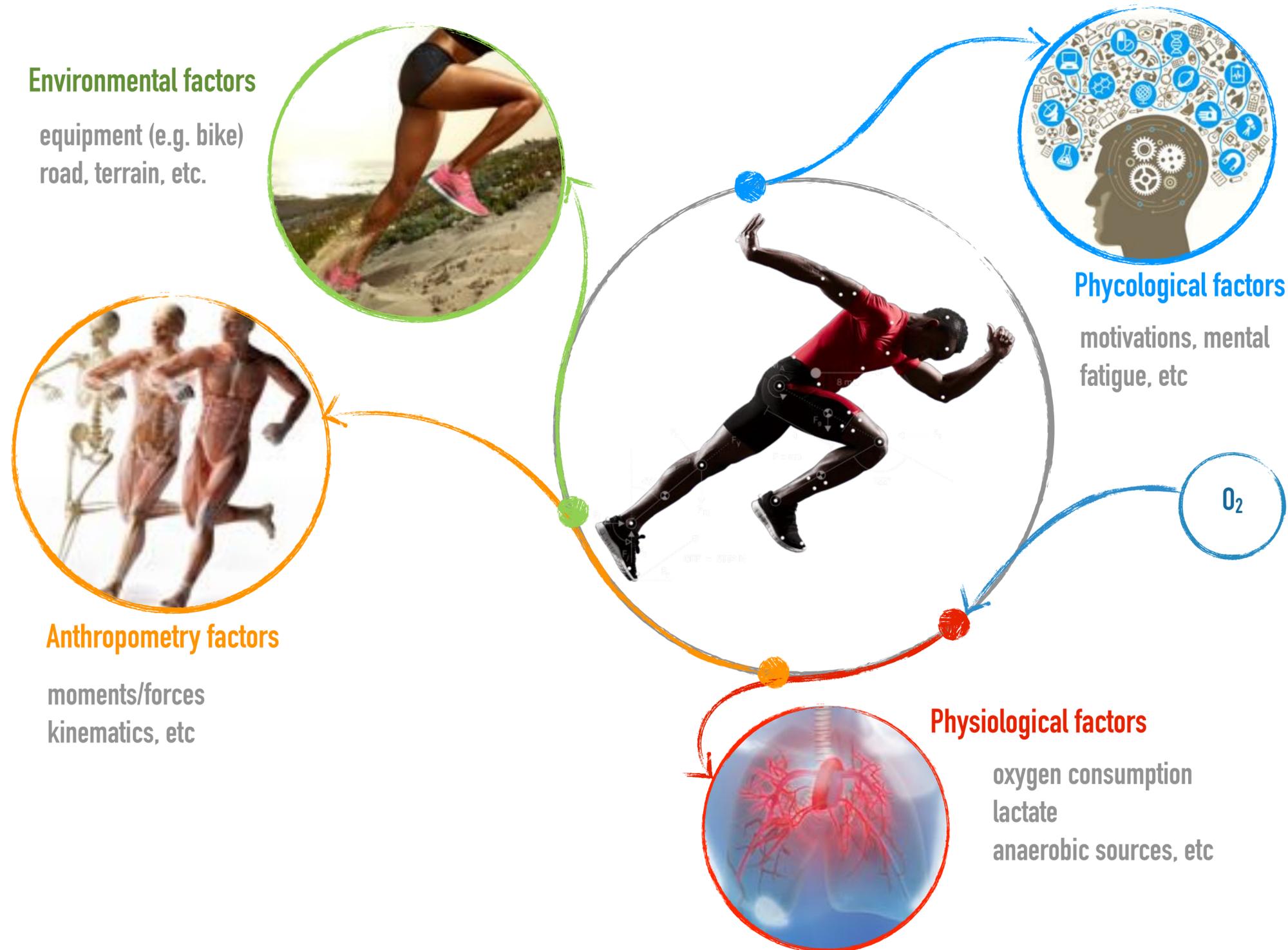




MODELLING AND OPTIMIZATION OF SPORT PERFORMANCE: EXPLOITING WEARABLE TECHNOLOGY AND AI

Francesco Biral, Andrea Zignoli, Enrico Bertolazzi - DII-University of Trento
Barbara Pellegrini, Alessandro Fornasiero, Federico Schena - CeRiSM Research Centre, University of Verona, Rovereto, (TN), Italy
Paul Laursen, Sports Performance Research Institute NZ, Auckland University of Technology

FACTORS IN HUMAN PERFORMANCE



Many challenges:

- Extremely complex system
- need a large variety of data
- in completely different scientific domains



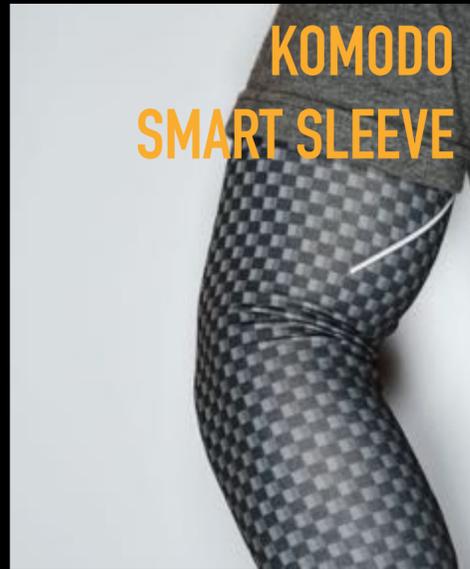
PERFORMANCE IS EVERYTHING

Notio Konect is a state-of-the-art tool. Whether you're looking to boost performance or just increase your enjoyment, this compact piece of technology measures and correlates multiple data in real time. Notio Konect helps both competitive and recreational cyclists perform better, at any level.

NOTIO KONECT



System"?
h is an



KOMODO SMART SLEEVE



HEXOSKIN SMART SKIRT



KOMODO SUIT



SUPA POWERED BRA

MOTION CAPTURE

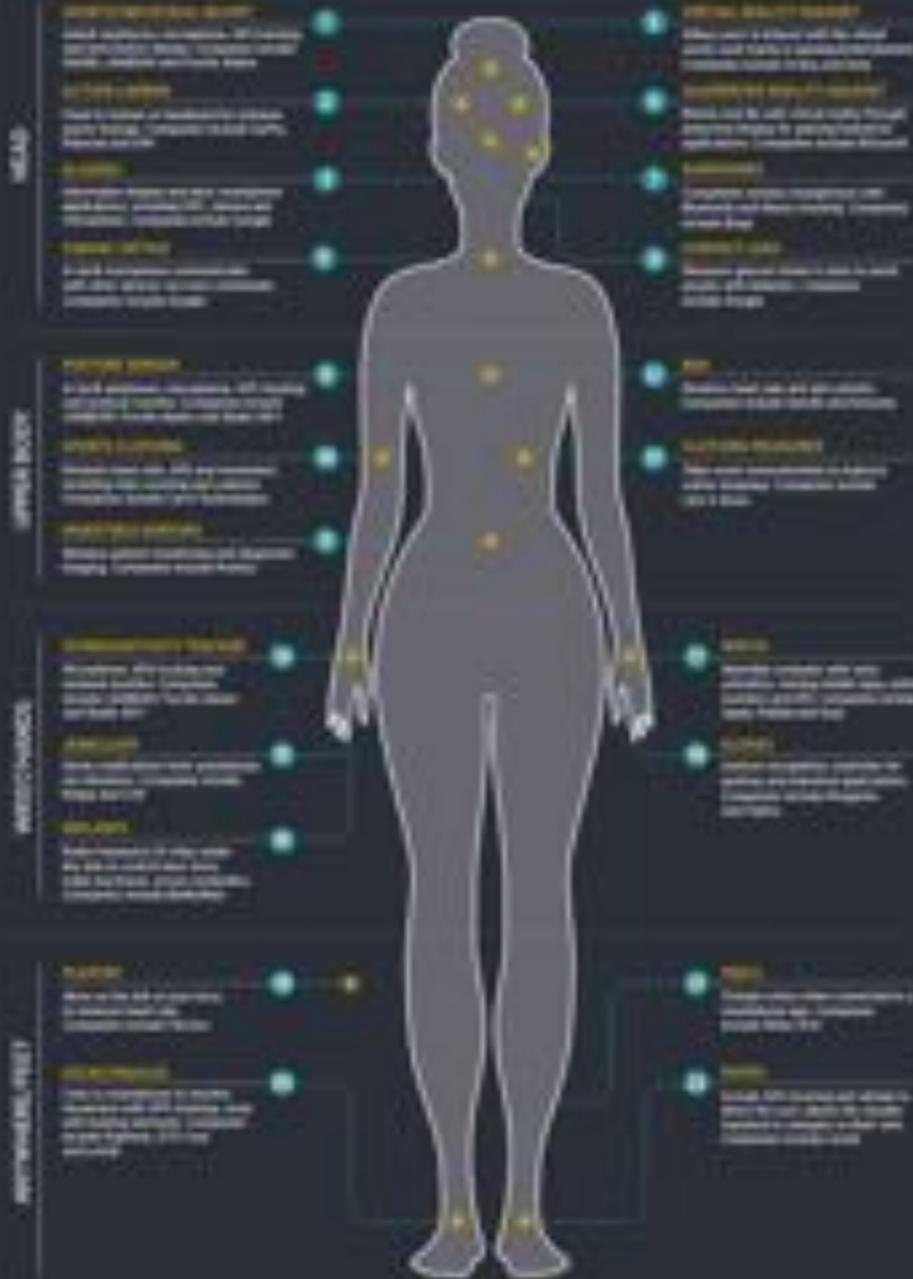
PIVOT



BSX LACTATE SENSOR

Miniaturised wearable biosensors, microelectronics and low power wireless communications

ANALYSIS AND APPLICATION OF WEARABLE DEVICES



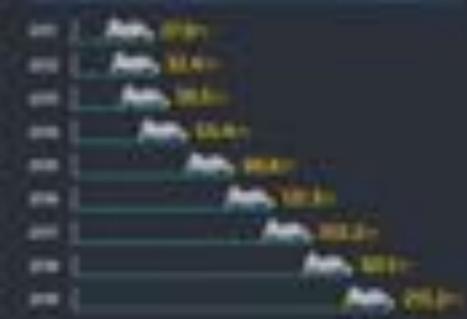
WEARABLES REGIONAL MARKET SHARE



TOP BENEFITS OF USING A WEARABLE DEVICE IN AN ENTERPRISE



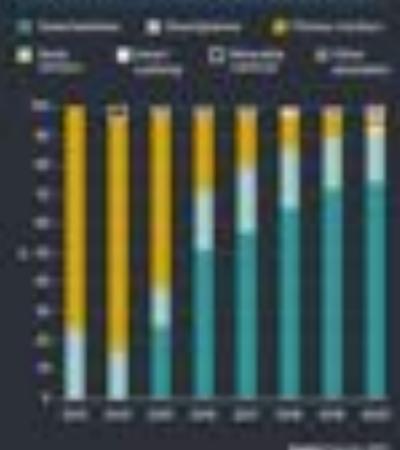
TOTAL ESTIMATED SHIPMENT VOLUME OF GLOBAL WEARABLES (IN UNIT SALES)



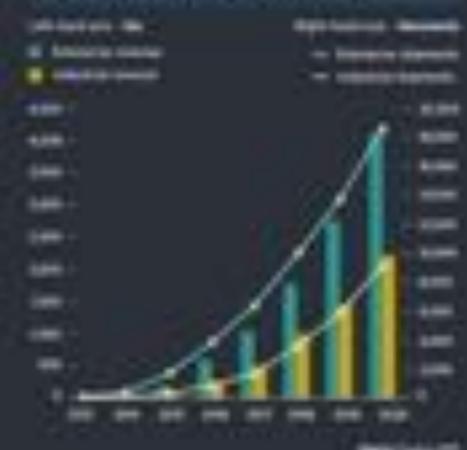
QUARTERLY PRIVATE WEARABLE TECHNOLOGY FUNDING 2010-2025



