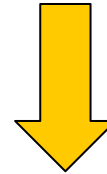


Internal Combustion Engines (ICE)...

Carbon-based (fossil) fuel



Food



Oxygen



«Hot» combustion



Mechanical power



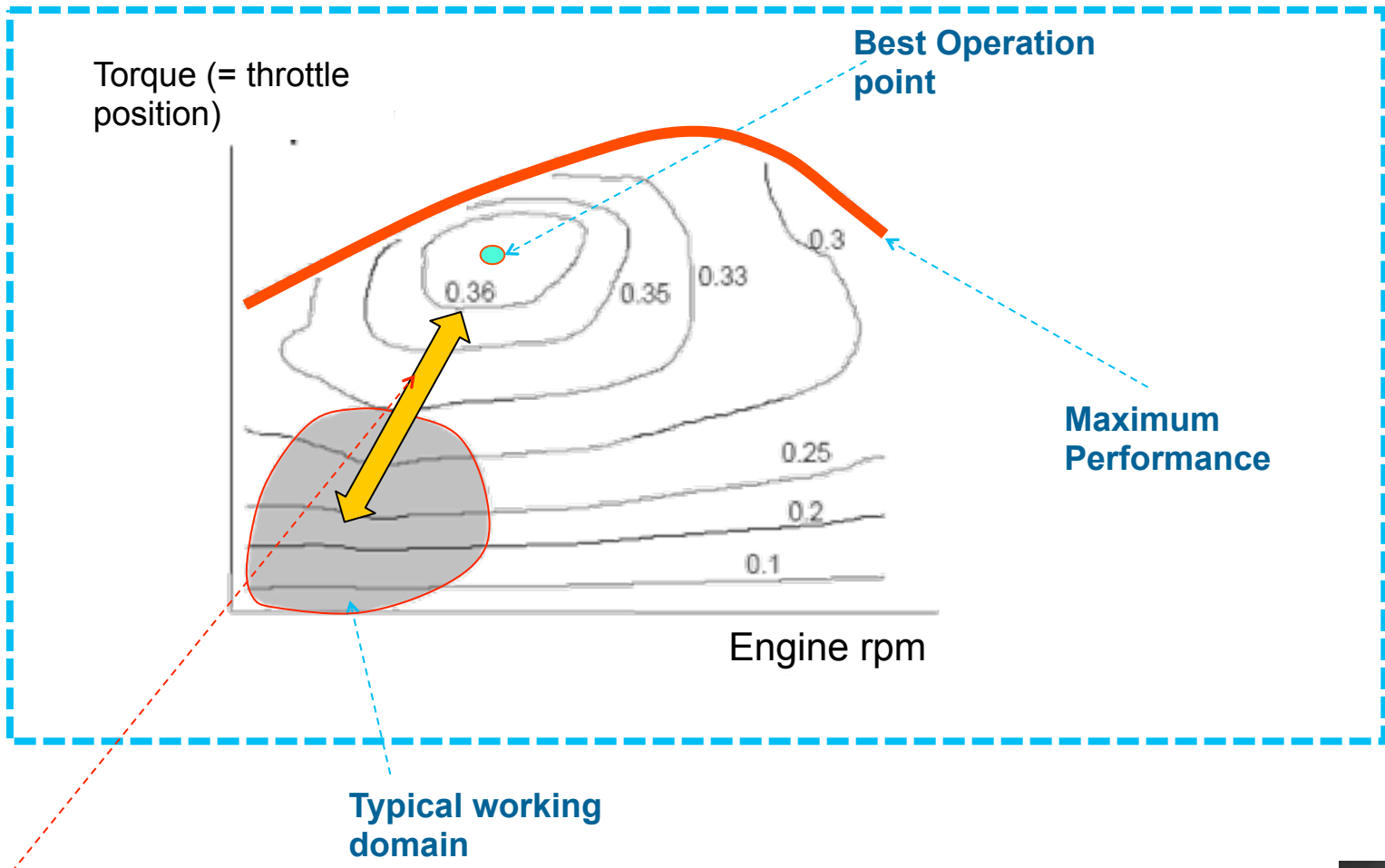
«Cold» combustion



Mechanical power



Internal Combustion Engine

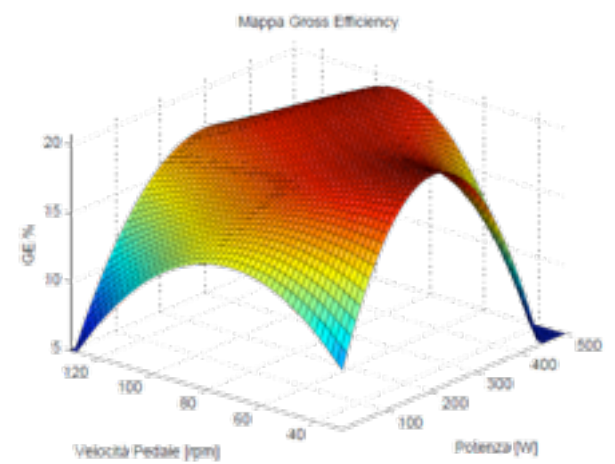
