Heart rate modelling as a potential physical fitness assessment for runners and cyclists

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Machine Learning and Data Mining for Sports Analytics
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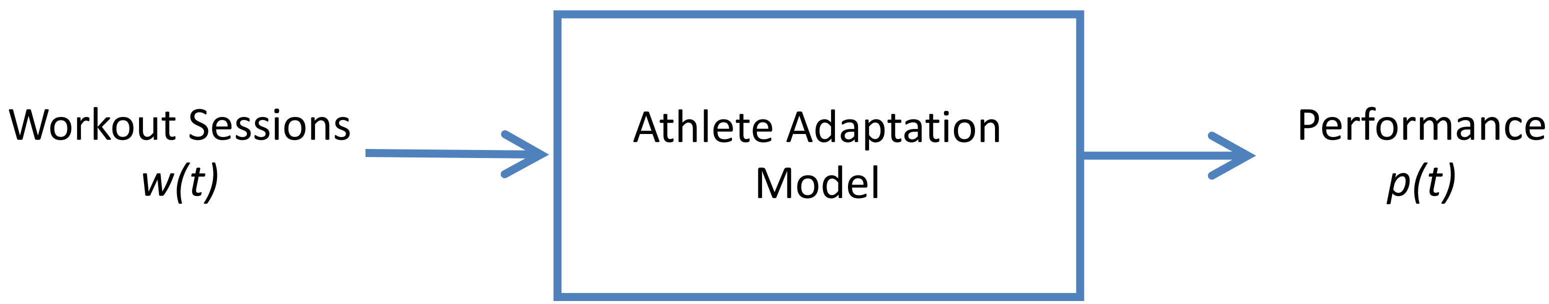
Outline

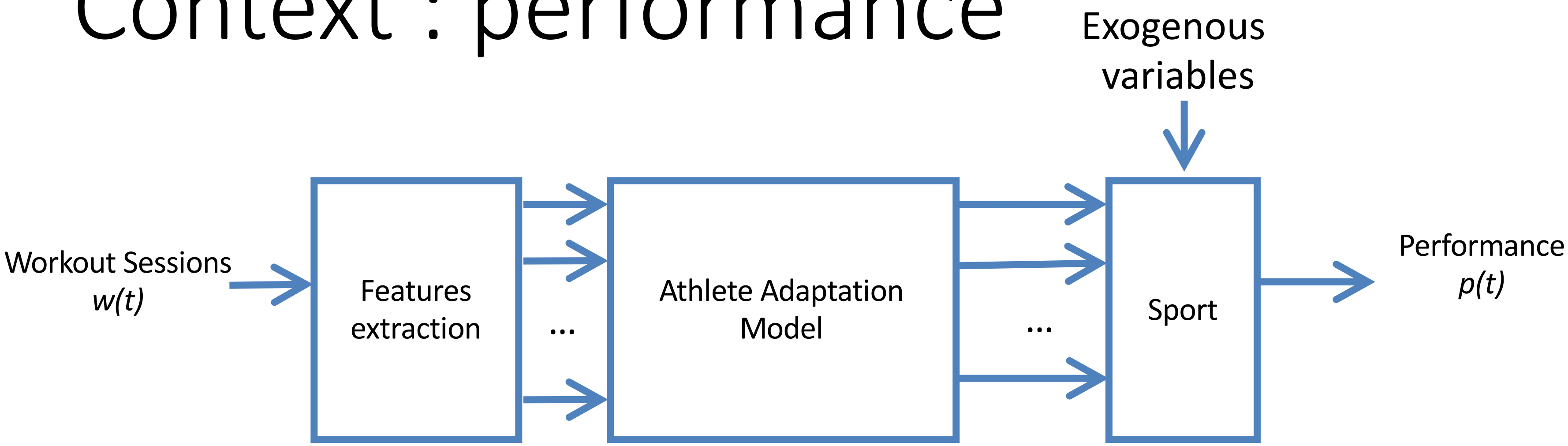
- Context and machine learning perspectives
- Contribution
  - Novel heart rate parametric model
  - Parameters identification
  - Validation
- Conclusion

Context : automated coaching

Coaches are more and more relying on scientific approach that requires a model



Context : performance



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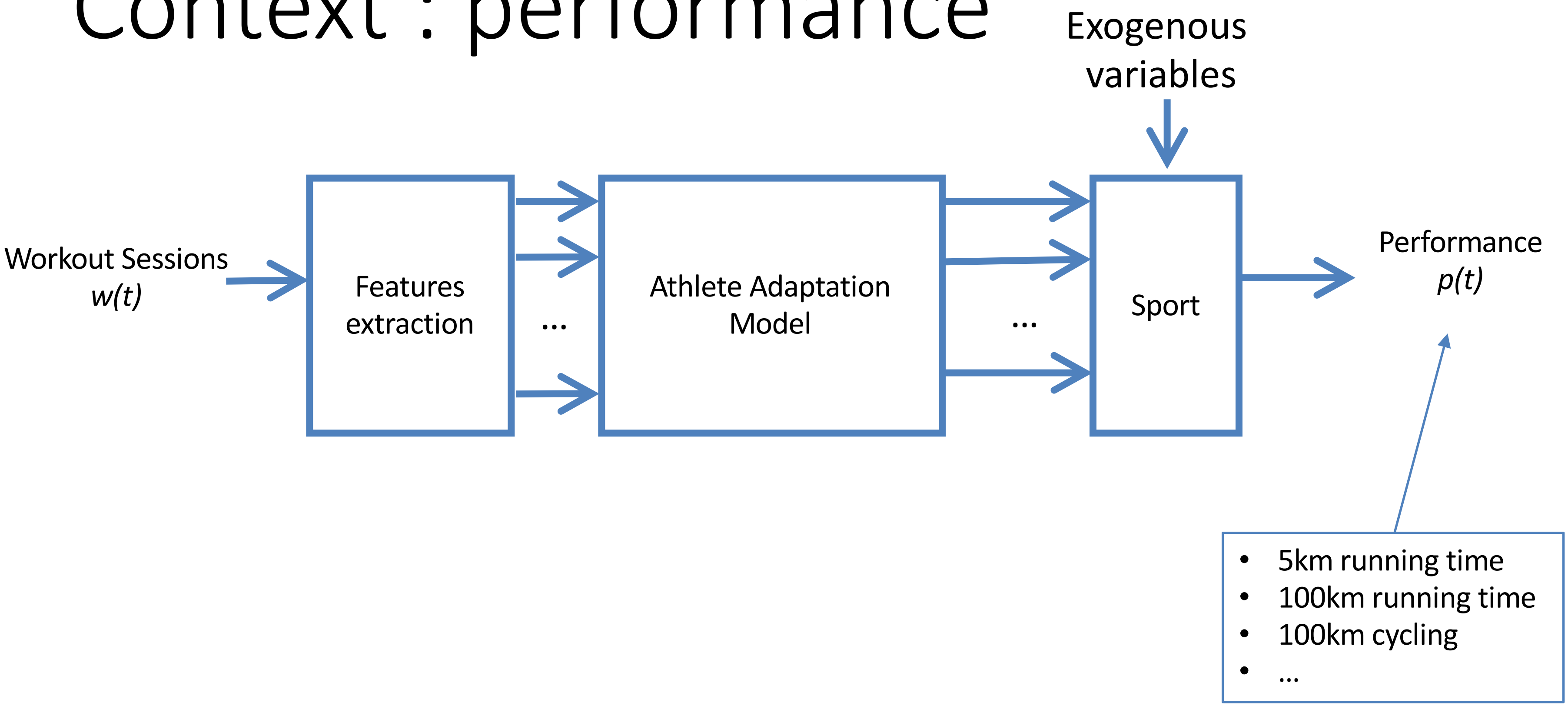