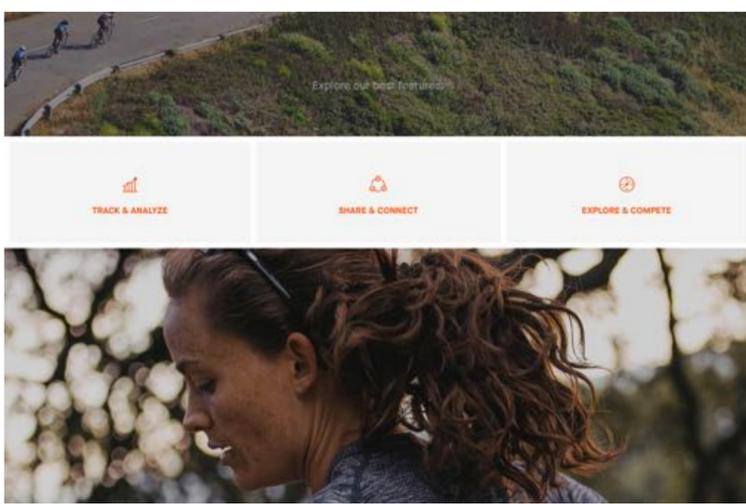
GLOBAL ENTERPRISE AND INDUSTRIAL WEARABLE REVENUE SHARE BY DEVICE



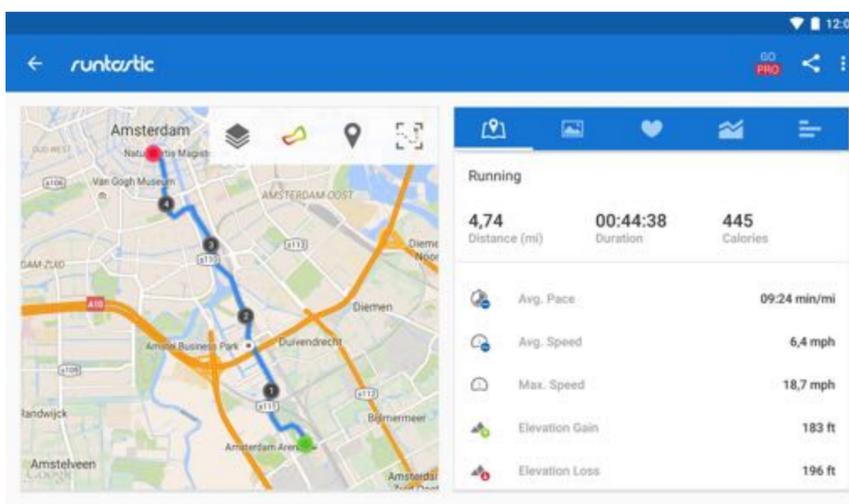
GLOBAL ENTERPRISE AND INDUSTRIAL WEARABLE SHIPMENT AND REVENUE



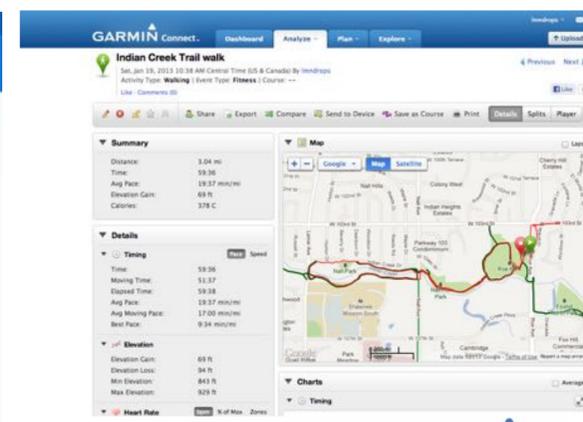
Growing trends in wearable technology



STRAVA™



runtastic



GARMIN™



TRAINING PEAKS™



LARGE DATABASE OF COLLECTED DATA: READY TO BE EXPLORED!



HOW DO WE INTERPRET AND USE THIS LARGE AMOUNT OF DATA?

- ***Models***: we can learn from *past data*
- we can use model to *predict* future data
- if prediction is “good” we can *optimise*

MODELS

'mɒd(ə)l/

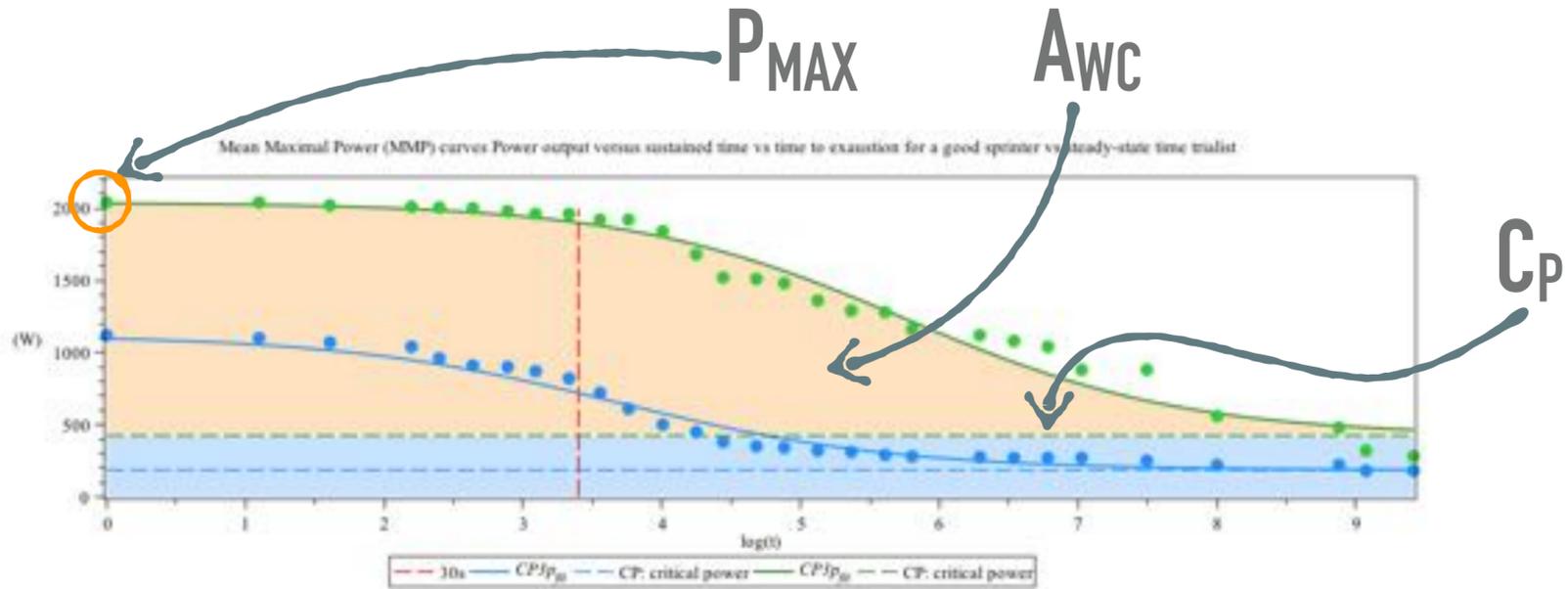
noun

A simplified description, especially a mathematical one, of a system or process, to assist calculations and predictions.

"a statistical model used for predicting the survival rates of endangered species"



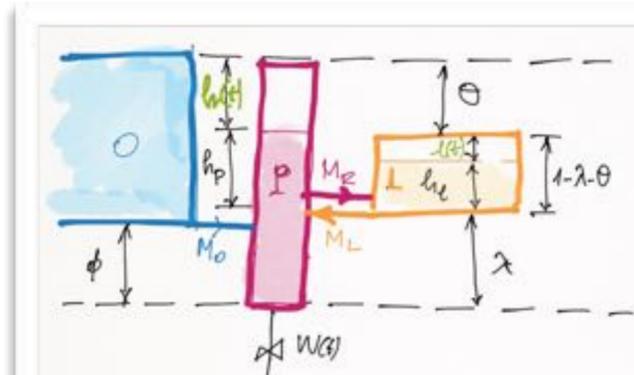
TRADITIONAL MODEL FOR PHYSIOLOGICAL RESPONSE ($\dot{V}O_2$ [LA])



$$\frac{d}{dt} \dot{V}O_2(t) = -\frac{\dot{V}O_2(t) - P_{m_{ae}}(t)}{\tau_{\dot{V}O_2}}$$

$$PO = \frac{W'}{t} + CP$$

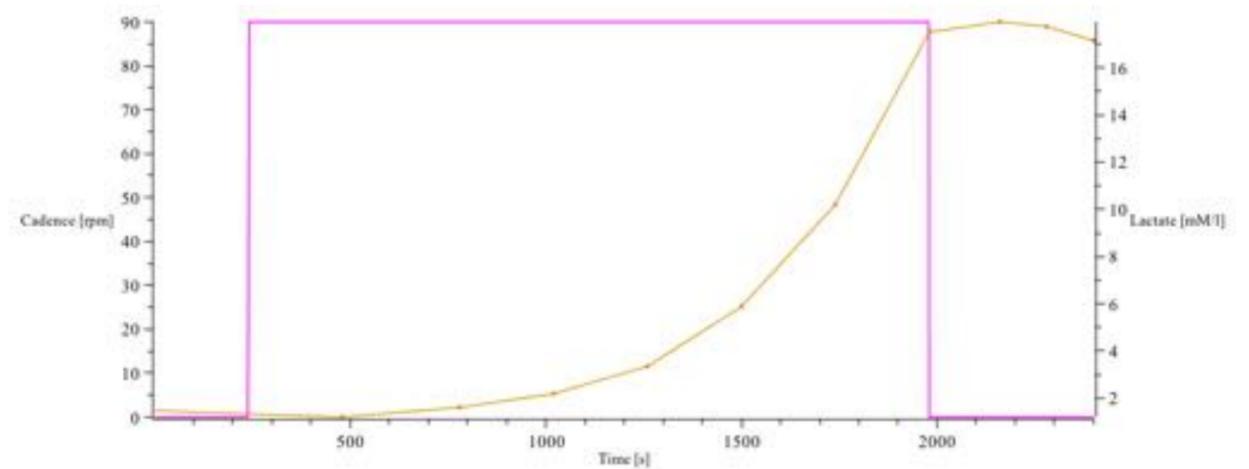
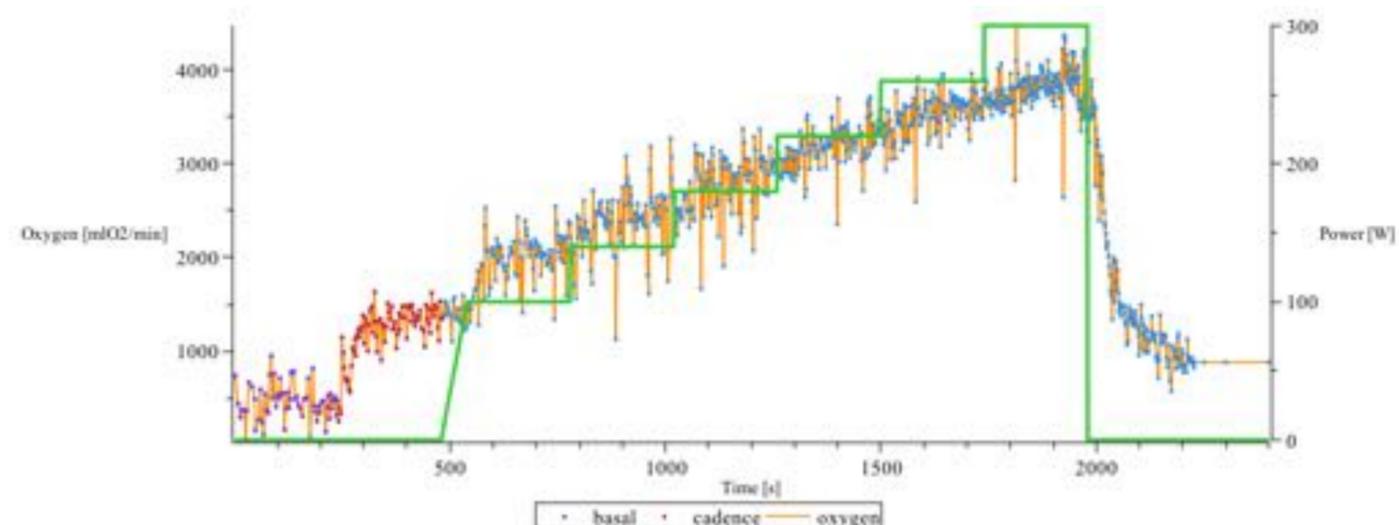
W' = Anaerobic Work Capacity, AWC