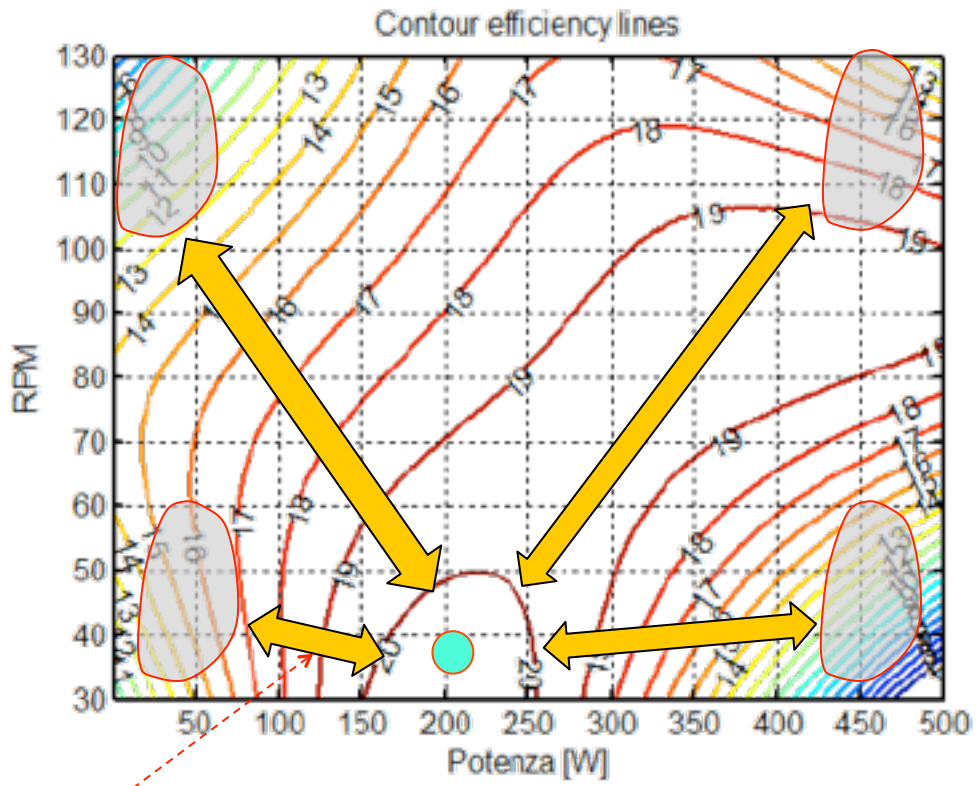


Large efficiency GAP





«HUMAN» Internal Combustion Engine



Very similar: large efficiency GAPS

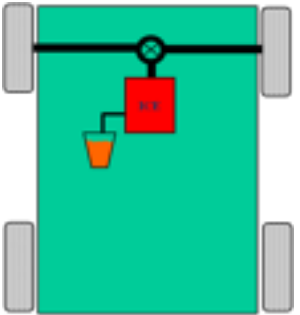




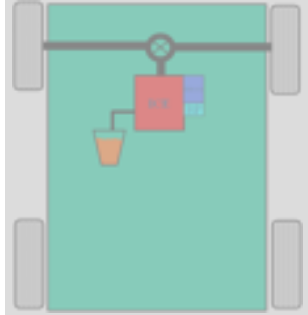
New «pedal-assisted» segmentation: learn from cars...