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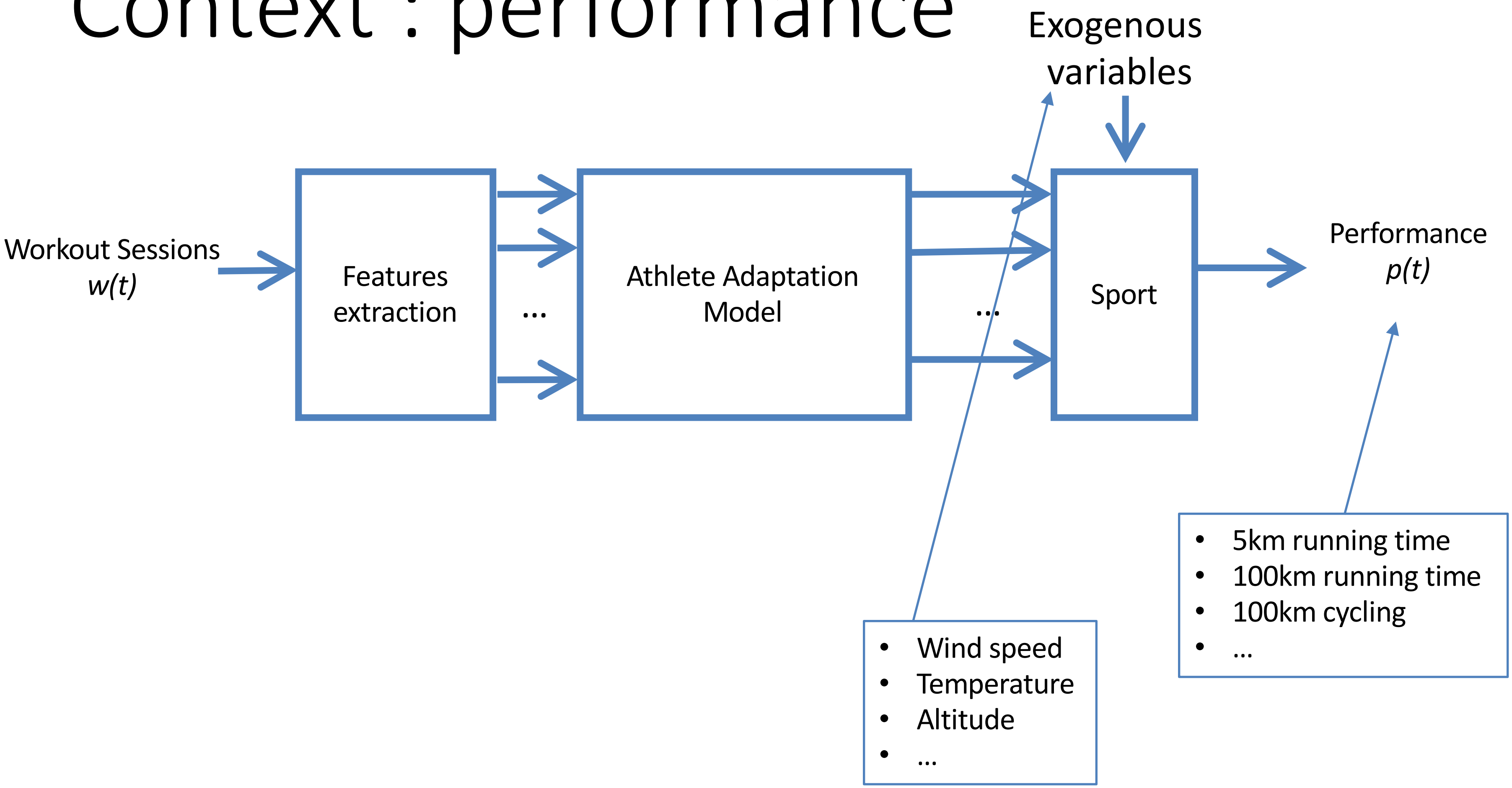