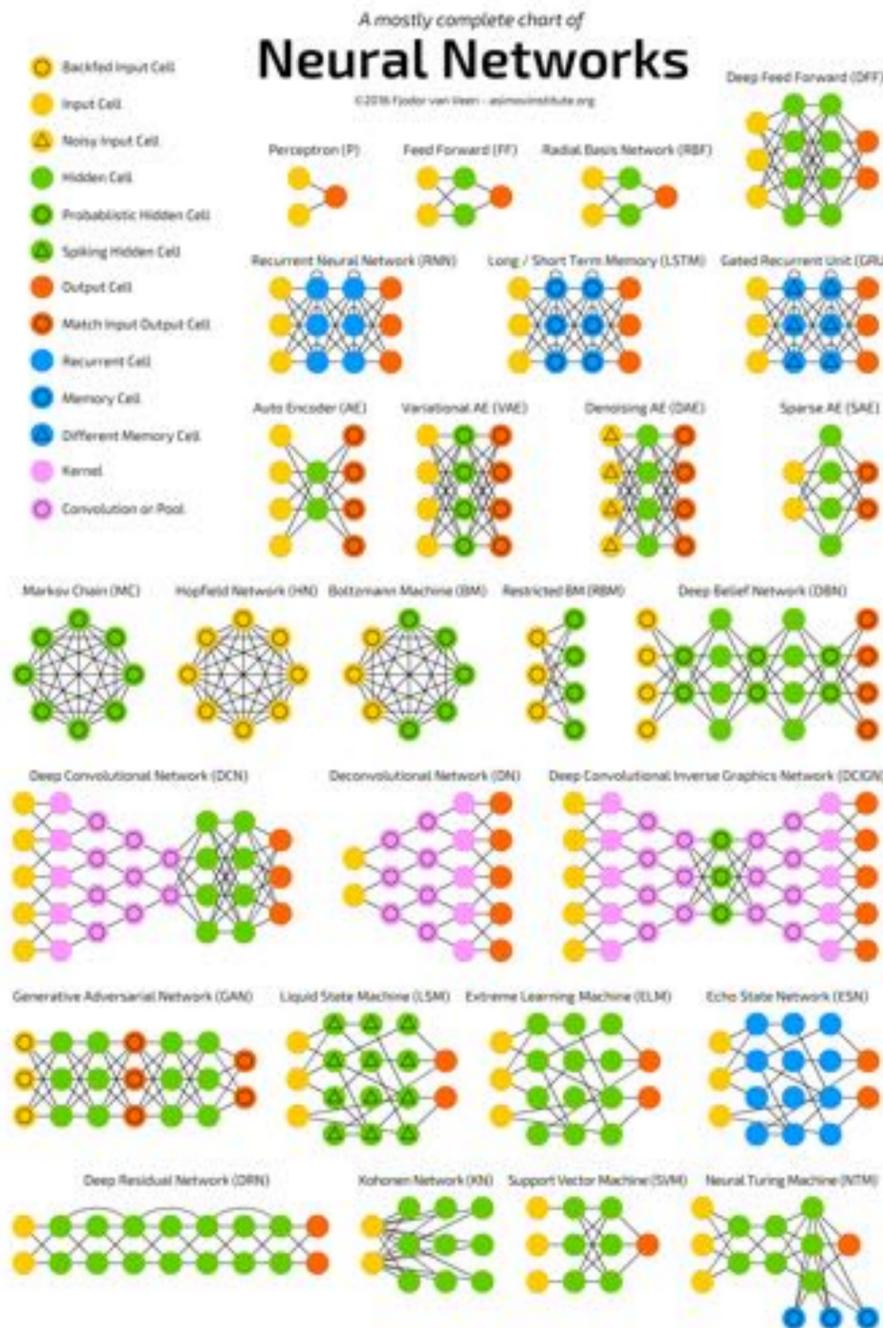
$$P_o = \frac{M_o}{1-\phi} \min(1-\phi, l(t))$$

OXYGEN CONTRIBUTION

$$P_p = W(t) - A_L \frac{dl(t)}{dt} - \frac{M_o}{1-\phi} \min(1-\phi, l(t))$$



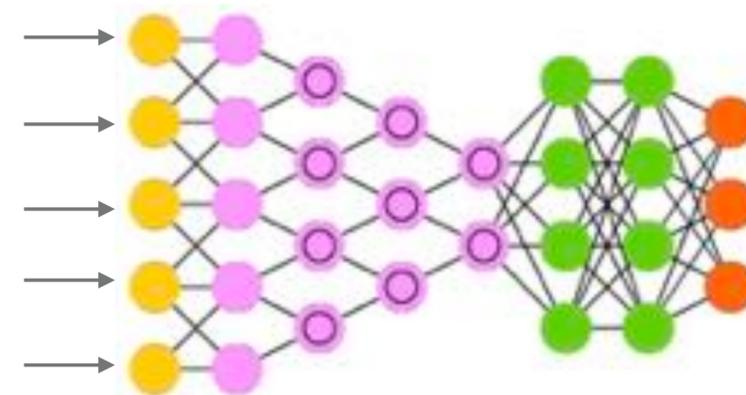
WHAT IF WE WANT TO LET ALGORITHM FIND KNOWLEDGE? ARTIFICIAL INTELLIGENCE



INPUT

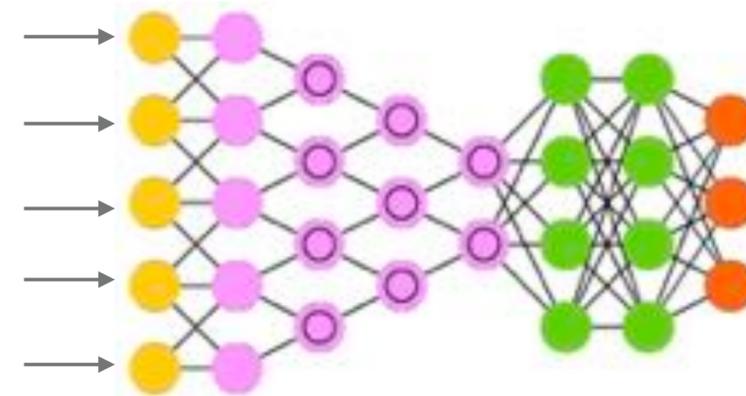
OUTPUT

TARGET

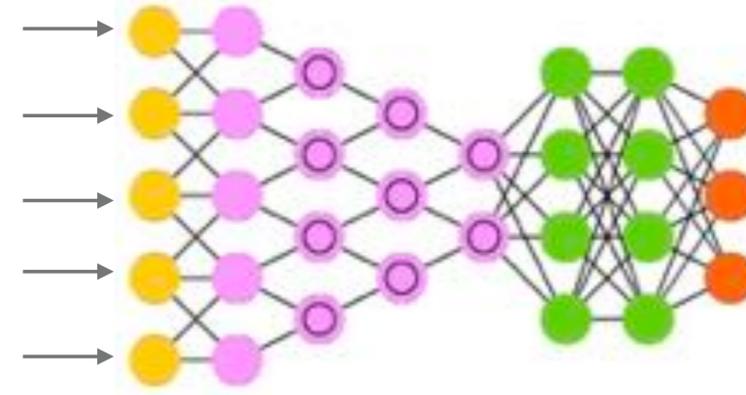


TRAINING

VALIDATION DATA



VALIDATION



USE

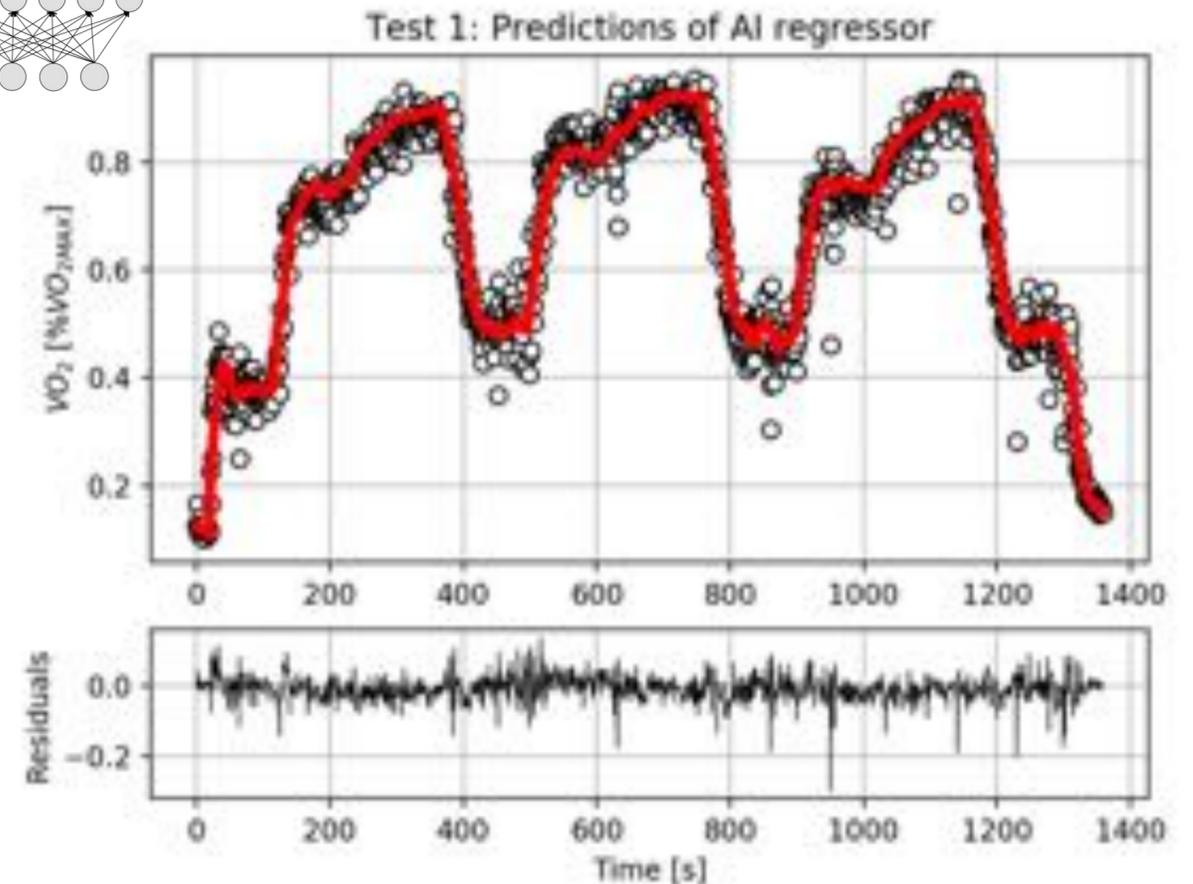
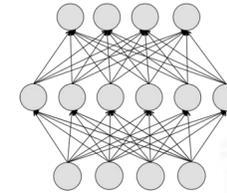
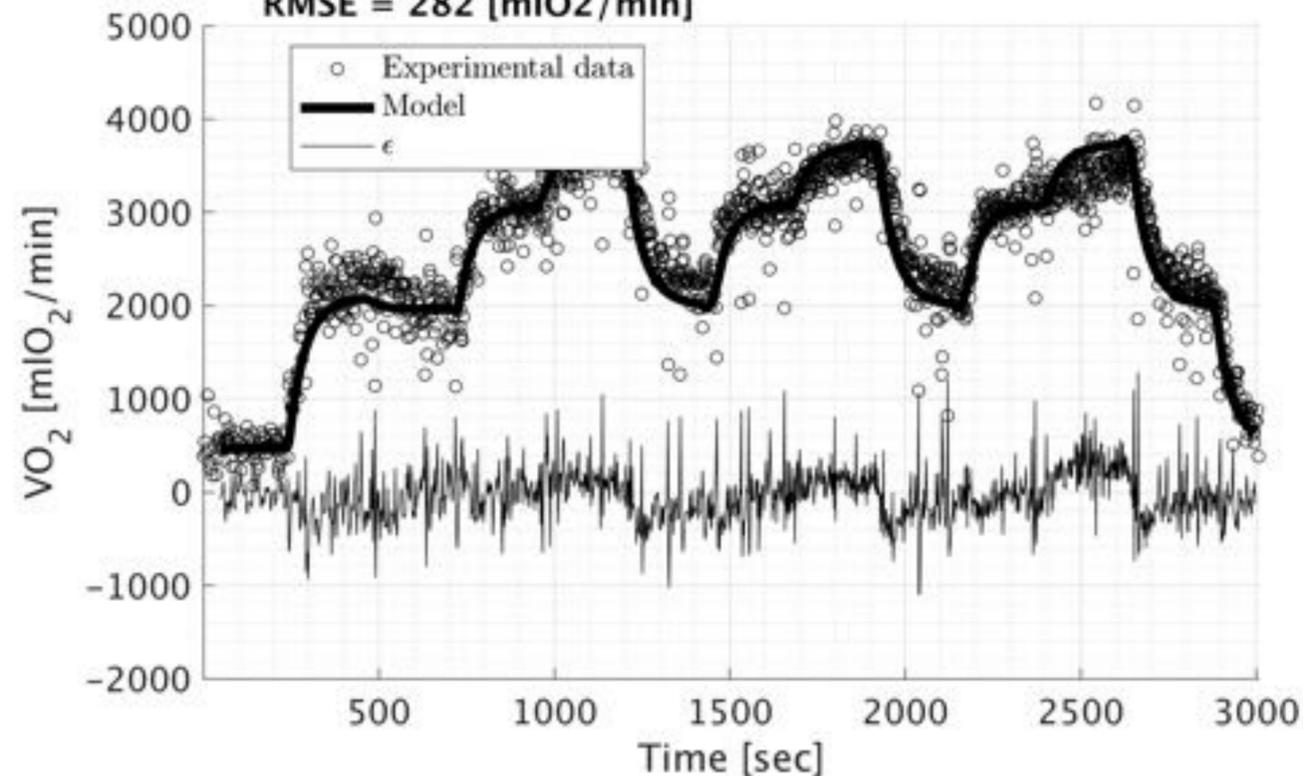
TRADITIONAL MODELS VS ARTIFICIAL INTELLIGENCE

- Is that possible to predict exercising VO_2 response by means of AI technologies like machine learning and Deep Neural Networks?