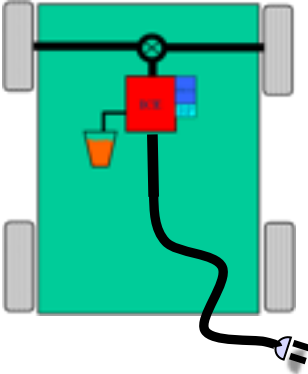
ICE (classic)



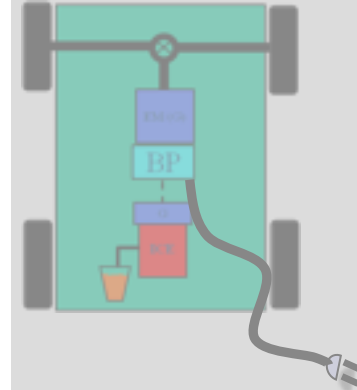
Parallel Hybrid



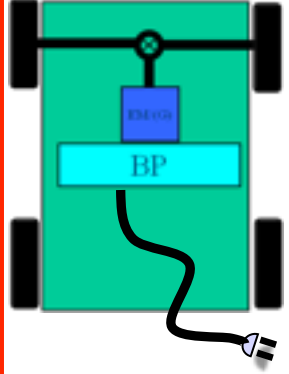
Parallel Hybrid Plug-IN



Serial Hybrid Plug-IN



Electric Plug-IN



Bicycle (classic)



E-Bike (PEDELEC)



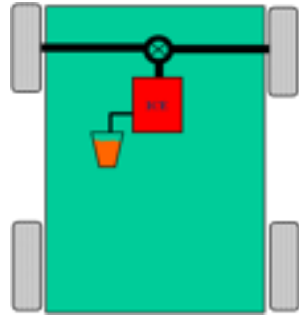
E-Scooter



ONLY Internal Combustion Engine (ICE) vehicle



ICE (classic)



Bicycle (classic)

Simple and classical architecture

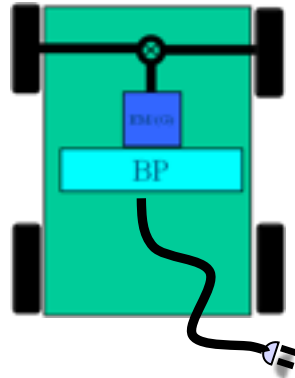
Light/cheap

Easy to use

Low-efficiency (fatigue and anaerobic power-peaks for the bike,...)



Electric Plug-IN



E-Scooter

Simple and classical architecture

High-efficiency

Limited-range (range anxiety)

Slow-refueling

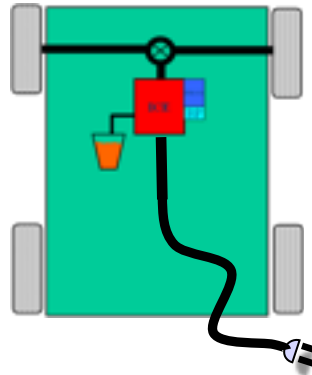
Weight/Cost of battery-pack



Parallel-hybrid PLUG-IN vehicle



Parallel Hybrid
Plug-IN



E-Bike (PEDELEC)

Higher efficiency (than ICE-only)

Possibility to use electric-energy from the grid

Weight/Cost of battery-pack

Limited-range with electric assistance (eBike)

Remark: slightly different architectures: PEDELEC, when battery empty, becomes a classical bike (no efficiency improvement)

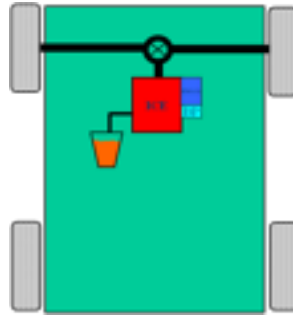




Parallel-hybrid vehicle (NOT plug-in)



Parallel Hybrid



Higher efficiency (than ICE)

Completely grid-independent

Light-cheap (small battery)

Easy (no recharge from grid)

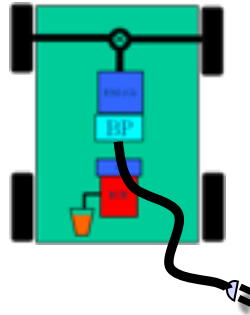


Cannot use electric energy from the grid

Lower help/assistance than a classical parallel-plug-in eBike



Serial-hybrid vehicle (EV with Range extender)



Serial Hybrid
Plug-IN

All the benefits of an electric vehicle

Maximum flexibility of ICE/human-power management

Battery-pack can be lighter and cheaper than an EV

No range-anxiety



Space-requirements (2 electric machines on board)

The «missing products» - examples



Example (first, only) of Parallel Hybrid (not-plug-in): ZEHUS «Bike+»



BIKE+

THE BIKE REVOLUTION





What is «Bike+»?

