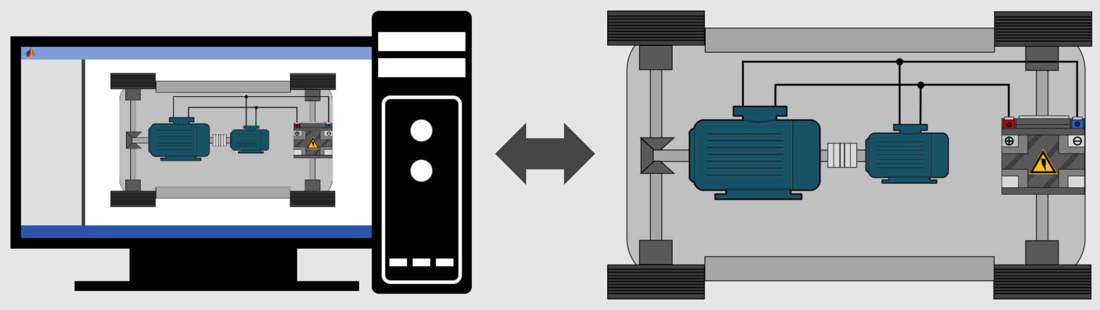
ELECTRICAL ENERGY LAB (EELAB)

Arne De Keyser and Guillaume Crevecoeur

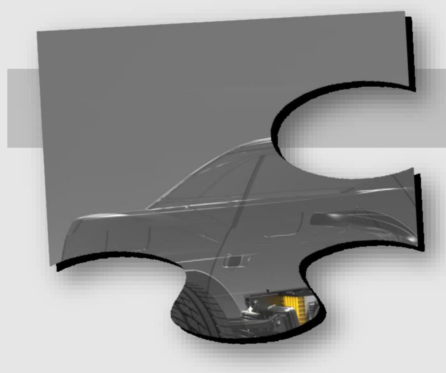
TOWARDS OPTIMAL EXPLOITATION OF ALL-ELECTRIC DUAL DRIVE POWERTRAINS IN SMART E-MOTION SYSTEMS

RESEARCH PROBLEM

Government institutions and industrial partners are aspiring green alternatives for contemporary transportation systems or industrial processes. All-electric drivetrains demonstrate interesting properties in this perspective, as direct harmful emissions in the atmosphere are eliminated. Optimal exploitation of the associated possibilities requires filling the gaps in state-of-the-art technology in terms of topology design, energy-efficient control strategies and supervisory power flow management agents.



An optimal power flow management is assessed for the represented dual-drive topology.