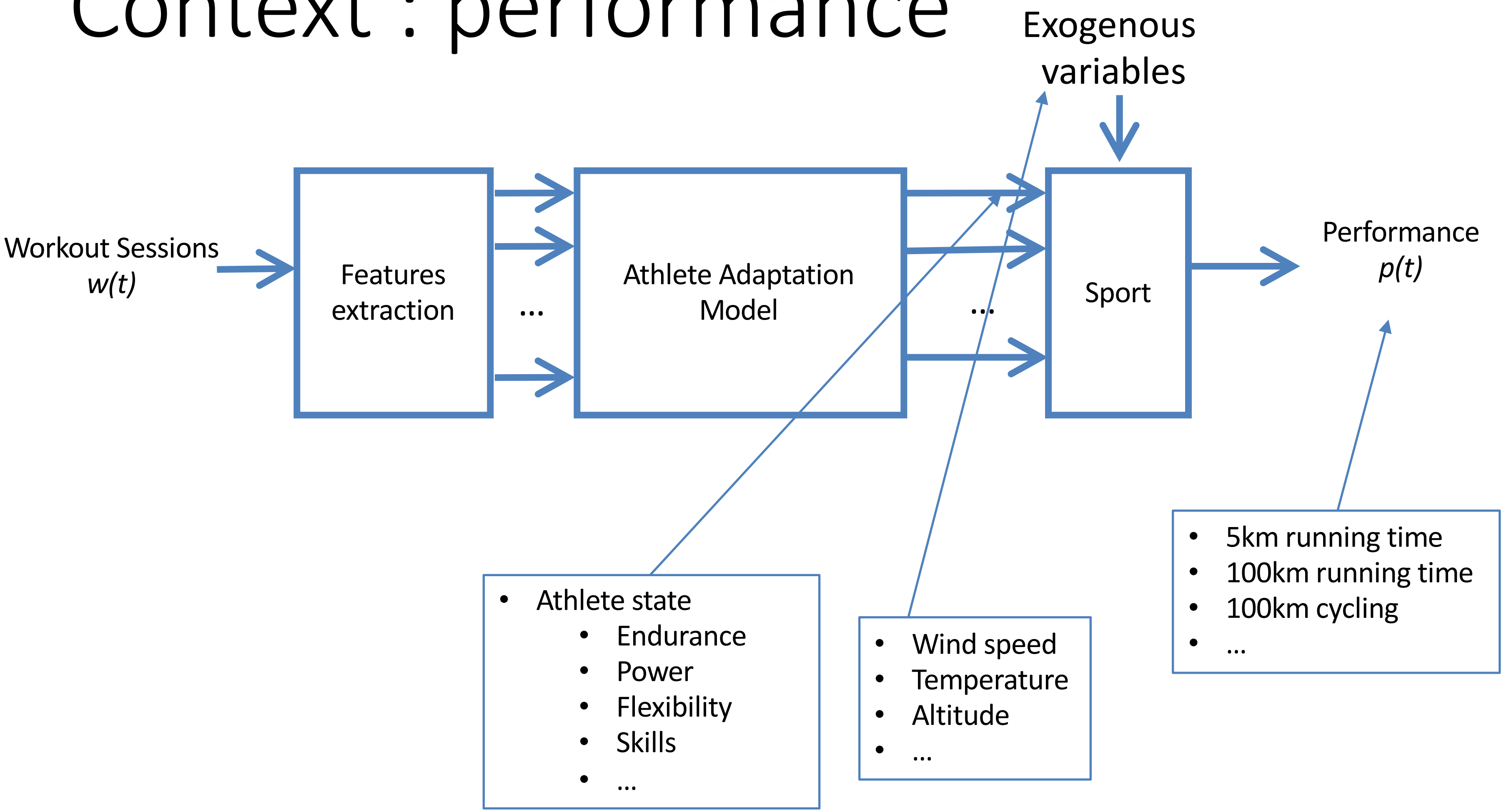
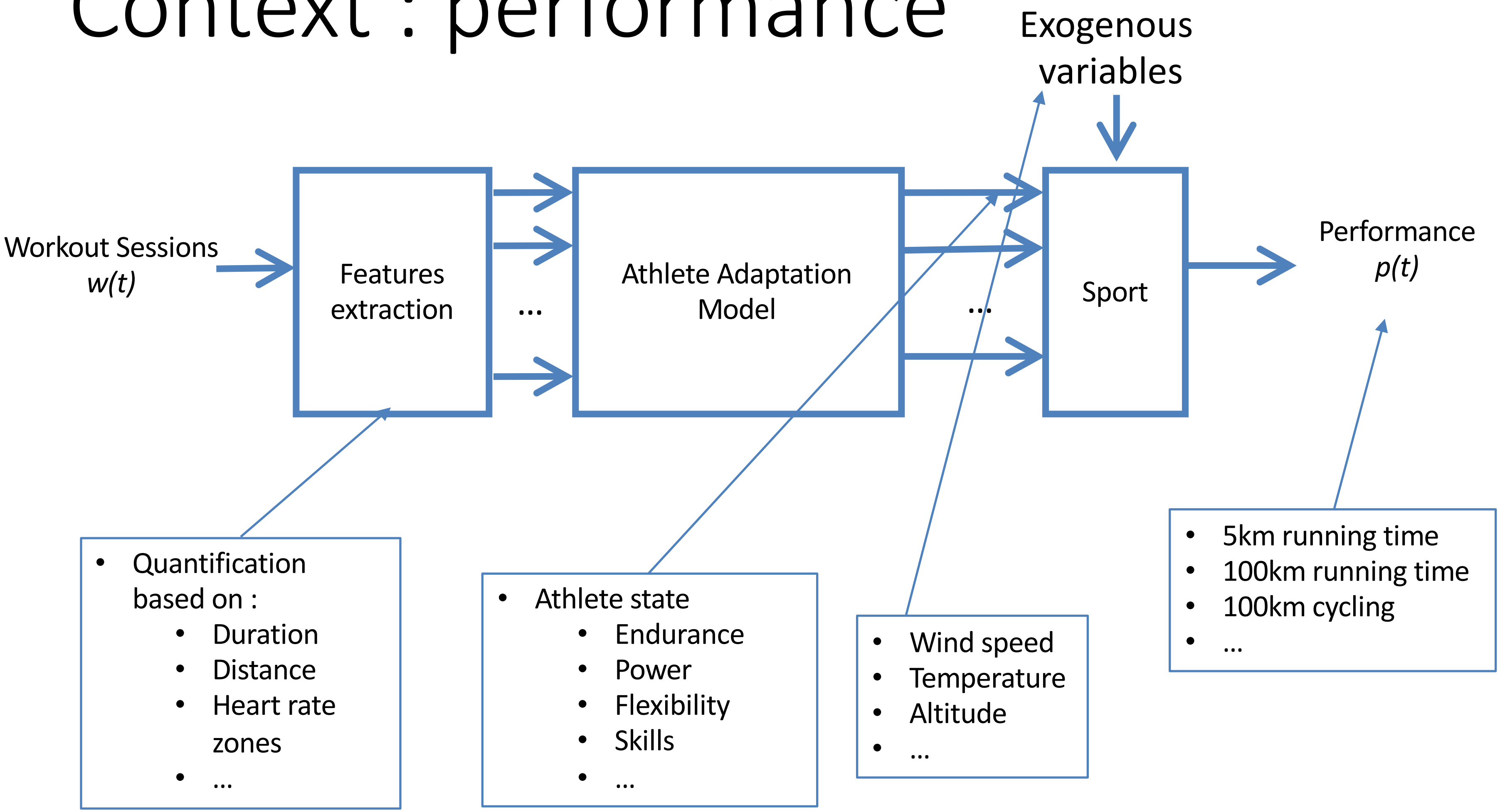