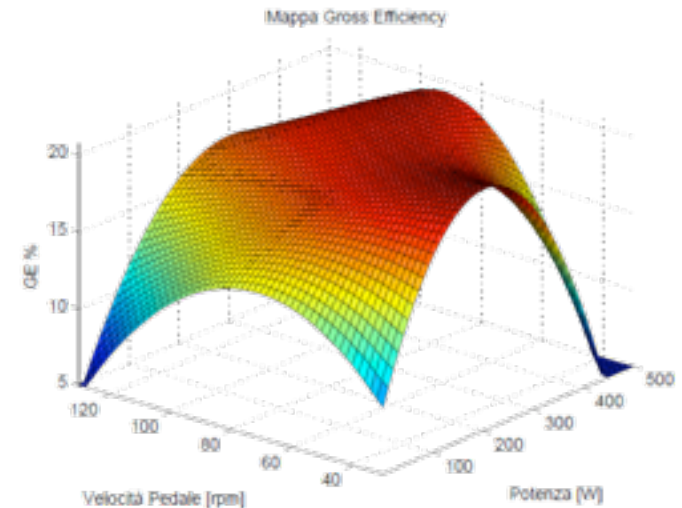
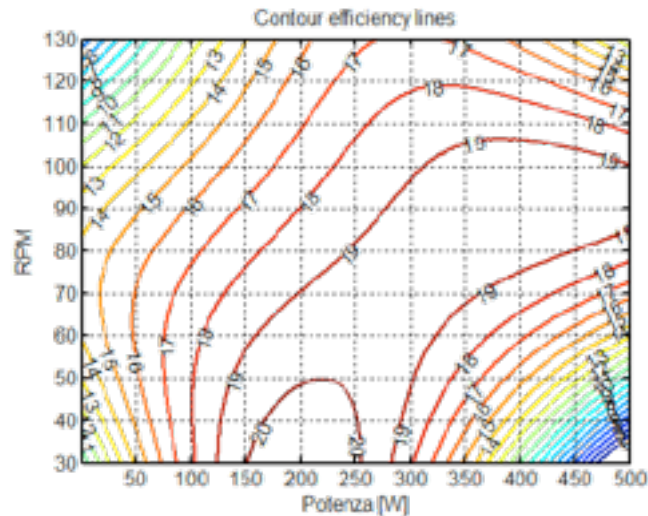
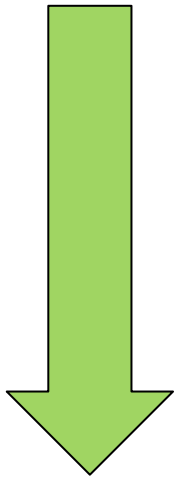
A **NEW** type of vehicle that:

- ⌘ Is **USED** exactly like a bicycle
 - ⌘ Never needs recharging
 - ⌘ Very light
 - ⌘ Switches on automatically
 - ⌘ Switches off automatically
 - ⌘ No user interface
- ⌘ **Reduces the cyclist fatigue**
 - ⌘ by better managing his/her energy
 - ⌘ Using a sophisticated and «smart» power-pack (electric motor, sensors, batteries, electronics, SW,...)



How does (can) it work?

- Human body has large **efficiency gaps**, similarly to an Internal Combustion Engine