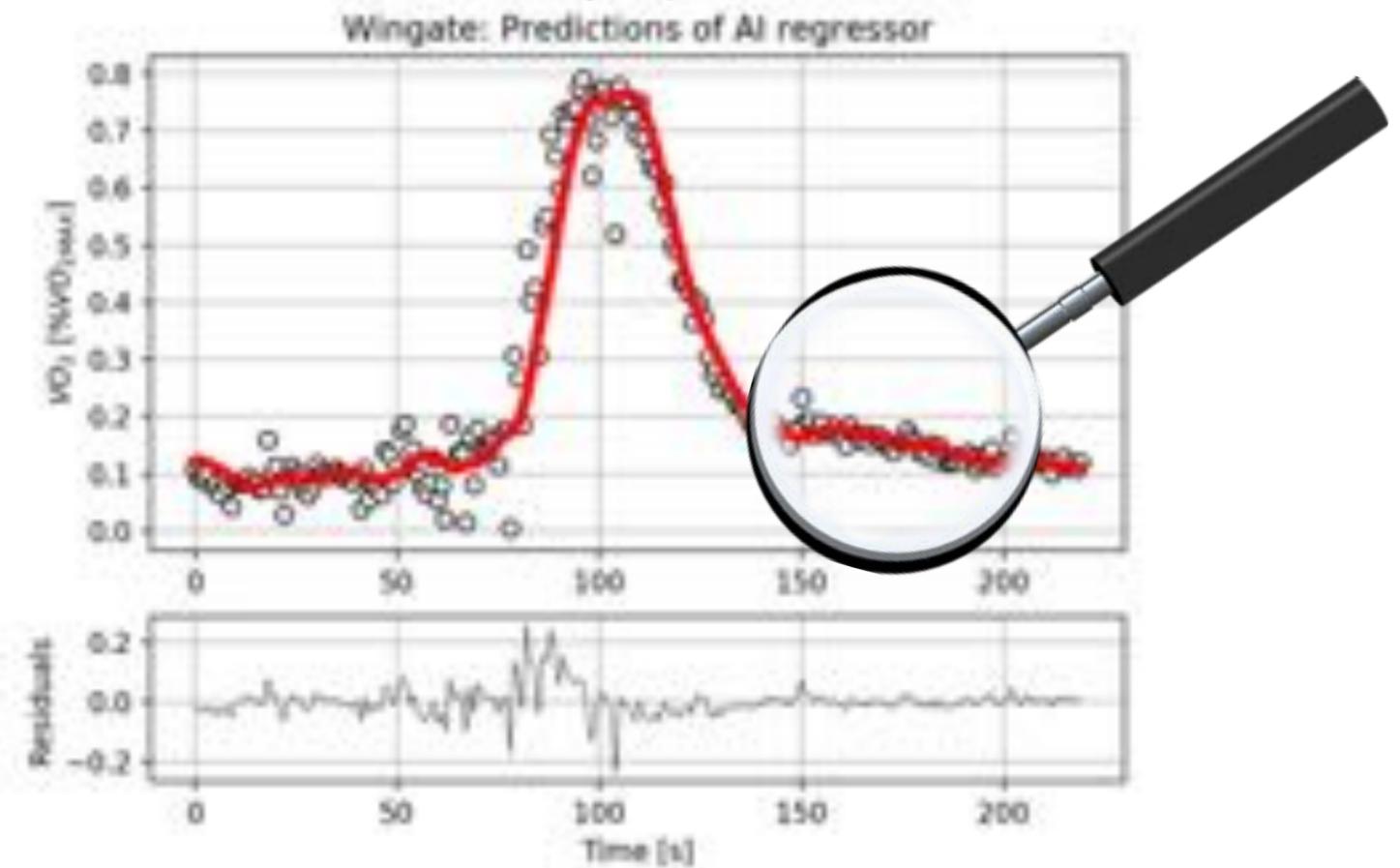
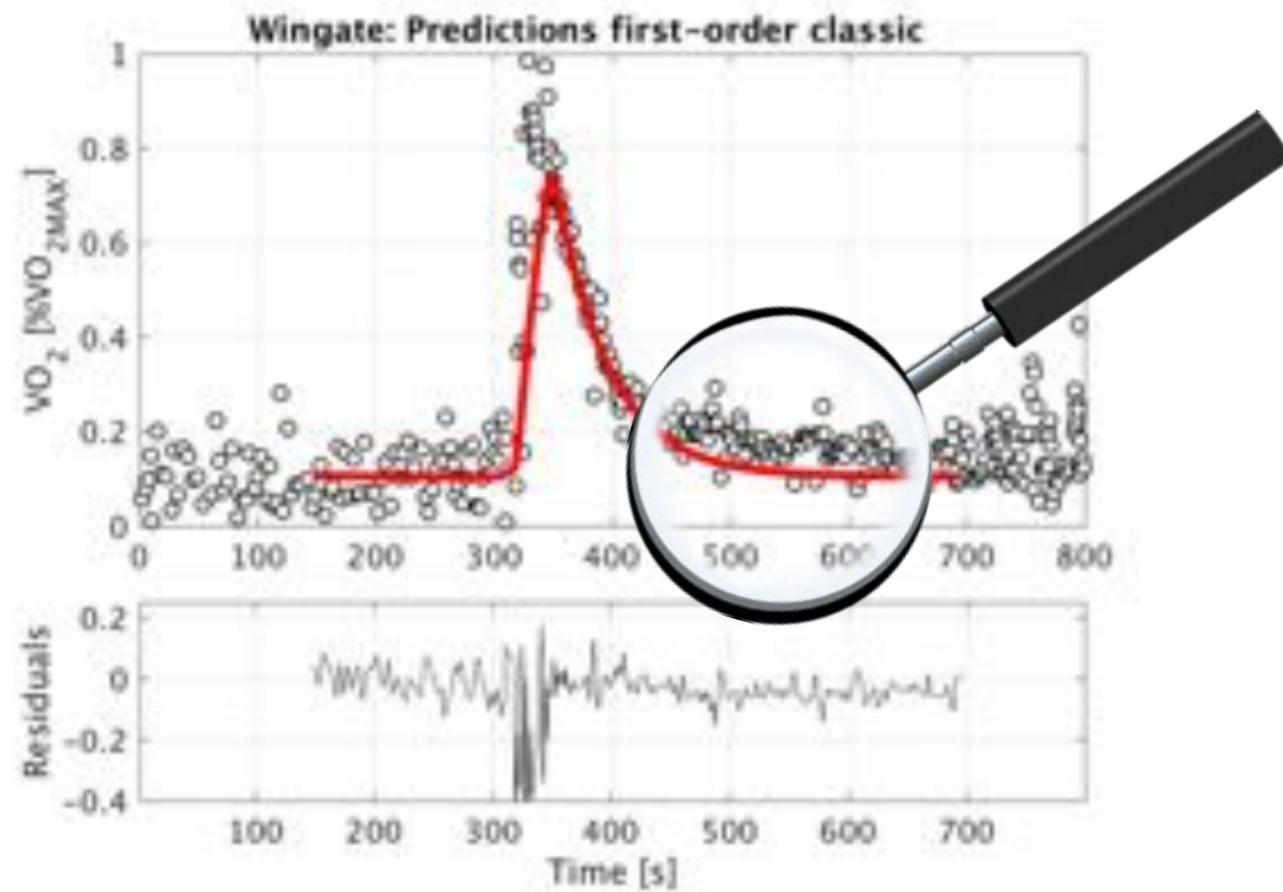
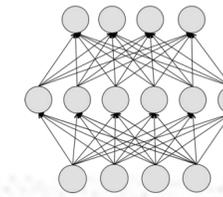


Pulmonary oxygen consumption (model n2)

$\epsilon = -41.1$ [mlO₂/min]
 $\epsilon \% = -0.879$ [%]
 $R^2 = 89$ [%]
RMSE = 282 [mlO₂/min]



TRADITIONAL MODELS VS ARTIFICIAL INTELLIGENCE



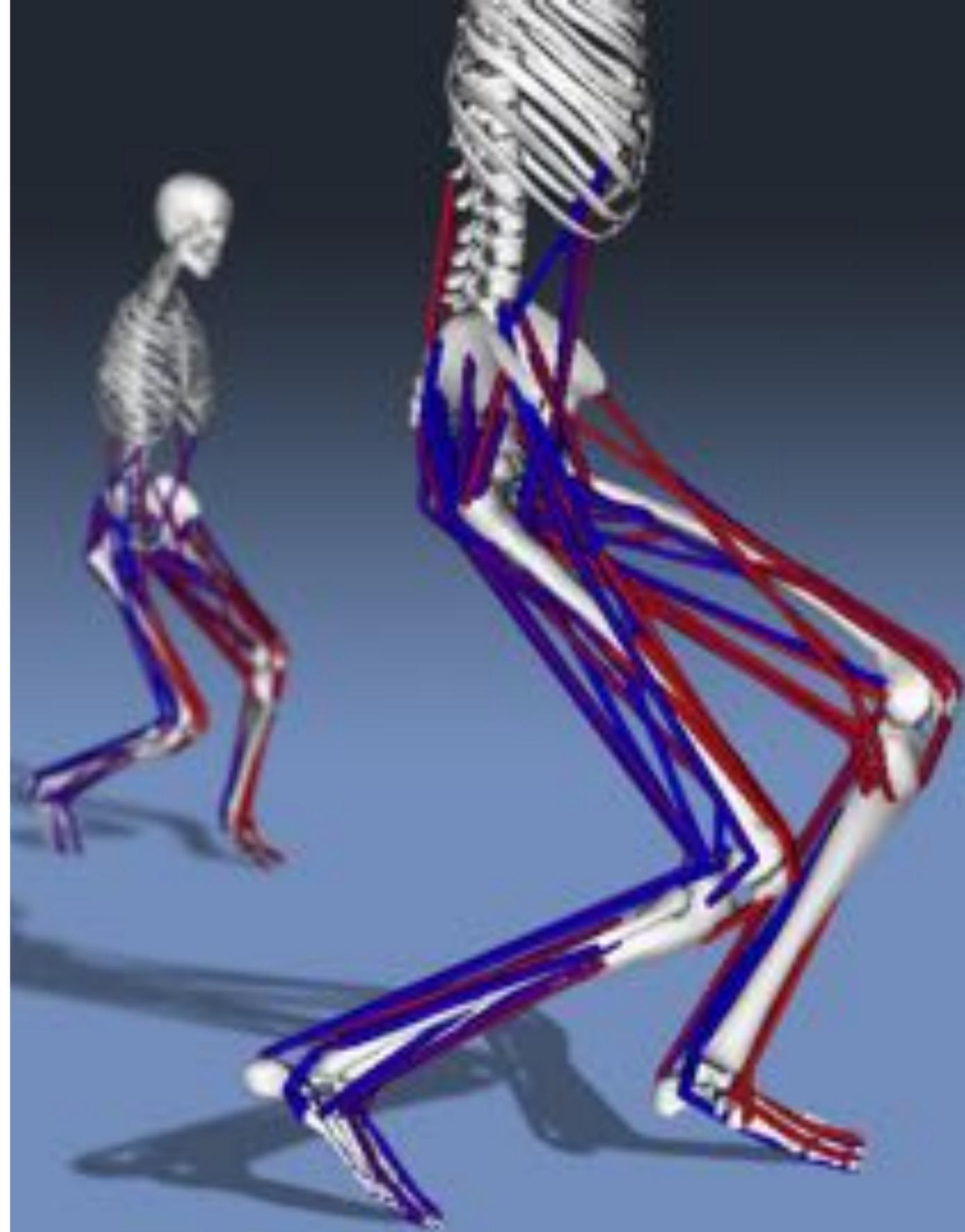
Zignoli et al. 2017 (in submission)