Context : performance



Context : performance



Machine learning perspectives

Model building and **athlete fitting** require input-output examples:

- Inputs (workout sessions)
- Output (performance)

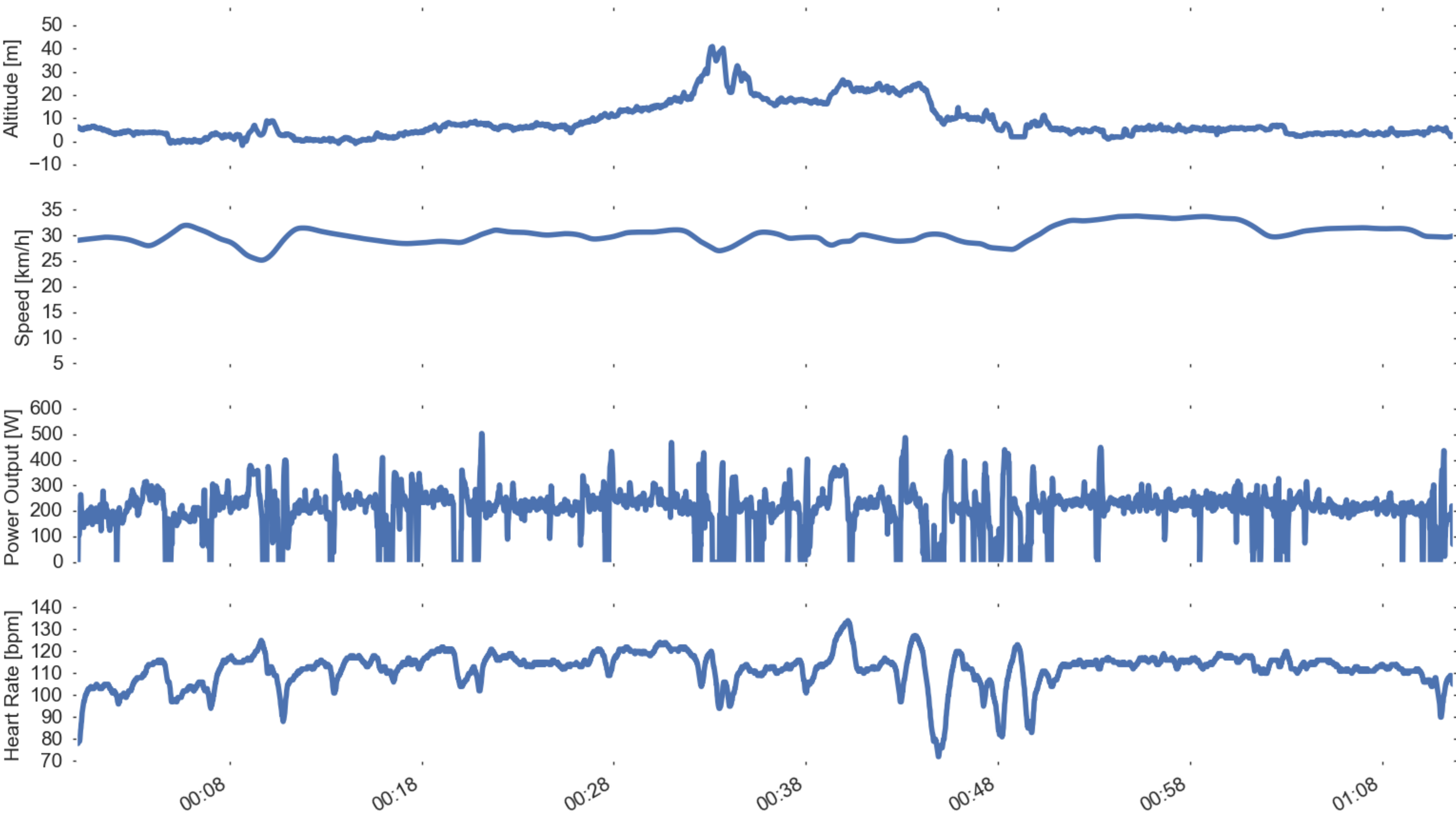
Data profusion

- Many activity sharing platforms
- Activity export = Track

Track Name : Morning ride					
Timestamp	Location (lat, lon)	Altitude	Heart Rate	Power Output	…
2016-06-21 13:27:28.00	(50.4307, 3.736080)	16.60 m	97 bpm	125 W	…
2016-06-21 13:27:29.00	(50.4308, 3.736082)	16.62 m	96 bpm	147 W	…
…	…	…	…	…	…