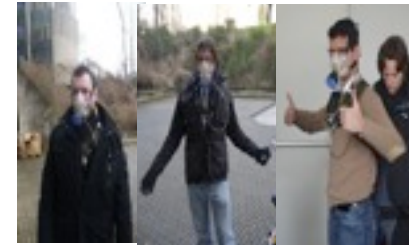
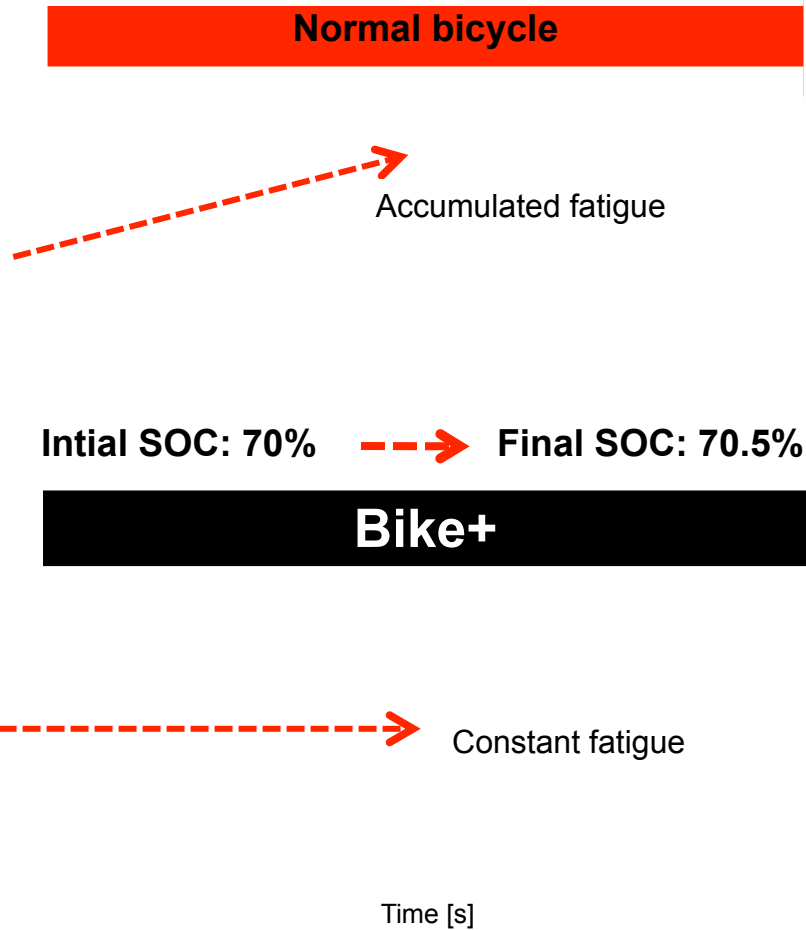


- Using these efficiency gaps, energy can be optimized using an electric energy buffer and sophisticated control algorithms
- Bike+ is the first example of optimized electric-human synergy**



The benefit has been scientifically PROVEN

- Testing protocol (on a flat cycling track)



**Fatigue
reduction:
up to
+30-40%**



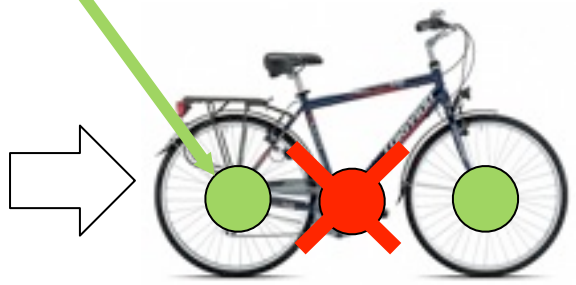
Bike+ in a PRODUCT

An **all-in-wheel rear-hub** solution that integrates Bike+ technology



Technical remark: Bike+ concept requires:

- Energy recuperation from **braking**
- Energy recuperation in **downhill slope**
- Energy generation from **pedaling**



Not (easily) feasible with central-motor layout



Who can be interested?

Private users who:

- like the lightness and **simplicity** of a bicycle
- like having **assistance** in hard situations



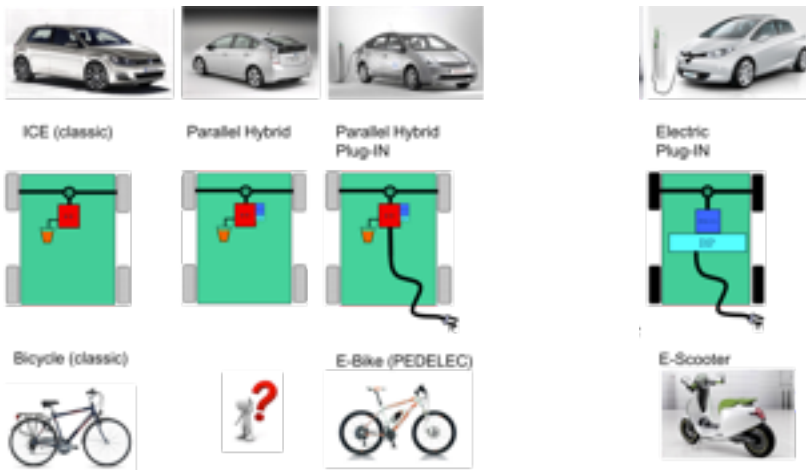
Bike-sharing initiatives that:

- have already an infrastructure for bike-sharing
- would like to **upgrade** to pedal-assisted vehicles **WITHOUT** changing the infrastructure