PREDICTION

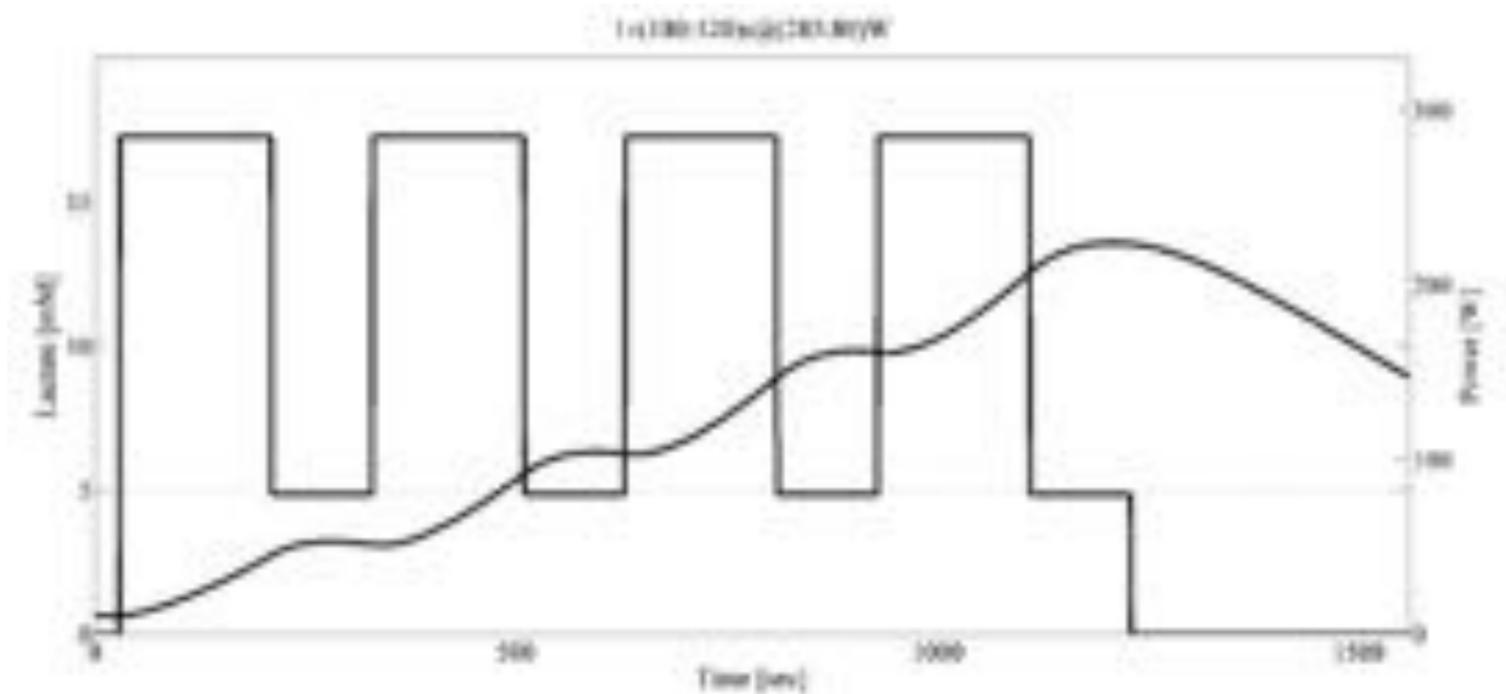
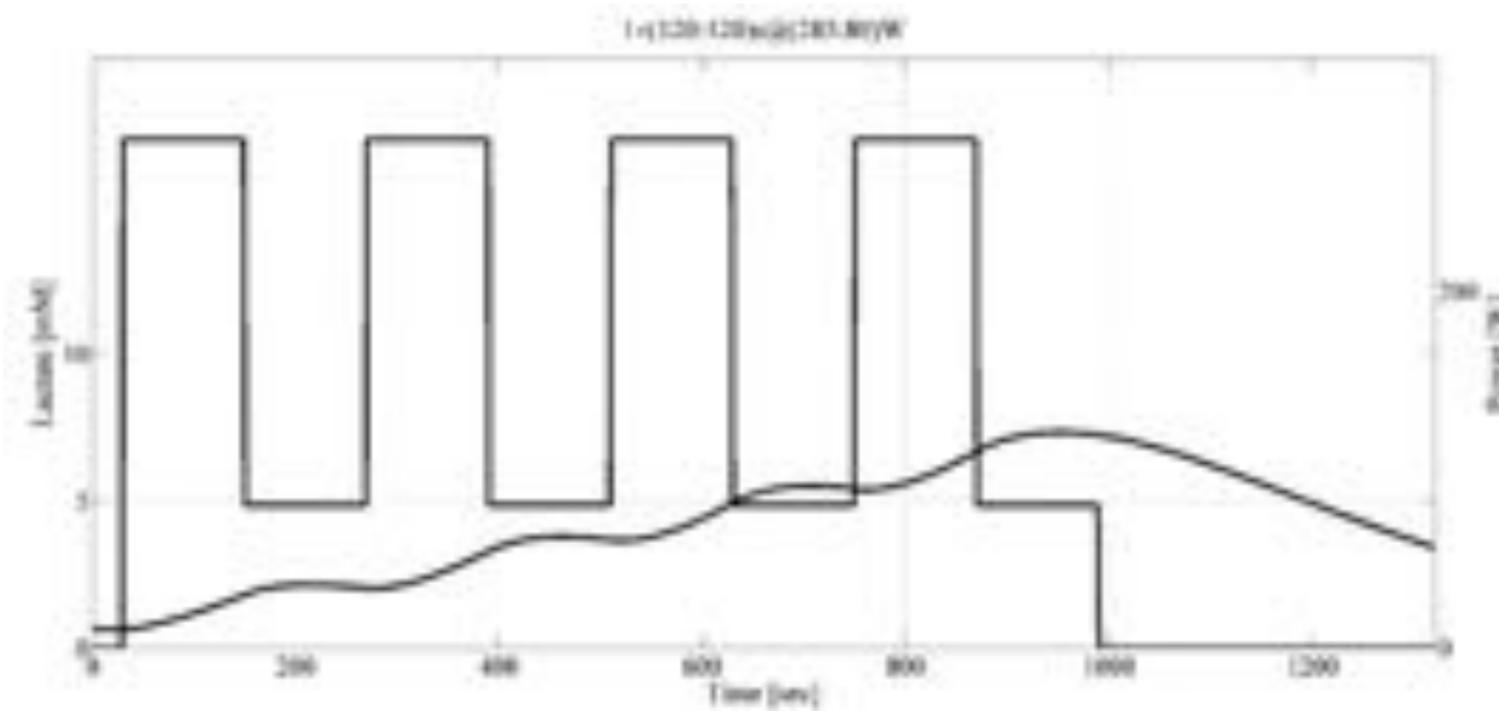
pri'diks(ə)n/
noun

- 1. a thing predicted; a forecast.*
"a prediction that economic growth would resume"
- 2. the action of predicting something.*
"the prediction of future behaviour"



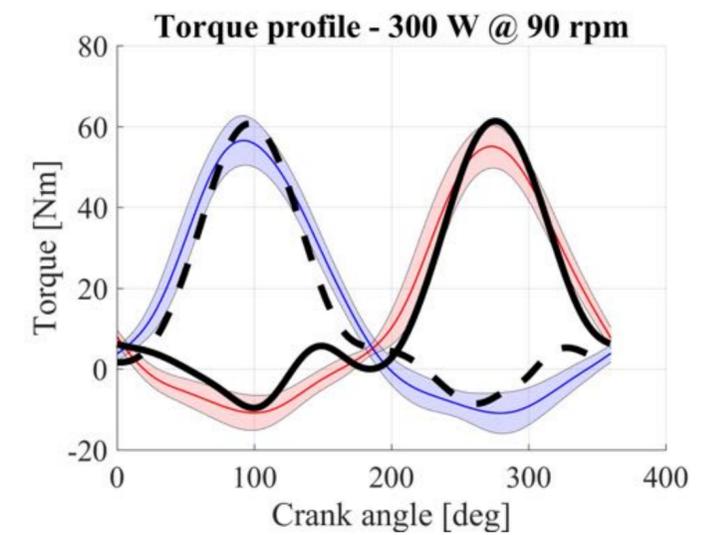
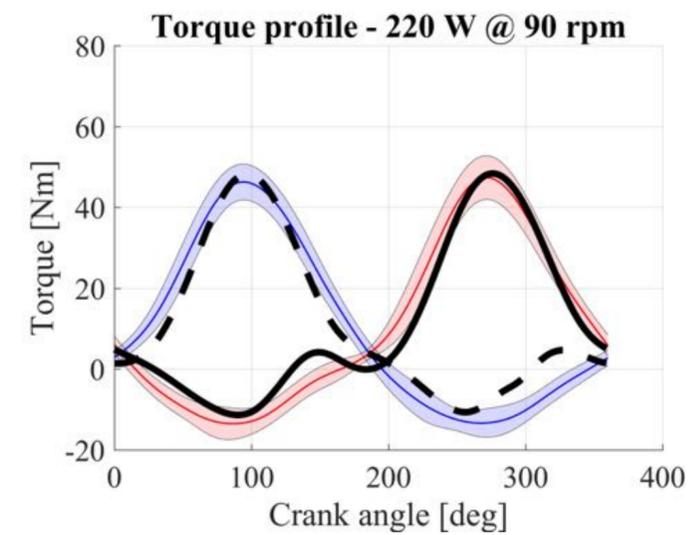
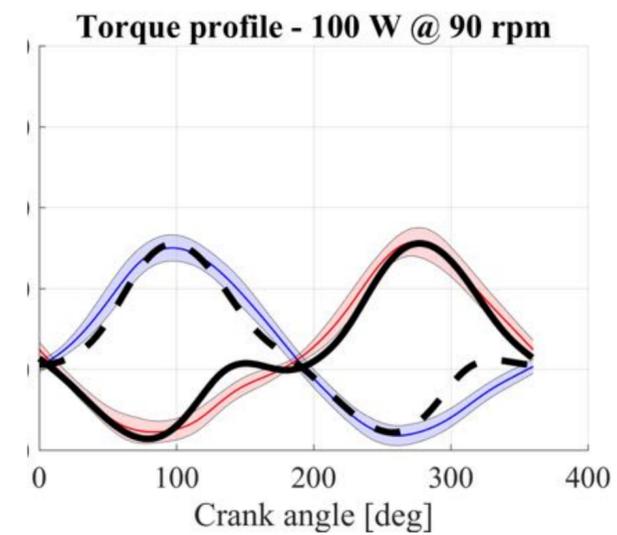
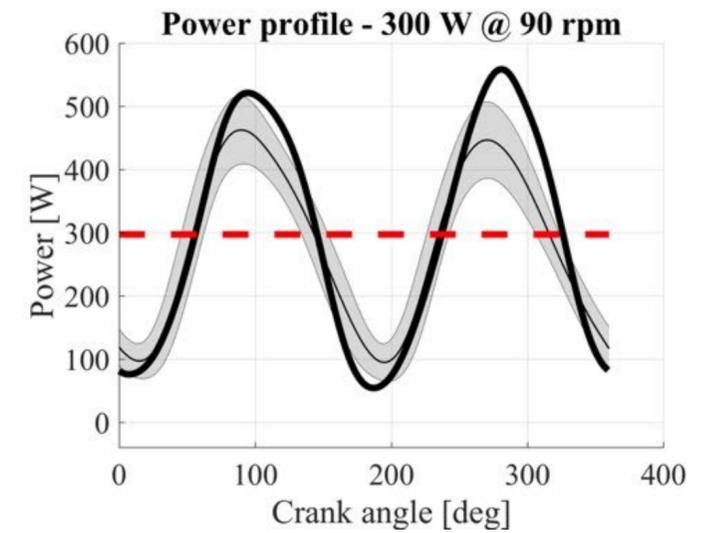
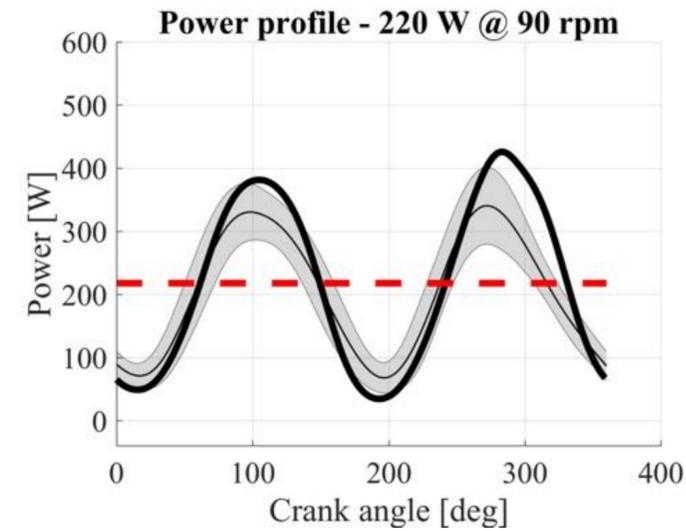
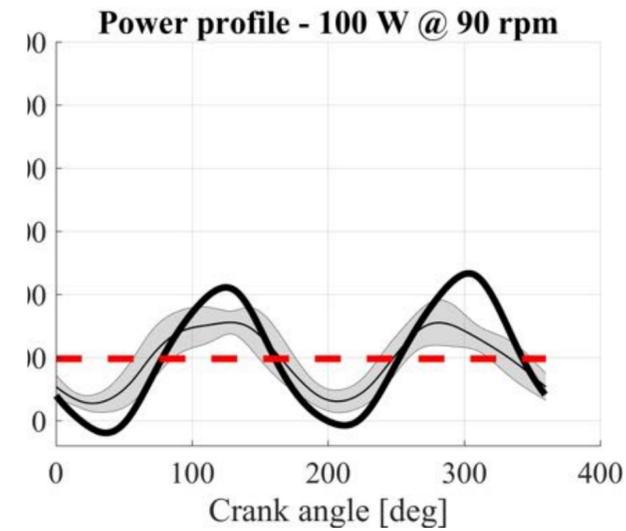
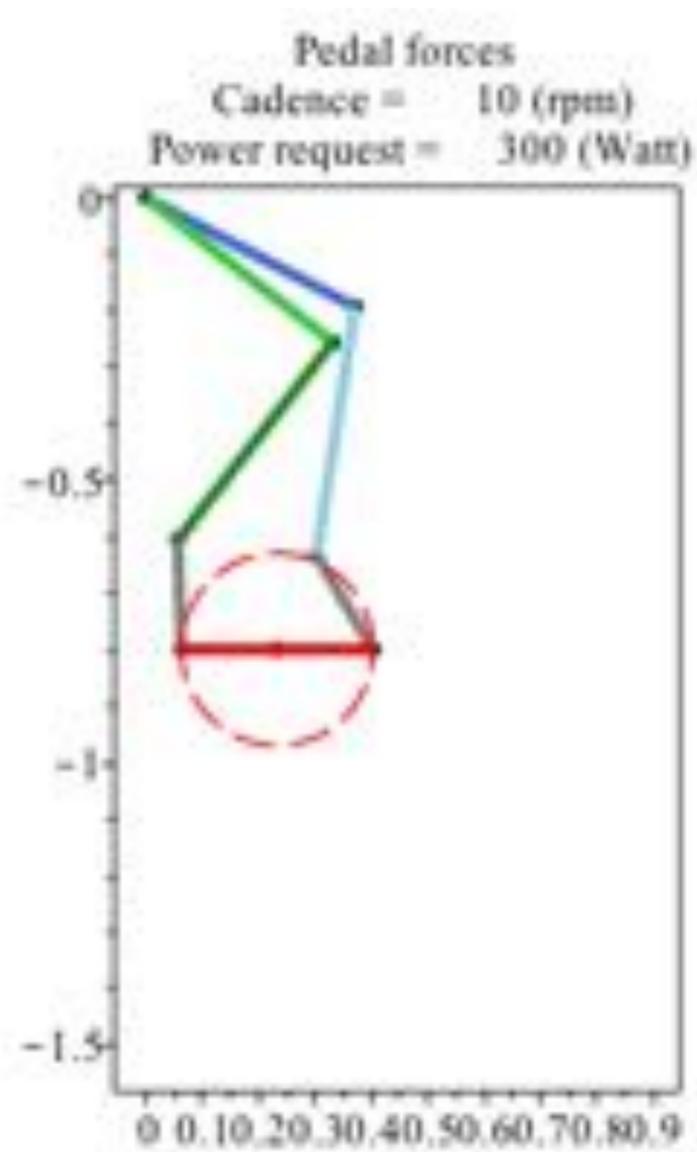
PREDICTION

- use prediction to understand performance, to see the effect off parameters or to evaluate different training protocols



PREDICTION OF CYCLING POWER OUTPUT

- We predict power output and pedal torques and forces (without measuring them).