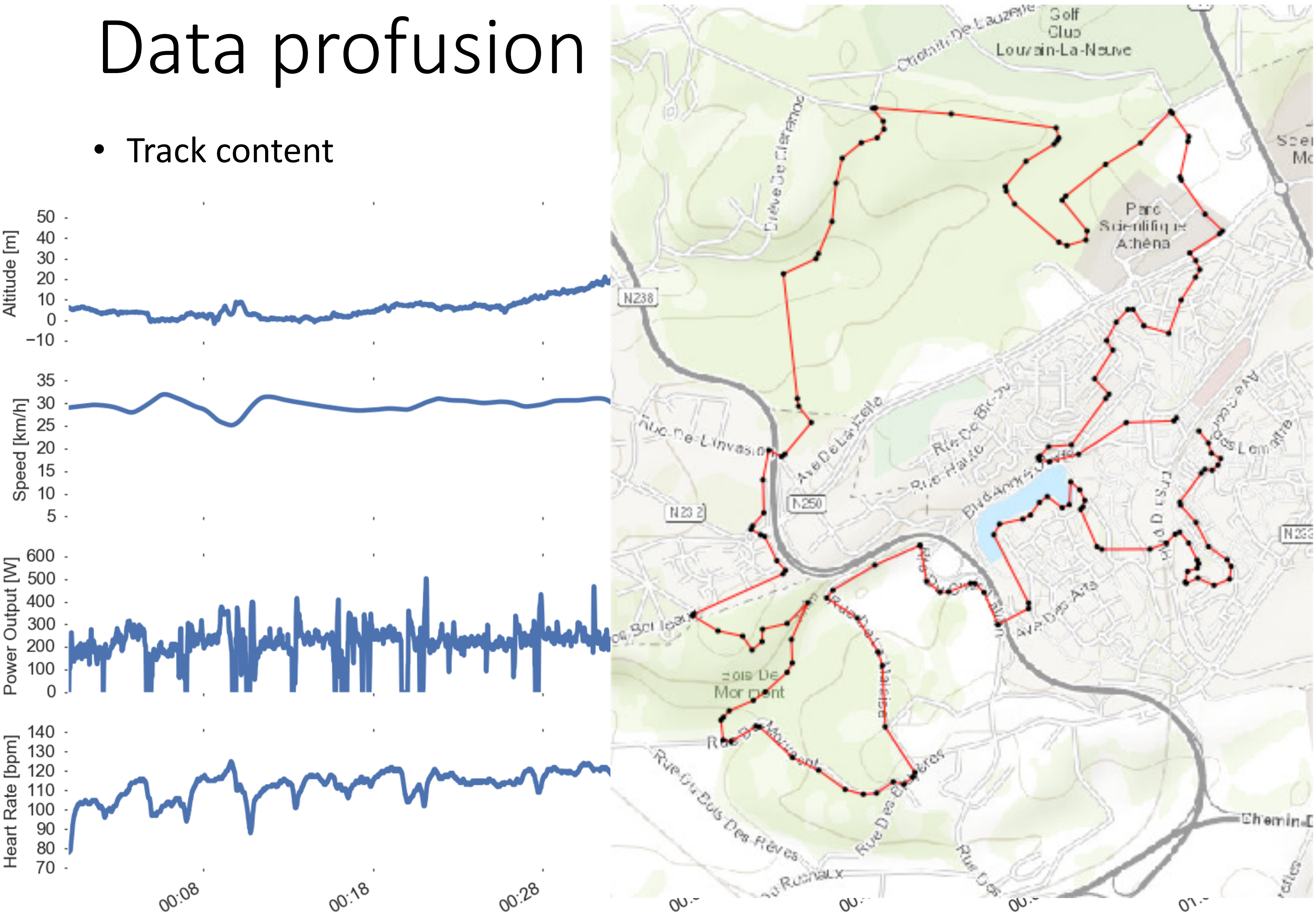
Data profusion

- Track content

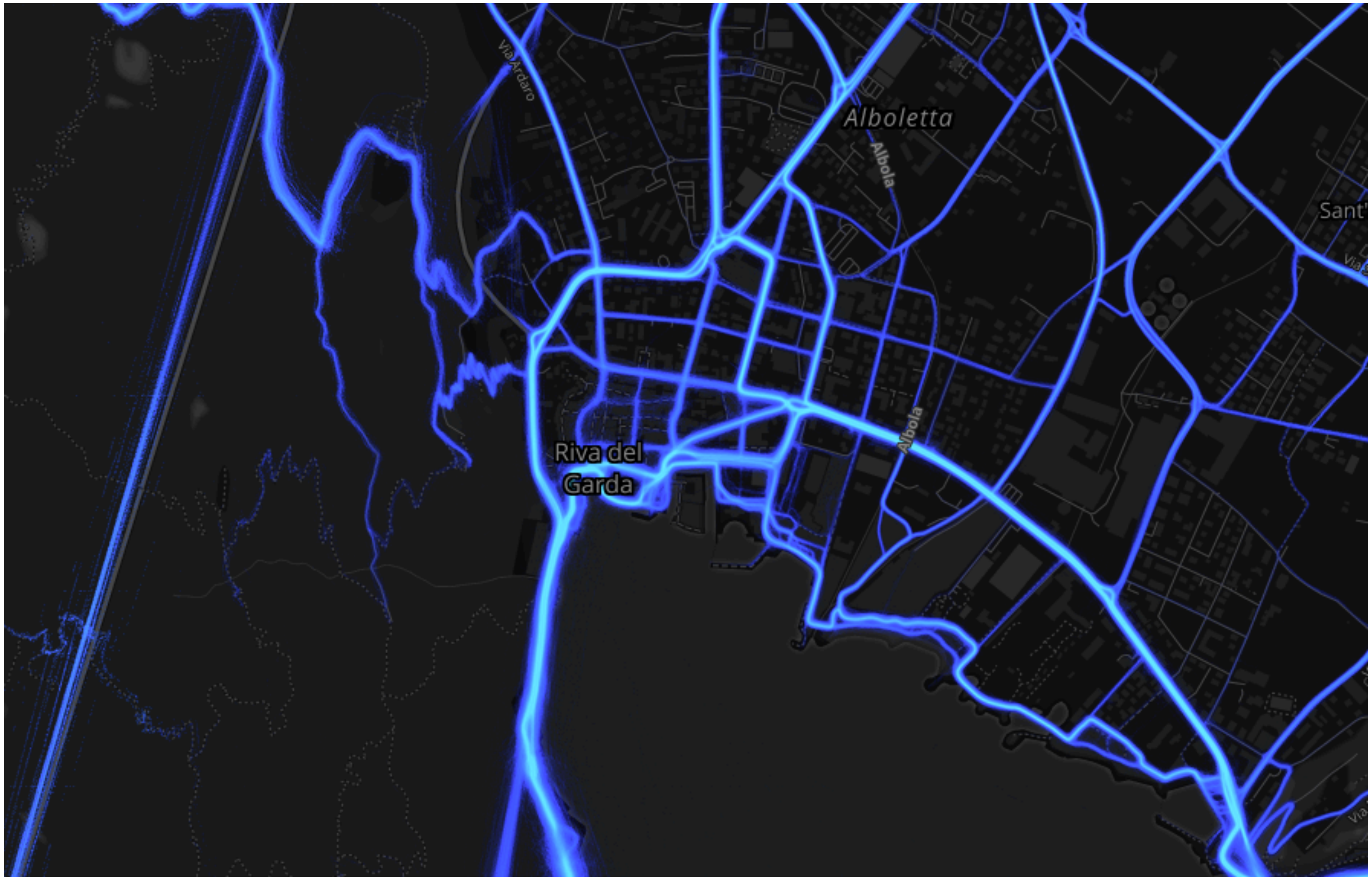


Data profusion

- Track content

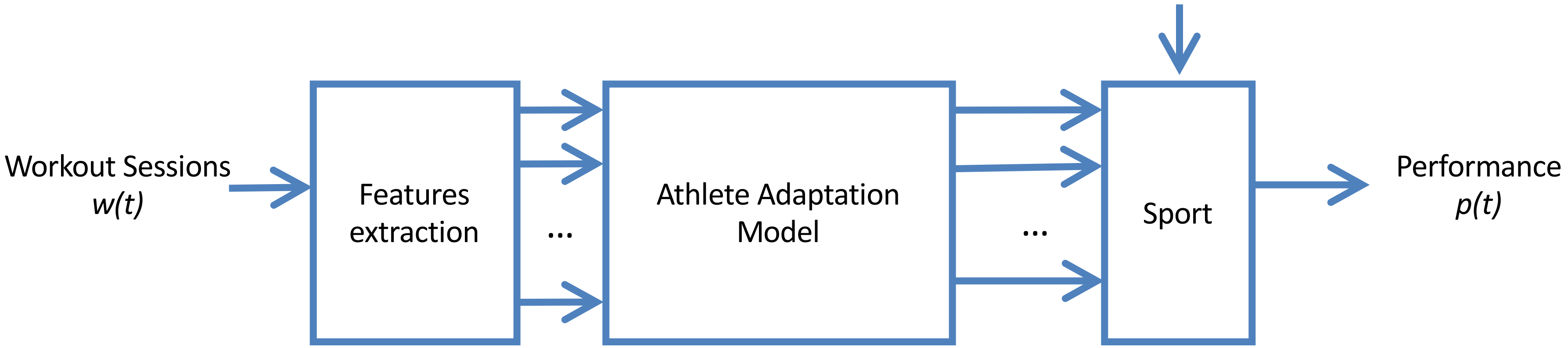


Data profusion



(strava heatmap)