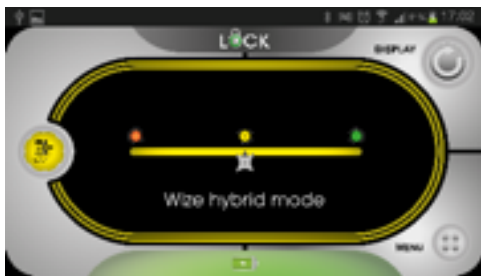
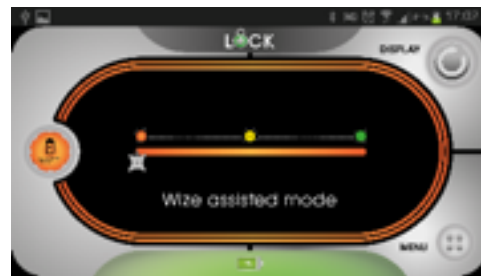


Remark on ZEHUS Bike+: «4-in-1»



ZEHUS «Bike+» covers a wider spectrum of modes and architectures:

- Classic bike (when off, with a negligible weight increment and aesthetic modification)
- Parallel-hybrid not-plugin (in «Bike+mode»)
- Parallel hybrid Plug-in (with human-synergy optimization and different levels of assistance and range)
- Full-assistance (almost electric)



Example of Serial Hybrid, plug-in: «SENZA»