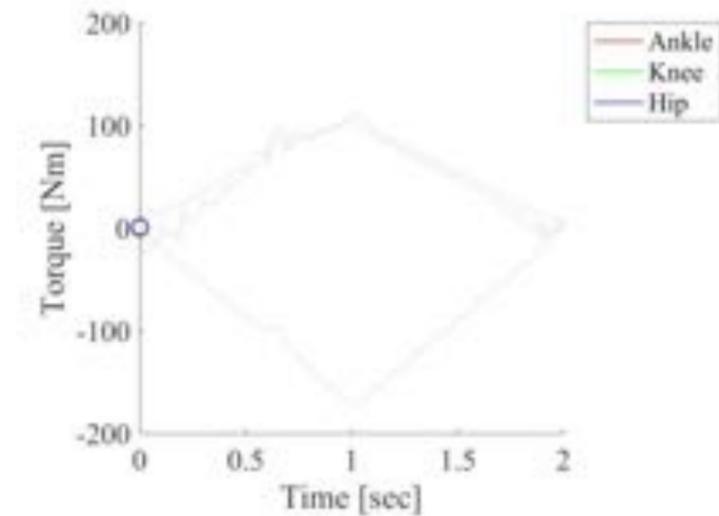
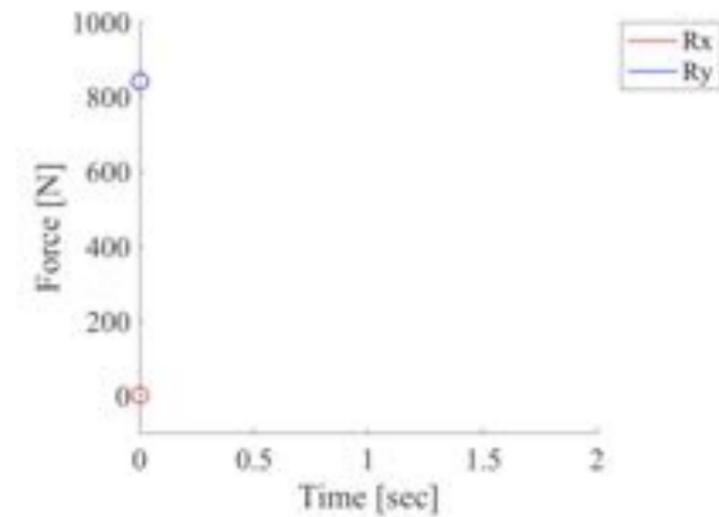
SIMULATE SQUAT EXERCISE: PREDICT JOINT FORCES

- decision how to active muscles is a complex problem: solve with optimistion of a desired goal

Eccentric phase

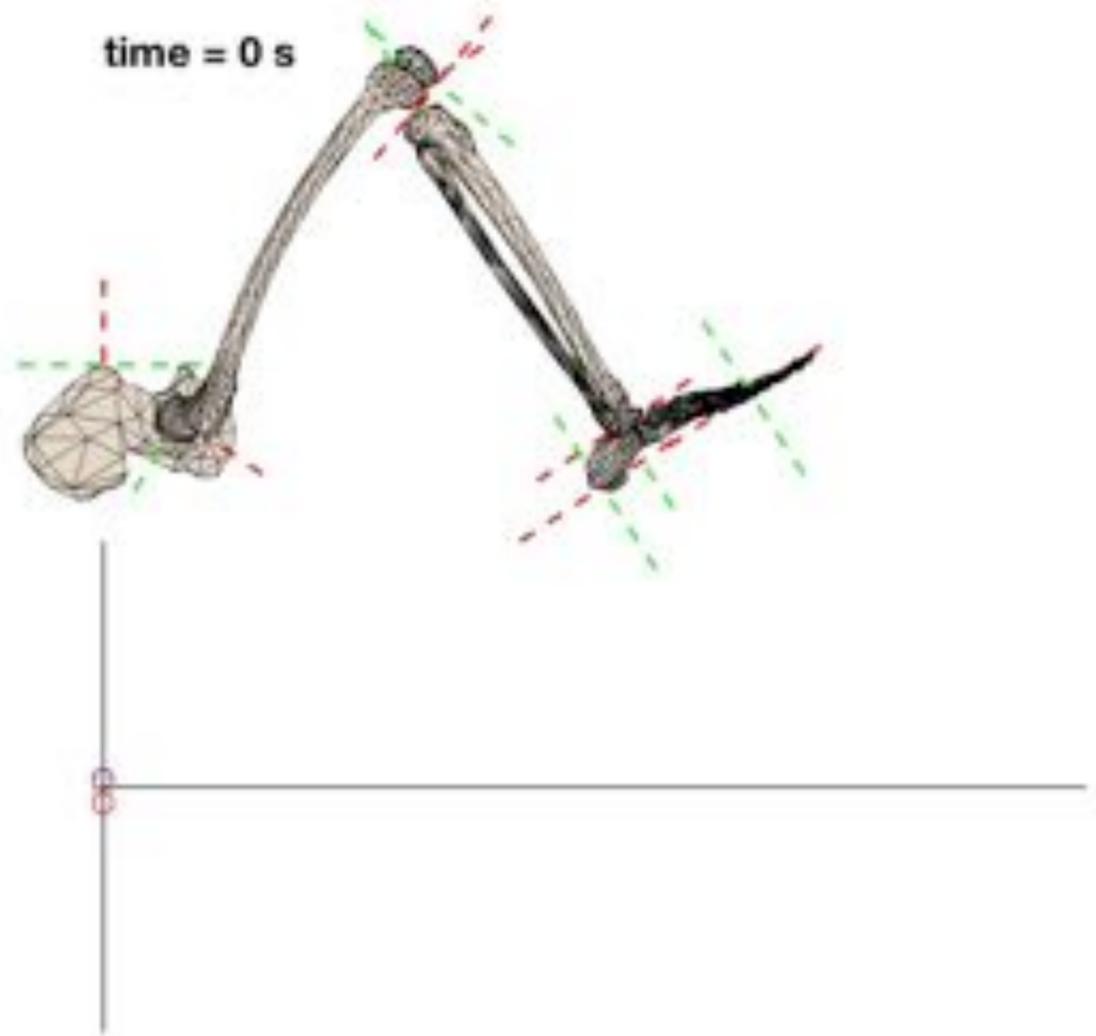


t = 0s



LEG EXTENSION EXERCISE: HUMAN ROBOT INTERACTION

Leg extension exercise -- Optimal control and bilateral Control



OPTIMIZATION

The action of making the best or most effective use of a situation or resource.

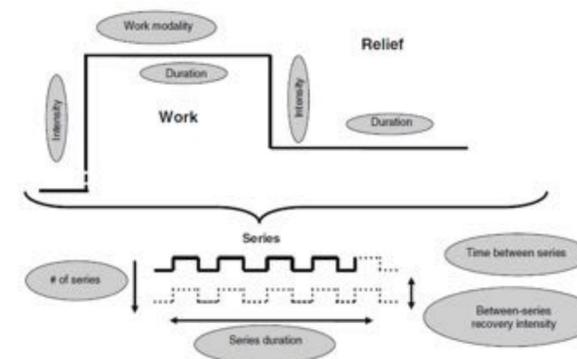
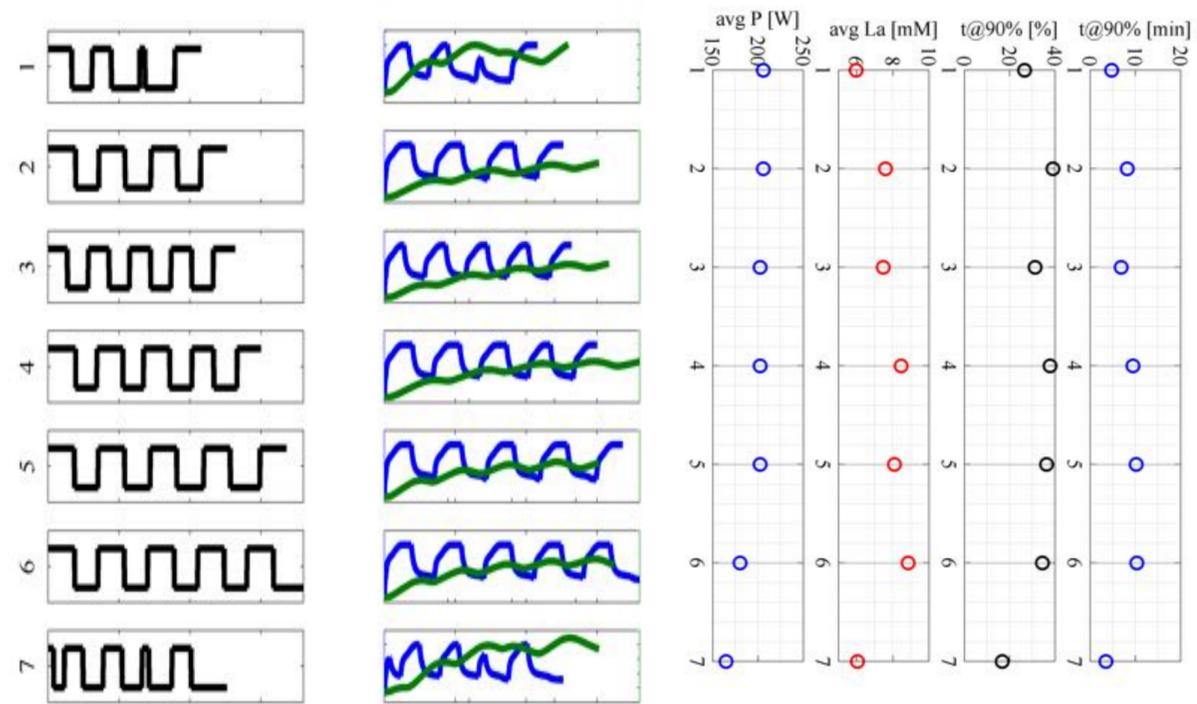
"companies interested in the optimisation of the business"



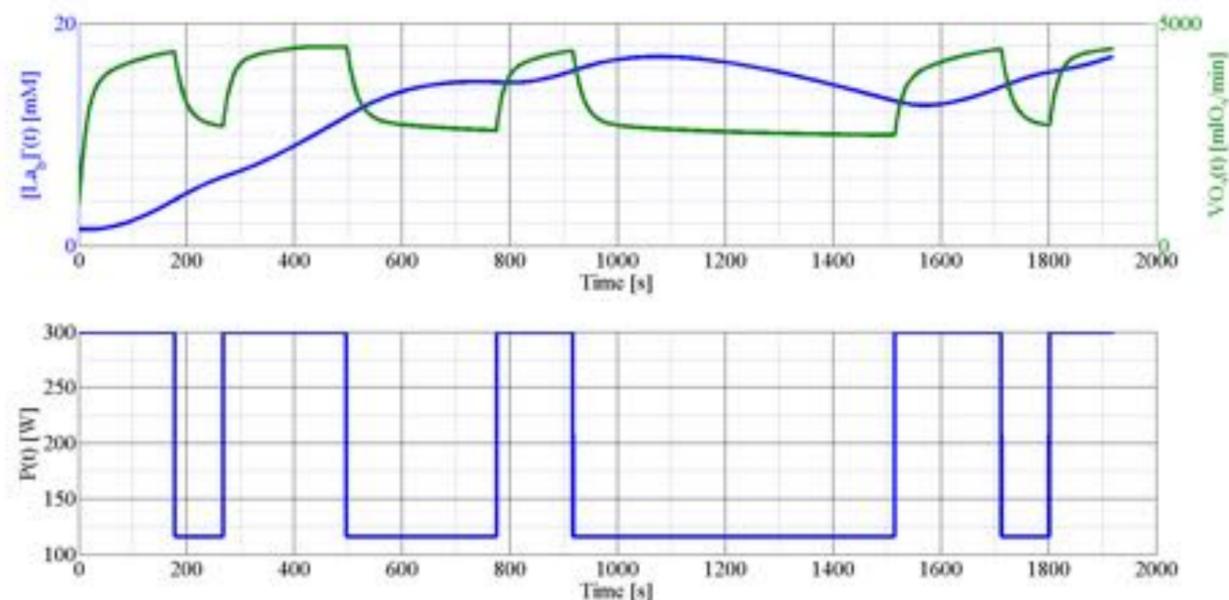
WHAT CAN WE OPTIMISE?