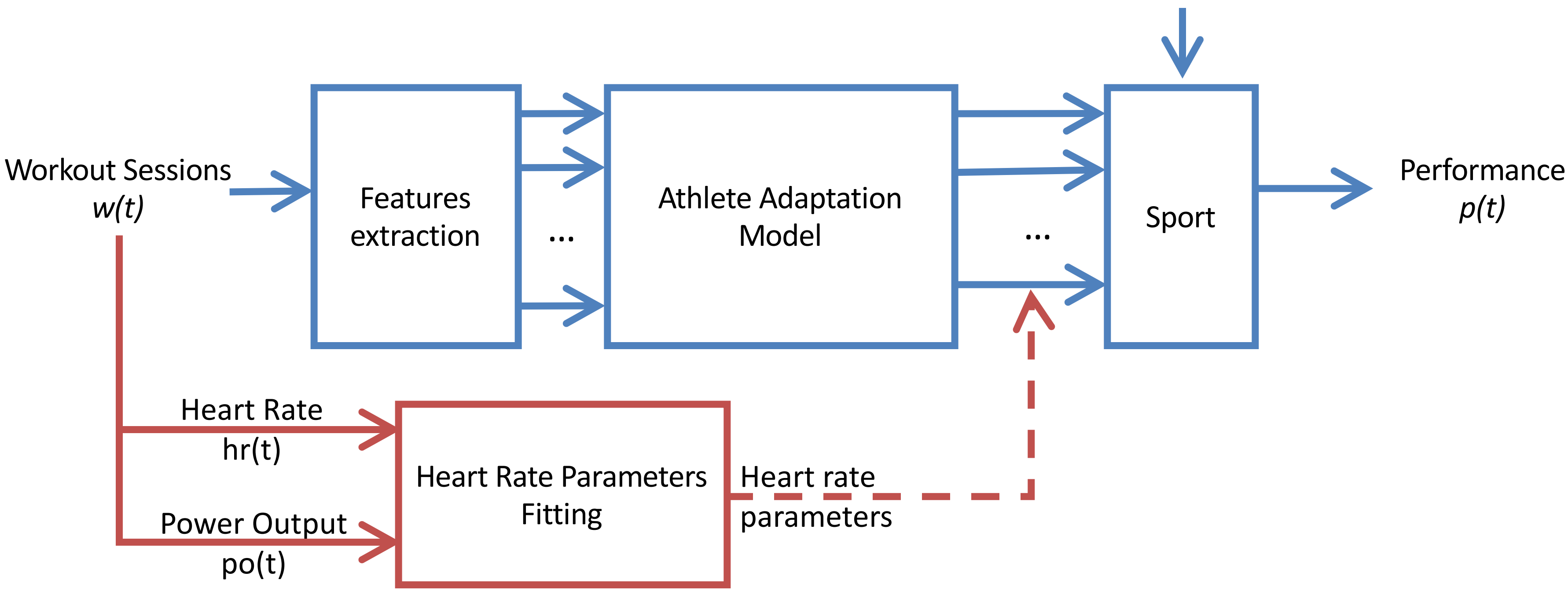
Machine learning perspectives



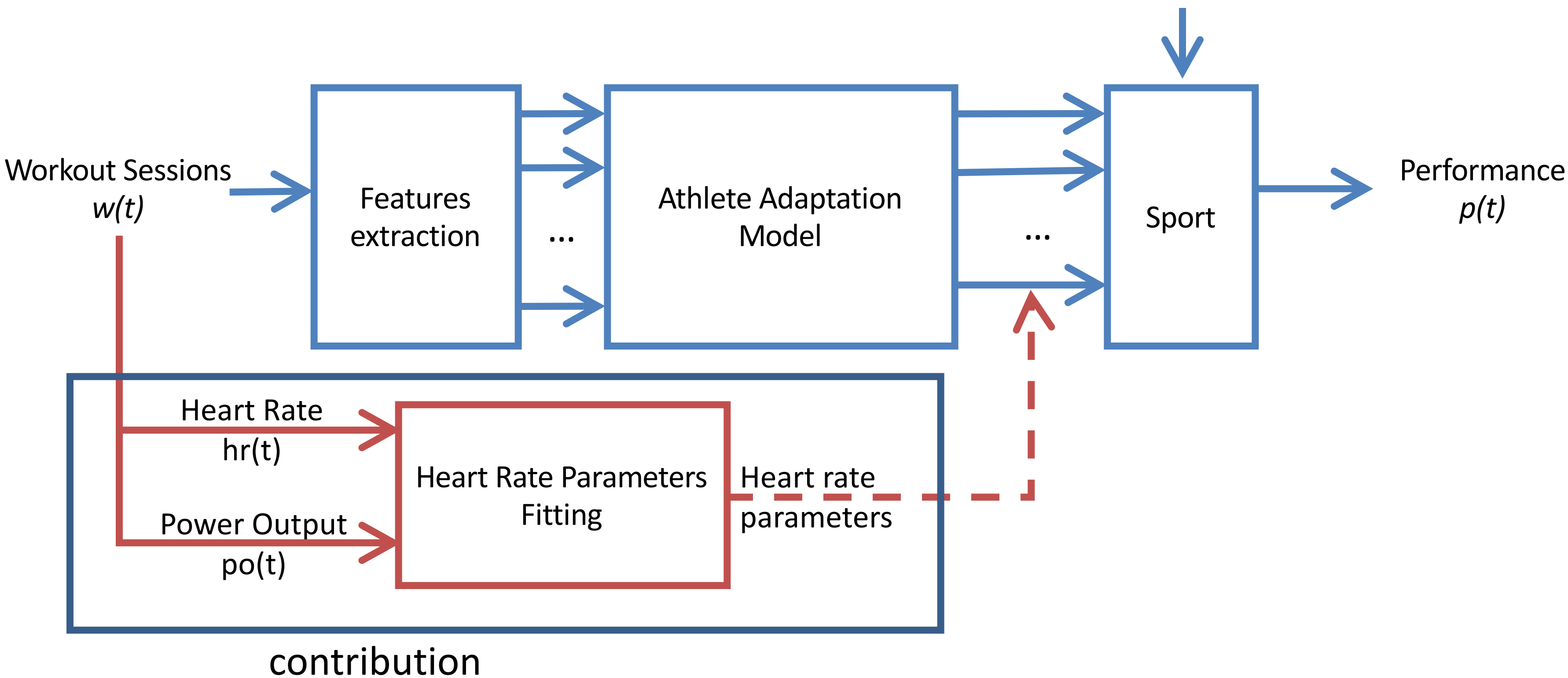
Model building and **athlete fitting** require input-output examples:

- Inputs (workout sessions) : massively available
- Output (performance) : sparse