Serial-hybrid: two products



MANDO «footloose»
In production

Emphasis on: **folding features**

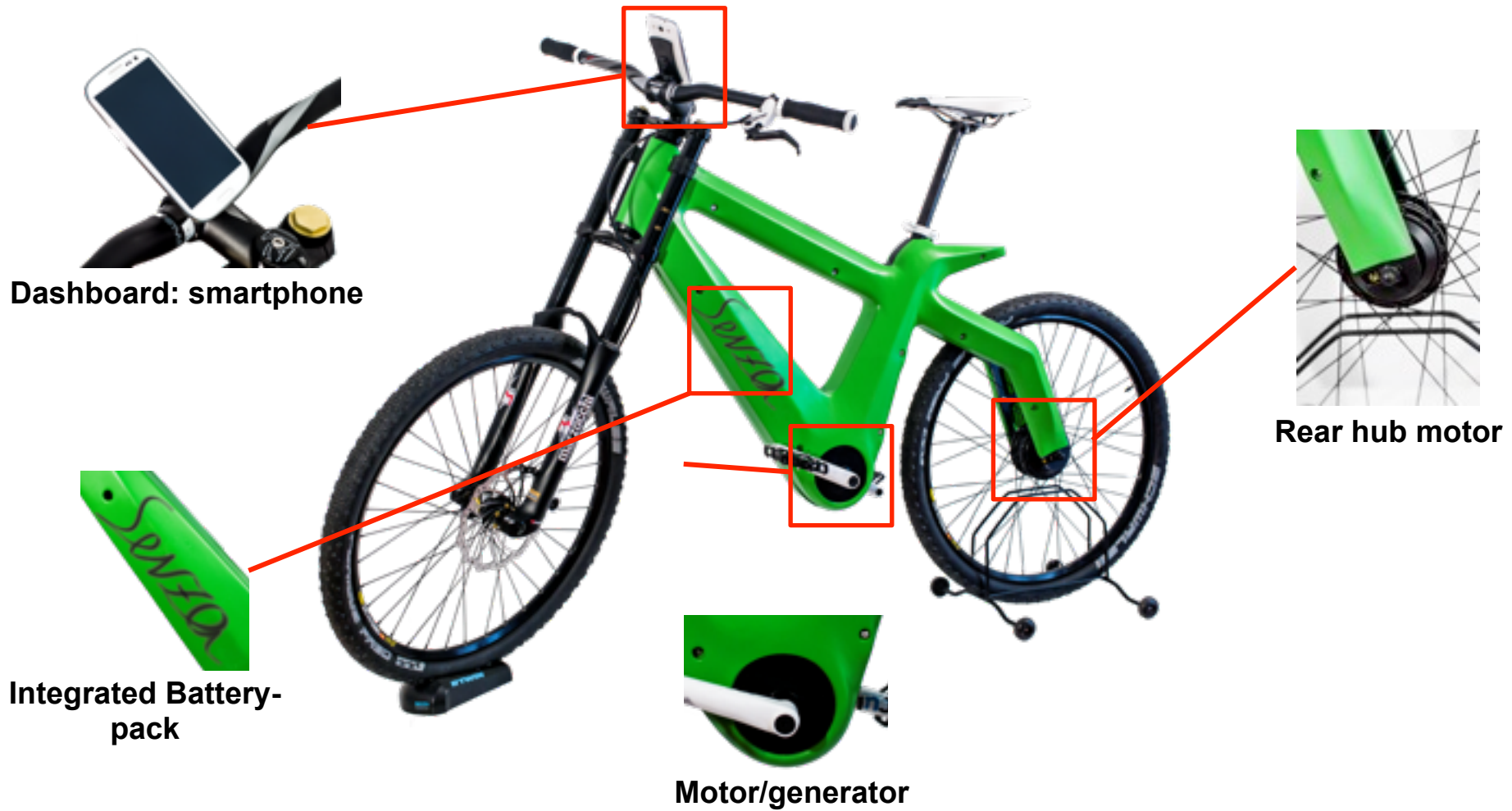


ZEHUS «senza»
Start Of Production : 2015

Emphasis on: **human-synergy**



SENZA: main elements

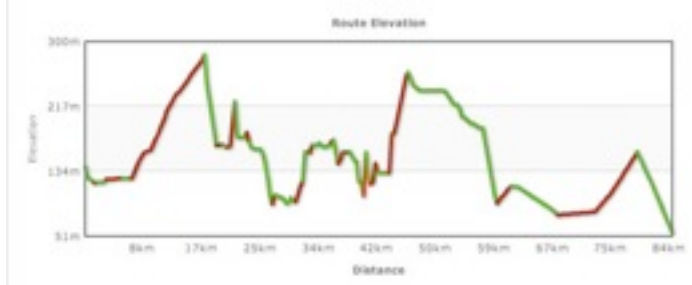
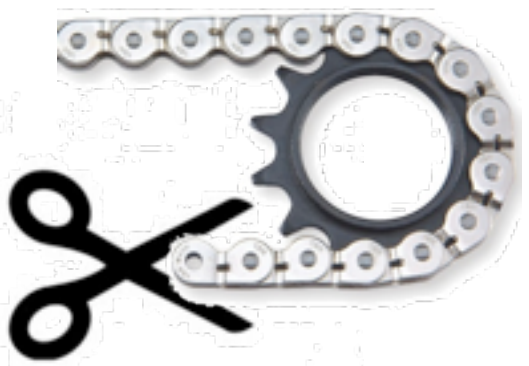




Plug-in serial Hybrid - Opportunity: effort and vehicle-dynamics decoupling

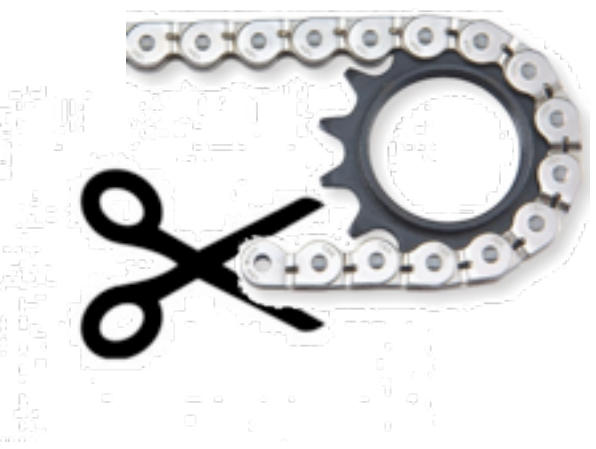
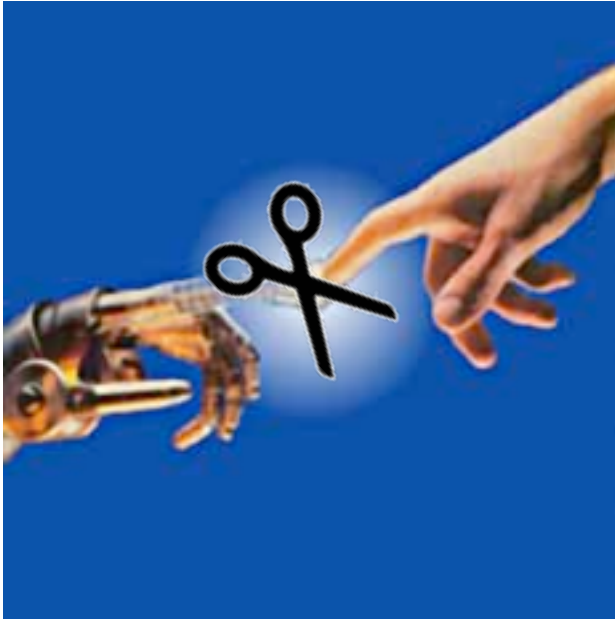


Human effort – Fatigue – Heart-beat profile



Road profile and vehicle dynamics (slopes, speed, accelerations, etc.)