- Optimize the combination of different working and resting intervals in high intensity interval training (HIT)
- Optimize the power delivery and the trajectory during a sprint
- Optimize the pacing strategy during a race

CAN WE FIND THE “PERFECT” COMBINATION OF A HIT?

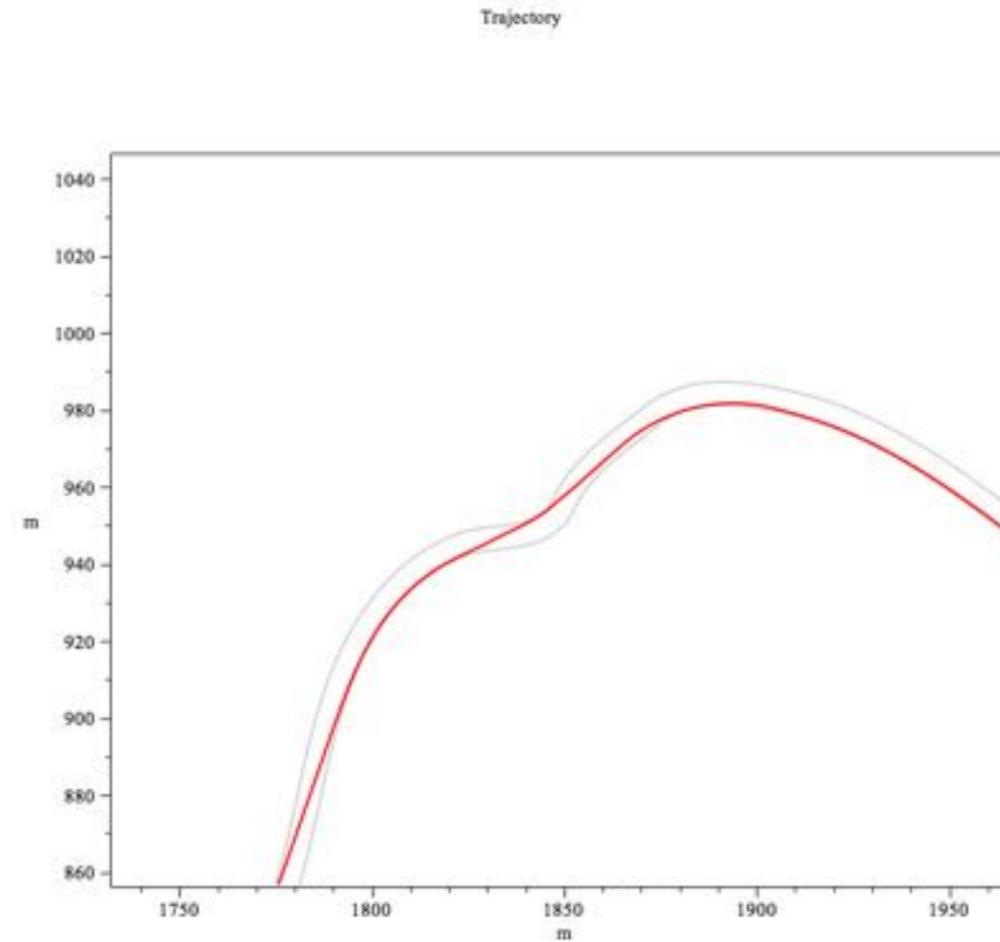
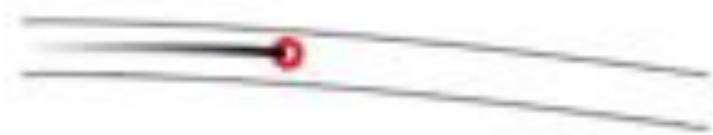


The method suggest moving towards protocol in which working and recovery time intervals are not constant across the exercise.

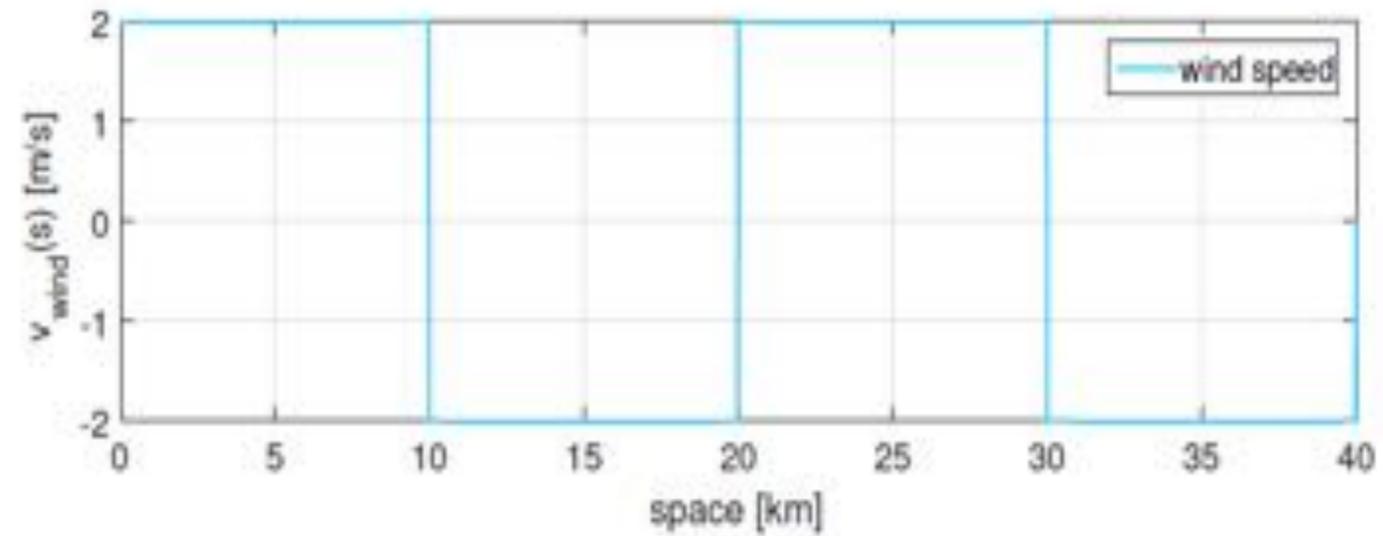
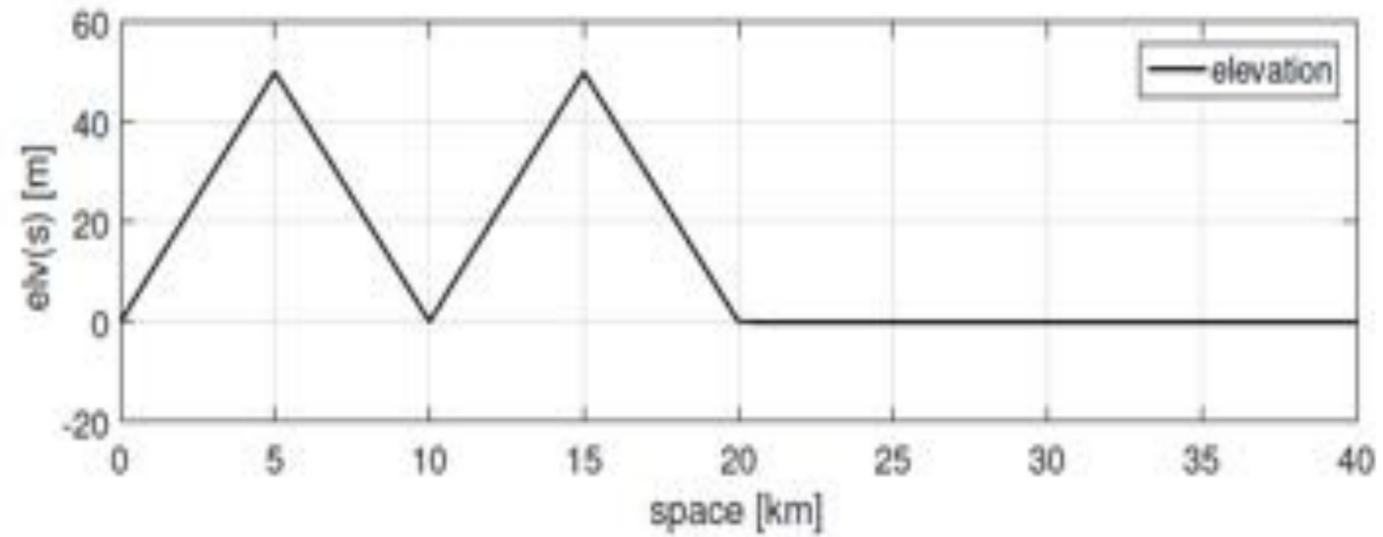


WHAT IS THE BEST SPRINTING STRATEGY?

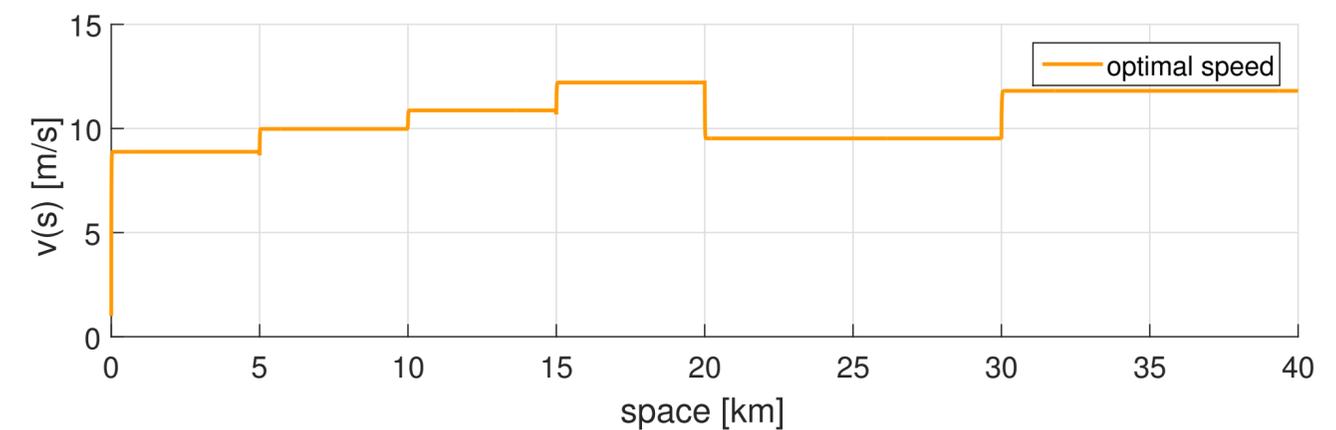
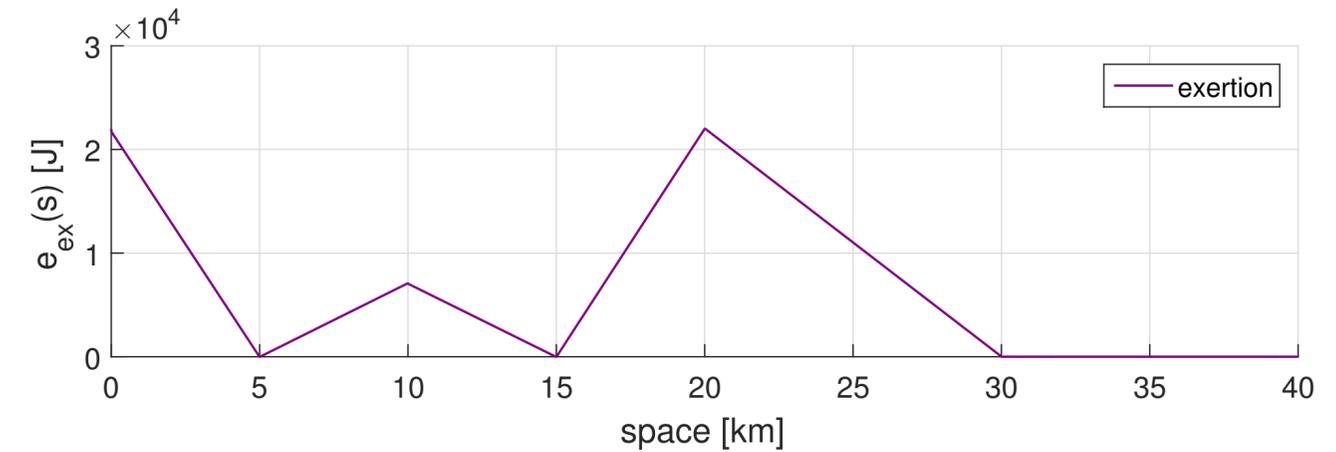
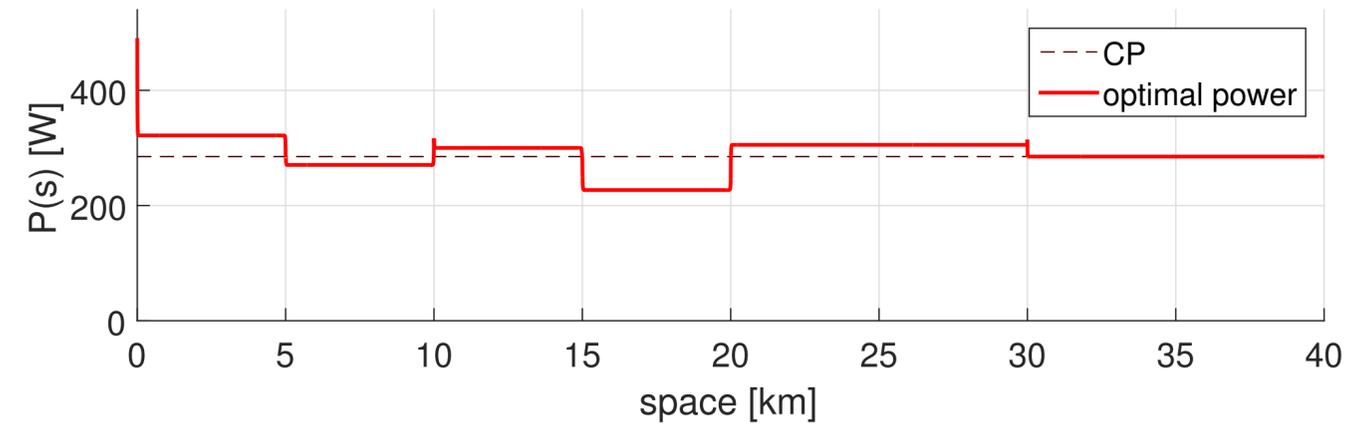
- When do we establish our break away?
- How do the wind or the turns influence the sprinting strategy?