OPTIMAL DESIGN OF AN ALL-ELECTRIC DUAL DRIVE

TIME-EFFICIENT SIZING OF BATTERY AND MOTORS

- Minimize computational time for design
- Minimize design and operational costs

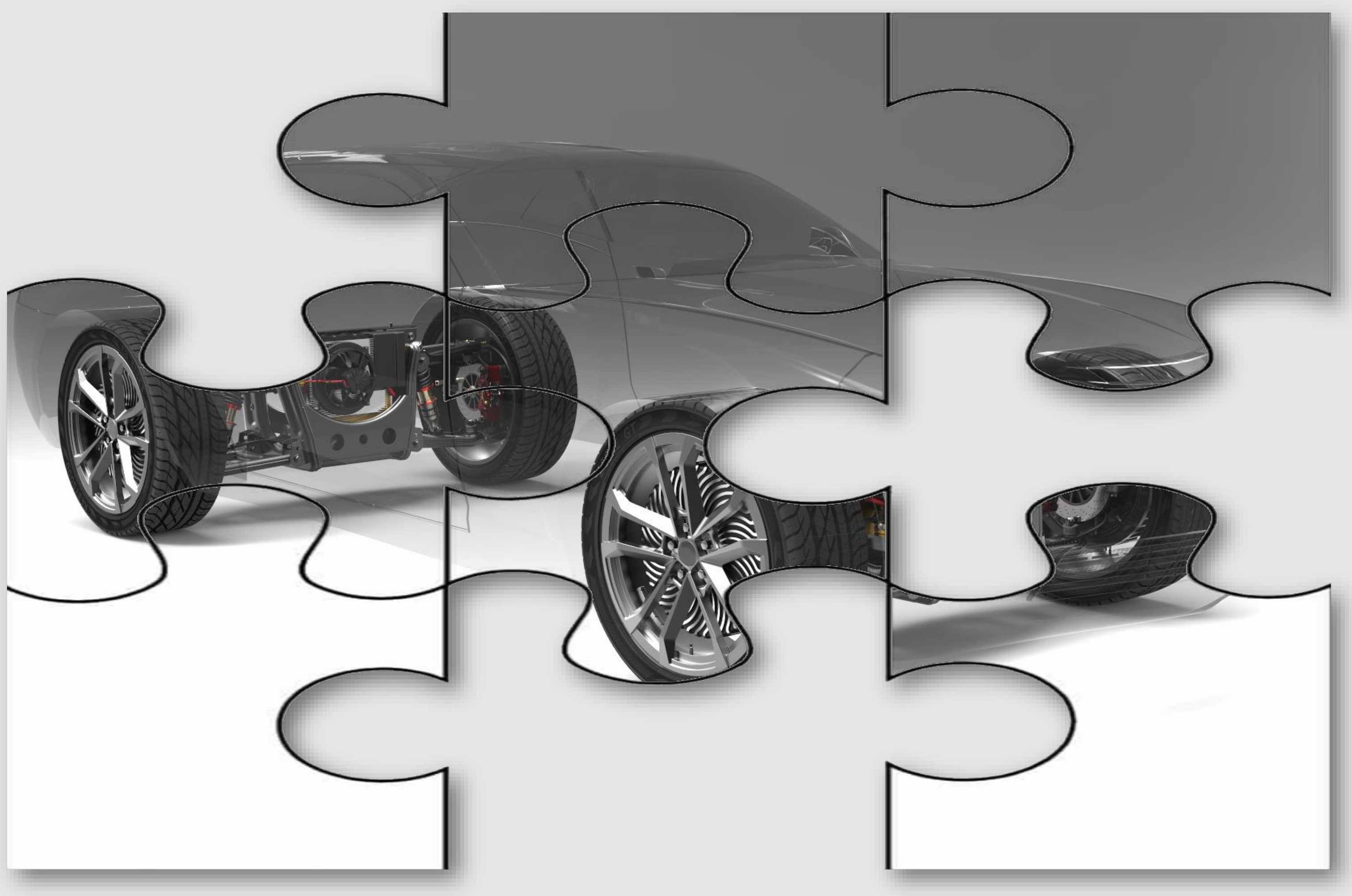
GENETIC ALGORITHM ← *cost function*

iterations ↓

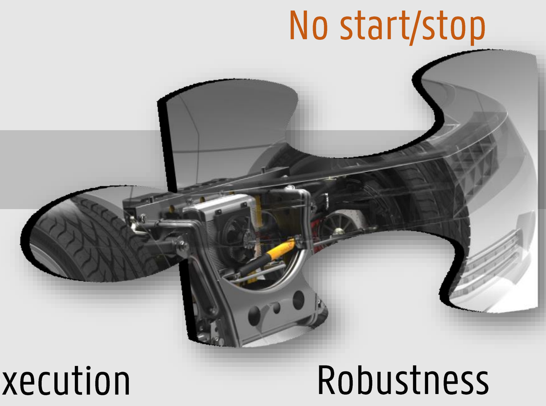
BATTERY PACK SIZE + POWER RATING MOTORS

RATIONALE BEHIND DUAL DRIVE TOPOLOGY

Highway		Traffic		Mountain
High speed High power No start/stop	VS	Low speed Low power Start/stop	VS	Low speed High power No start/stop



OPTIMAL CONTROL STRATEGY



ENERGY-EFFICIENT REFERENCE TRACKING

Energy-efficiency | Accurate tracking | Real-time execution | Robustness

APPROXIMATE DYNAMIC PROGRAMMING

$$\min_{S_{abc}} \sum_{k=1}^{N} \gamma^{k-1} \ell\left(\boldsymbol{x}(k)\right) + \gamma^{N} \hat{V}_{\Omega}\left(\tilde{\boldsymbol{x}}(N)\right)$$