Plug-in serial Hybrid - Challenge (threat): Human-Machine-Interface



Conection is LOST! 

The HMI on the pedals must be rebuilt «electronically»



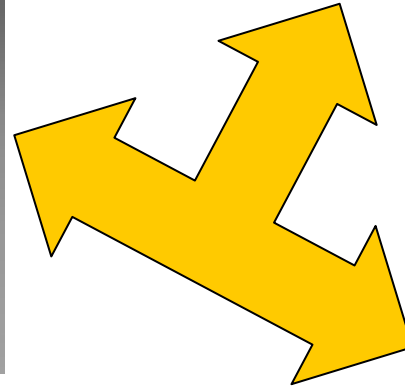
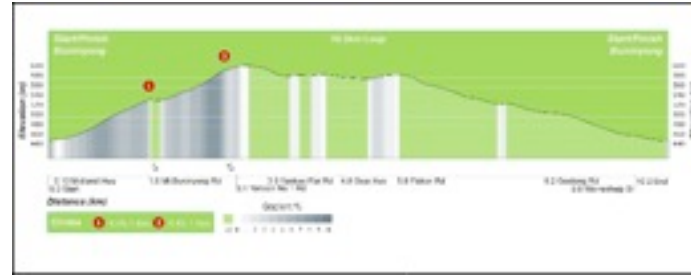
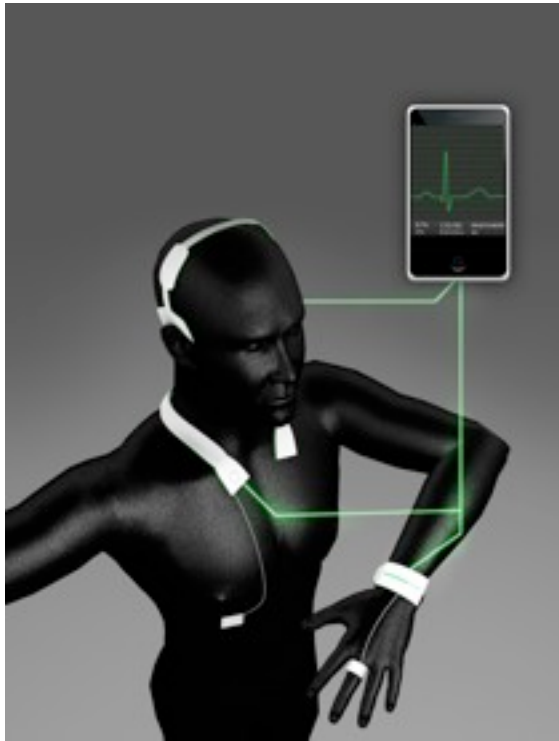
Conclusions

E-Bikes technologies: future (3) main technology challenges





Challenge #1: human synergy



Direct and **controlled** interaction of:

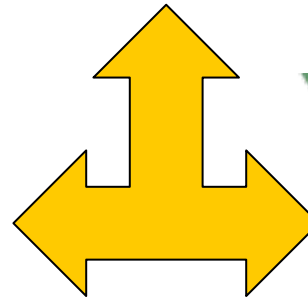
- Ambient conditions
- Human body
- Electric motor/generator



Challenge #2: Human Machine Interface

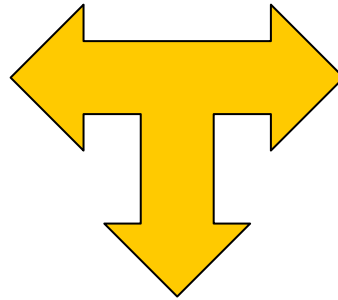
Develop and
personalize:

- Pedal-Force-
feedback Interface
- Personal mobile
device interface





Challenge #3: Internet of Things (IoT)



Intergrate the e-Bike in the networked social life of the user:

- Directly
- Via mobile device





Final remark: hidden (key) technologies

Sensing (slope, torque, road, etc.) or SW-sensing



Control algorithms (energy, force feedback, body parameters, vehicle dynamics)





Bicycle (classic)



E-Bike (PEDELEC)



E-Scooter



1) The technology-portfolio of pedal-assisted vehicles still has some gaps



2) Main technologies to be developed:
Human-synergy
HMI (mostly on pedals)
Networking

3) Hidden key technologies:

- Sensing
- Control





Thanks for your attention