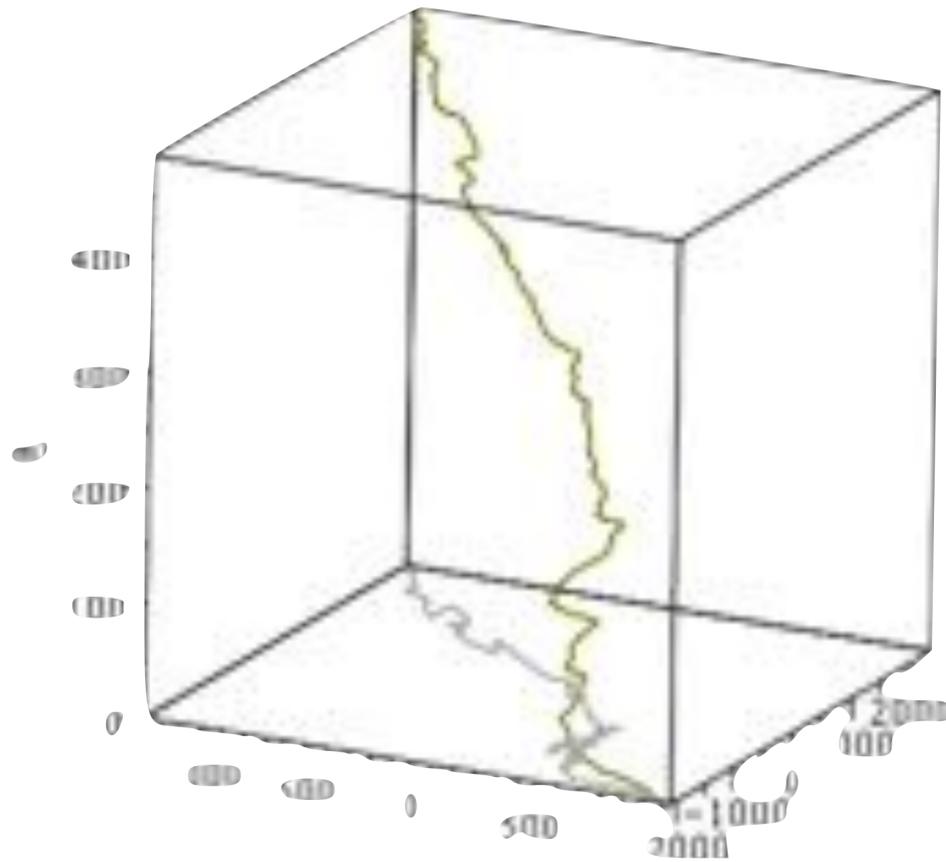
HOW DO WE DISTRIBUTE THE ENERGY OUTPUT ALONG THE RACE?



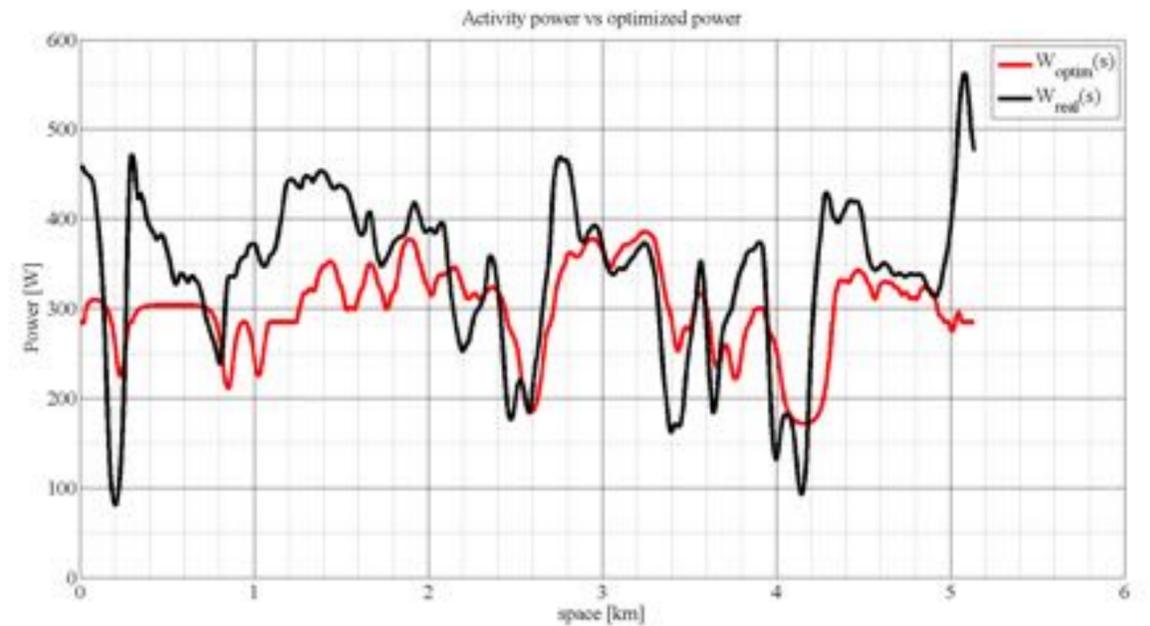
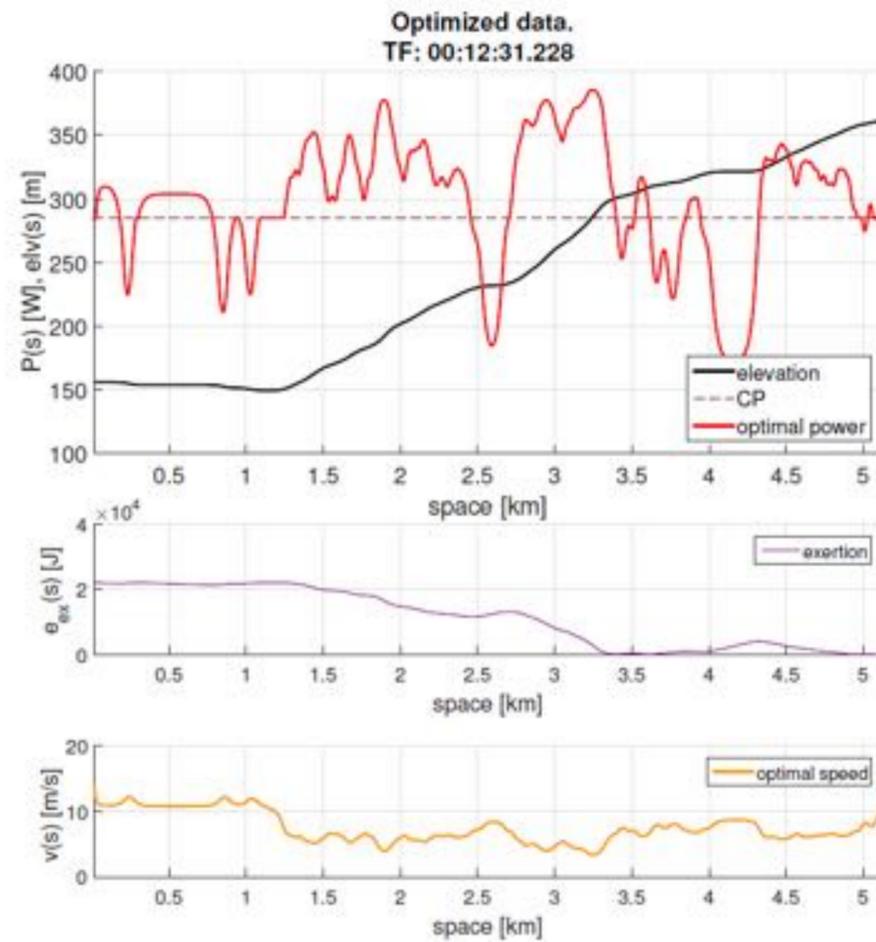
Optimized data.
TF: 01:03:51.724



HOW DO WE DISTRIBUTE THE ENERGY OUTPUT ALONG THE RACE?



Course	Length [km]	Constant pace	Real	Optimized
TT climb	5,13	13m 36s	13m 16s	12m 31s



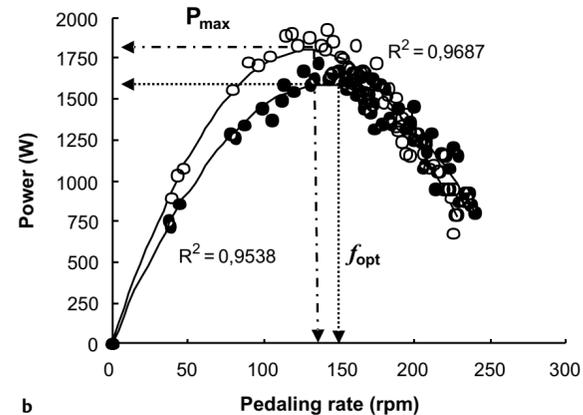
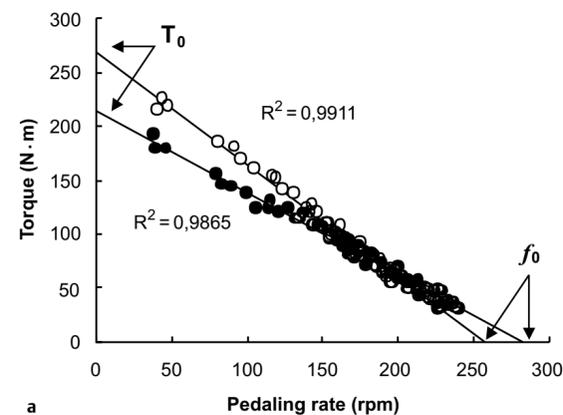
EXPLOIT KNOWLEDGE FOR SMART MOBILITY

- Can we share the delivered power with electric motors in a smart way?
- Support specific individual characteristics

New solutions to viability?



Tools for preventive treatments?



S. Dorel, C. A. Hautier, O. Rambaud, D. Rouffet, E. Van Praagh, J.-R. Lacour, and M. Bourdin, "Torque and power-velocity relationships in cycling: relevance to track sprint performance in world-class cyclists," *Int J Sports Med*, vol. 26, pp. 739-46, Nov 2005.



CONCLUSIONS

take home messages

CONCLUSIONS AND WHAT FUTURE HOLDS

- ◉ Without a mathematical model, measured data cannot be discussed critically and converted to useful information.
- ◉ The quality of a model in terms of **accuracy** and **reliability** strongly depends on quality of experimental data that needs clinical validation.
- ◉ More collaboration between model developers (e.g. engineers and mathematicians) and sport scientists (e.g. researchers, coaches) is needed to provide high quality models and usable tools.



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THANK YOU!