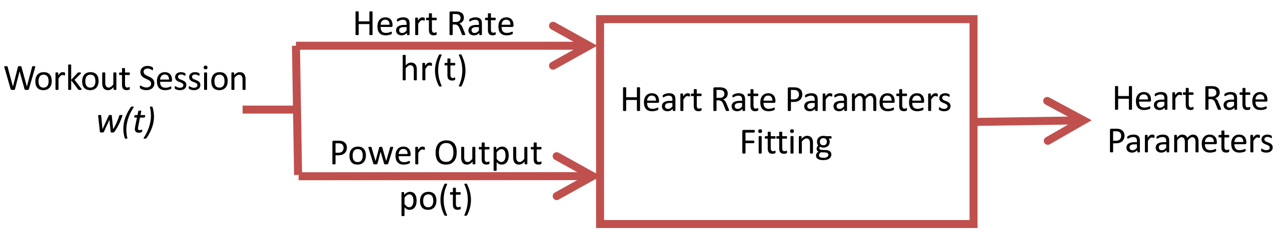
Contribution

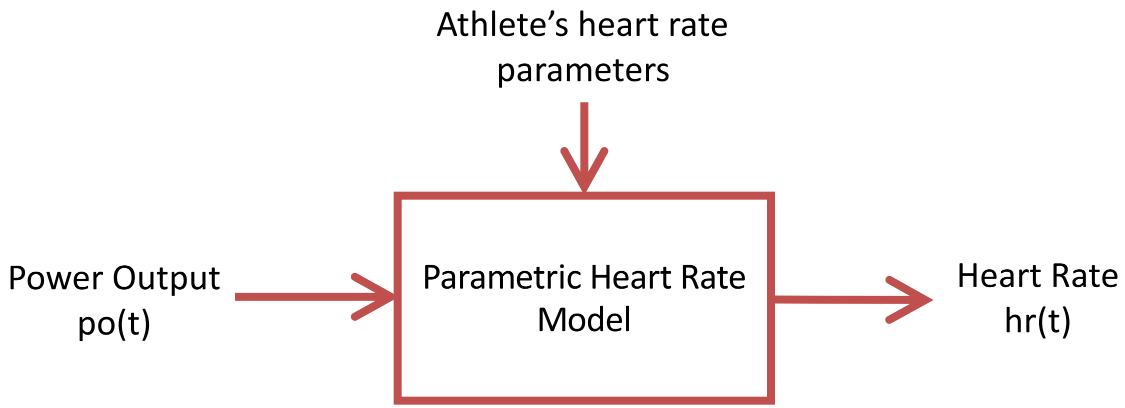


Contribution



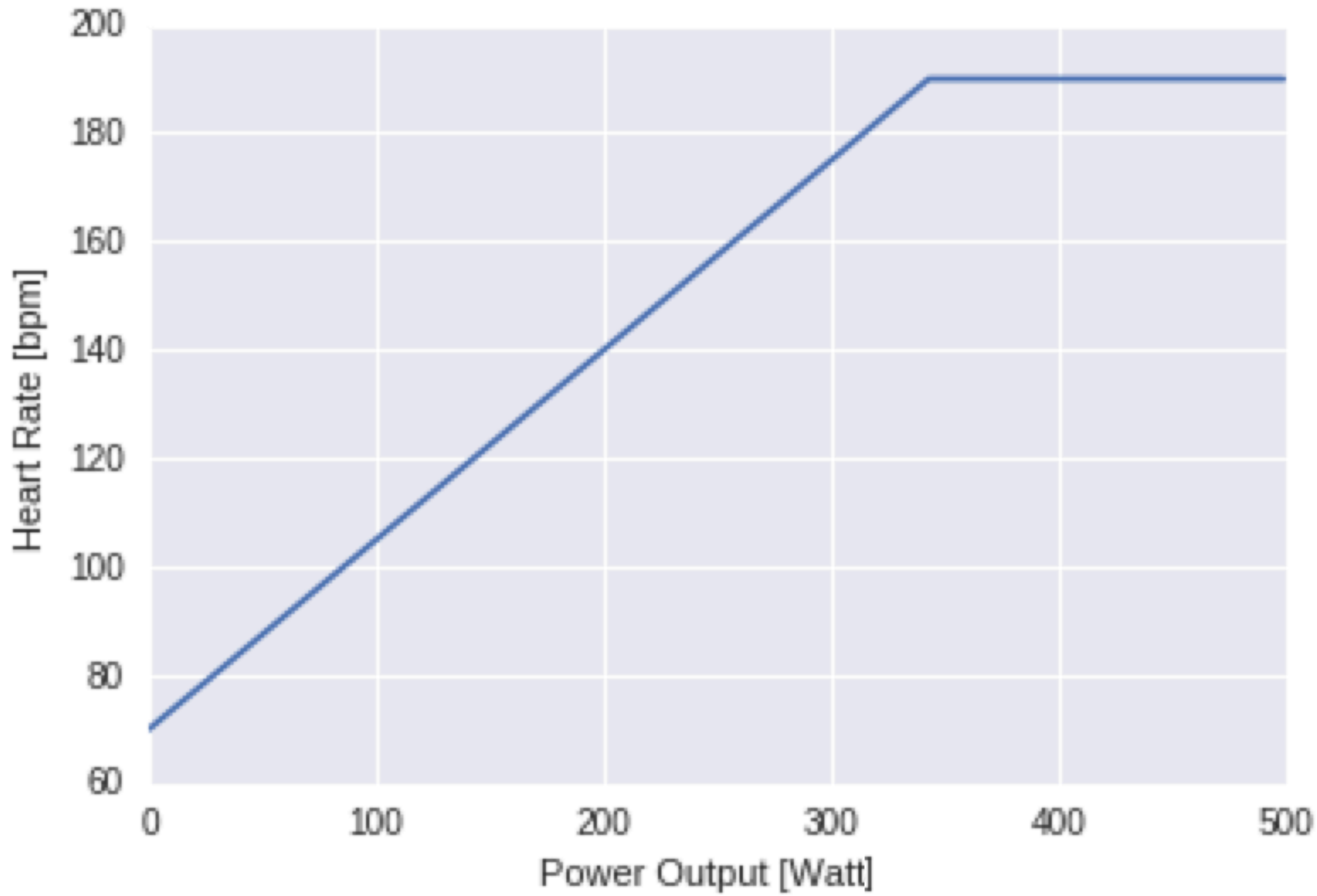
Heart rate modelling





Heart rate model : steady state

Parameters
- HR max [bpm]
- Resting HR [bpm]
- Slope [bpm/w]