Summarize expected future behavior

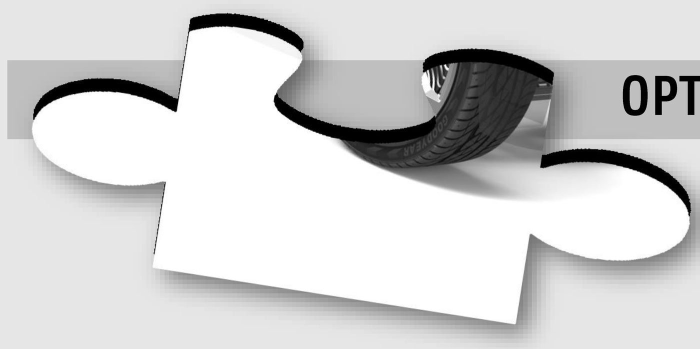
FPGA IMPLEMENTATION

FPGAs

Parallelized calculations

PARAMETER ESTIMATION

Sensor data
+
Model expectations
↓
Estimated parameters



OPTIMAL POWER FLOW MANAGEMENT

REAL-TIME DISTRIBUTION OF POWER DEMAND

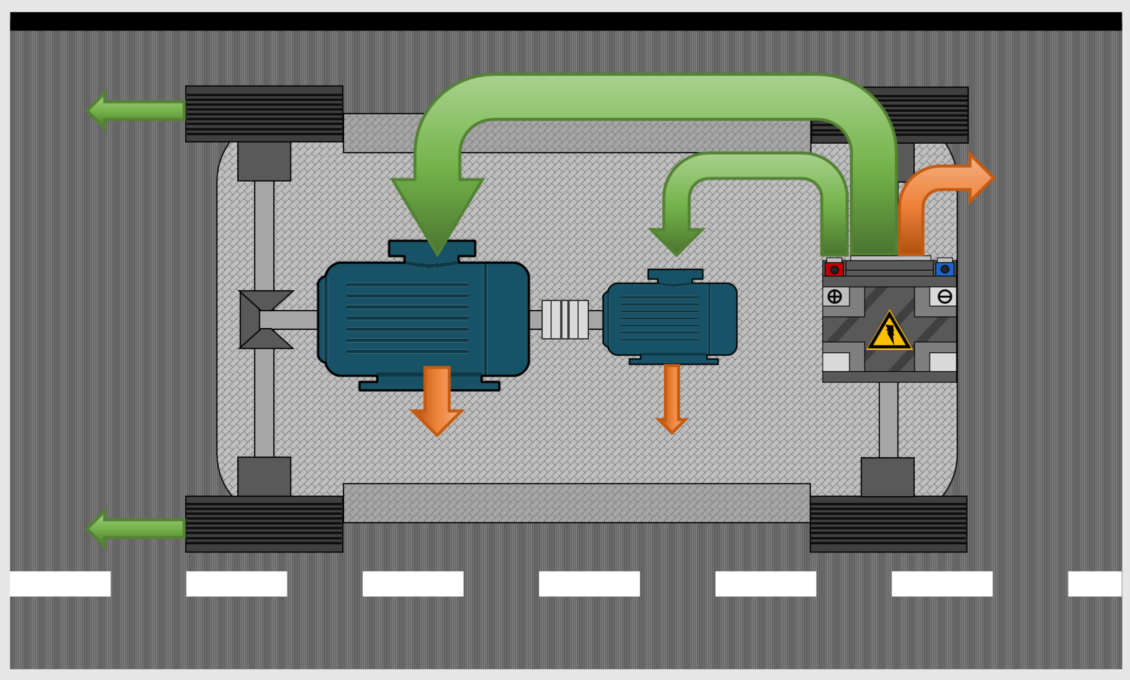
- Provide discrete on/off-commands to distinct motor drives
- Generate desired torque references for each separate motor
- Minimize consumed battery power $P_{i,ba}$

(first two items) → $\boldsymbol{u}_c^*$

$$\min_{\boldsymbol{u}_c^*} \sum_{k=1}^{M} P_{i,ba}\left(x_c, u_c\right) \Delta t \xrightarrow{\text{maximal radius}}$$

battery + motors → *automated regression* → POWER DISSIPATION → *dynamic programming*

+16%



RESEARCH RESULTS

The conducted research aims at assembling some of the missing pieces to render all-electric drivetrains into a viable alternative of their contemporary combustion-based counterparts. Several aspects have been covered:

- DESIGN: Efficient modeling strategies combined with the utilization of an evolutionary algorithm allows to cut down the necessary optimization time by 99,3% when benchmarked against traditional approaches.
- CONTROL: The challenge to be tackled consists of optimizing both torque tracking and energy efficiency simultaneously. Dedicated approximate dynamic programming is able to reduce the overall cost by up to 57,3%.
- POWER FLOW MANAGEMENT: Employing automated regression techniques to cast the power dissipation of the subsystems into efficient dissipation models and subsequently plugging this into a supervisory dynamic programming agent provides range extensions of approximately 16%.

Contact

arndkeys.dekeyser@ugent.be
www.ugent.be

Universiteit Gent
@ugent
Ghent University