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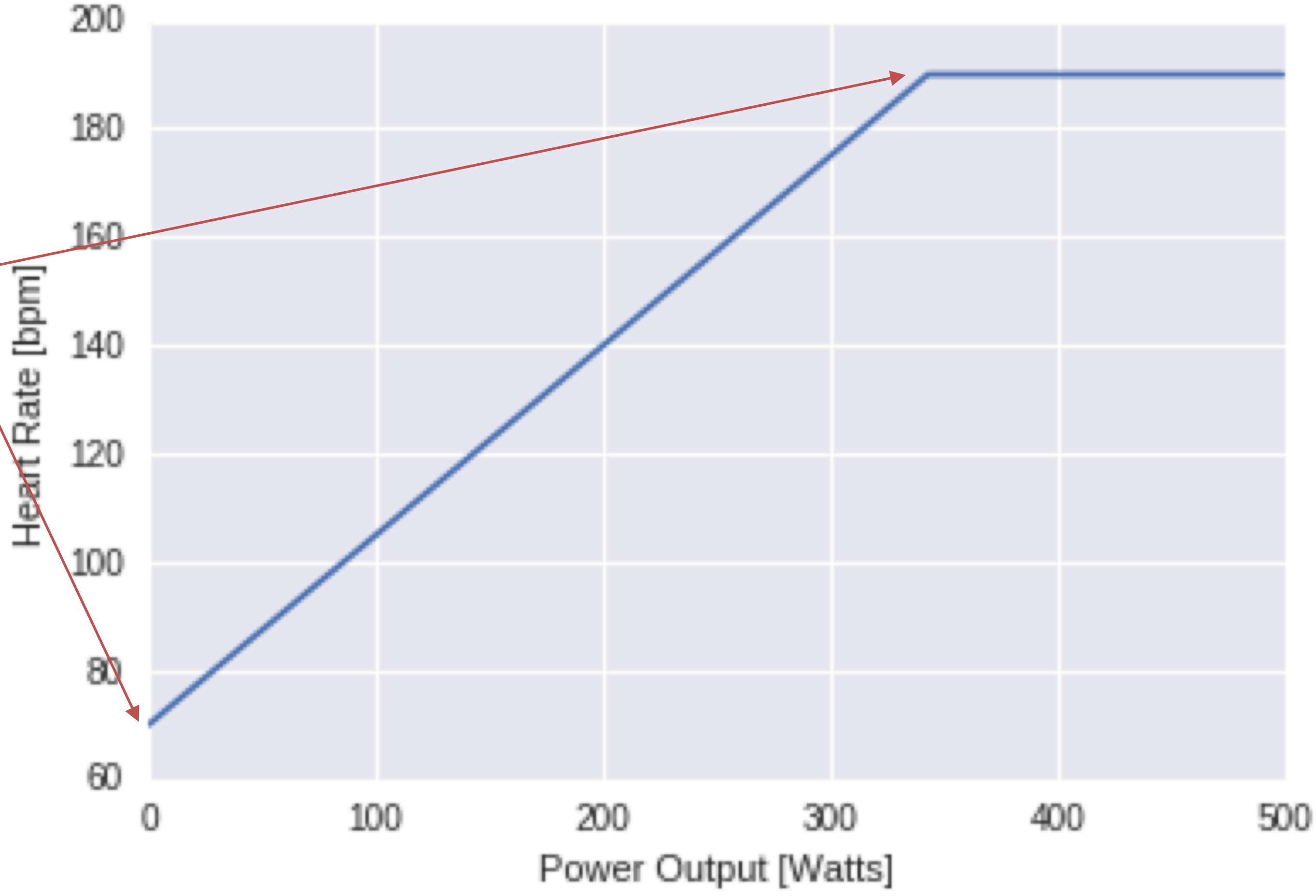
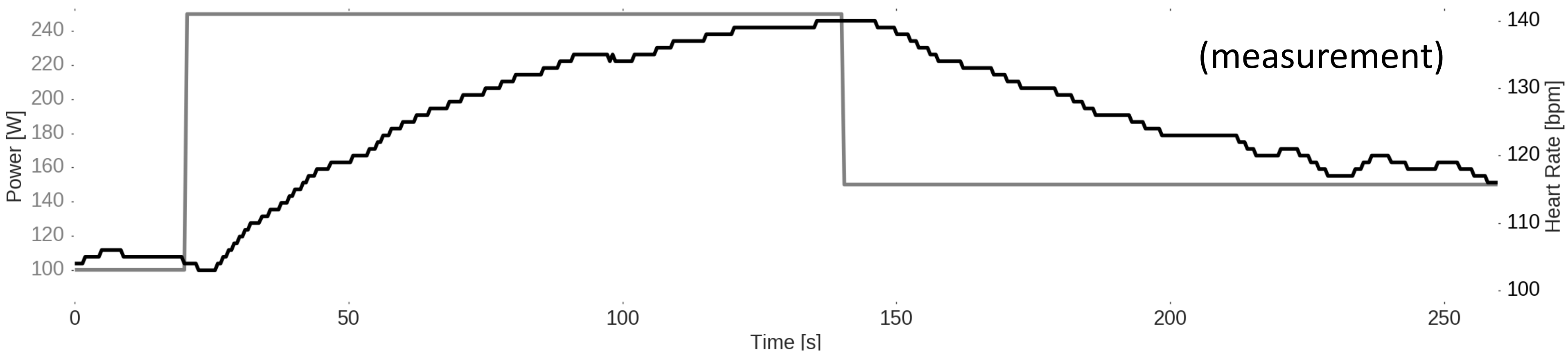


Heart rate model : transient response



$$\frac{d\ hr(t)}{dt} + \frac{1}{\tau} hr(t) = po(t)$$

$$hr(t) = hr(t_0) + (hr_{ss}(po(t)) - hr(t_0))e^{-\frac{t}{\tau}}$$

$$HR(t+1) = \begin{cases} HR(t) + \frac{1}{\tau_r}(HR_{ss}(po(t)) - HR(t)), & \text{if } HR_{ss}(po(t)) \geq HR(t) \\ HR(t) + \frac{1}{\tau_f}(HR_{ss}(po(t)) - HR(t)), & \text{if } HR_{ss}(po(t)) < HR(t) \end{cases}$$

Heart rate model : fatigue

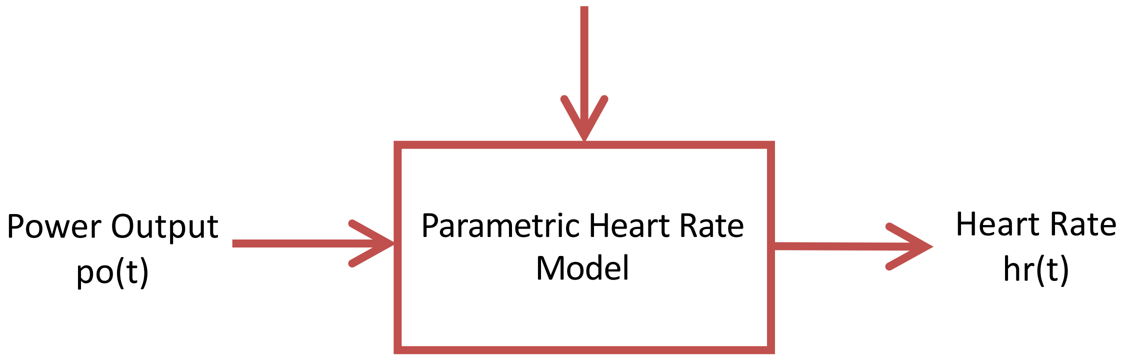
- Intra-session workload results in fatigue that induces increased heart rate for the same power output
- Modeled by replacing *po(t)* by

$$po(t) + k_f \int_{t_0}^{t} po(t) dt$$

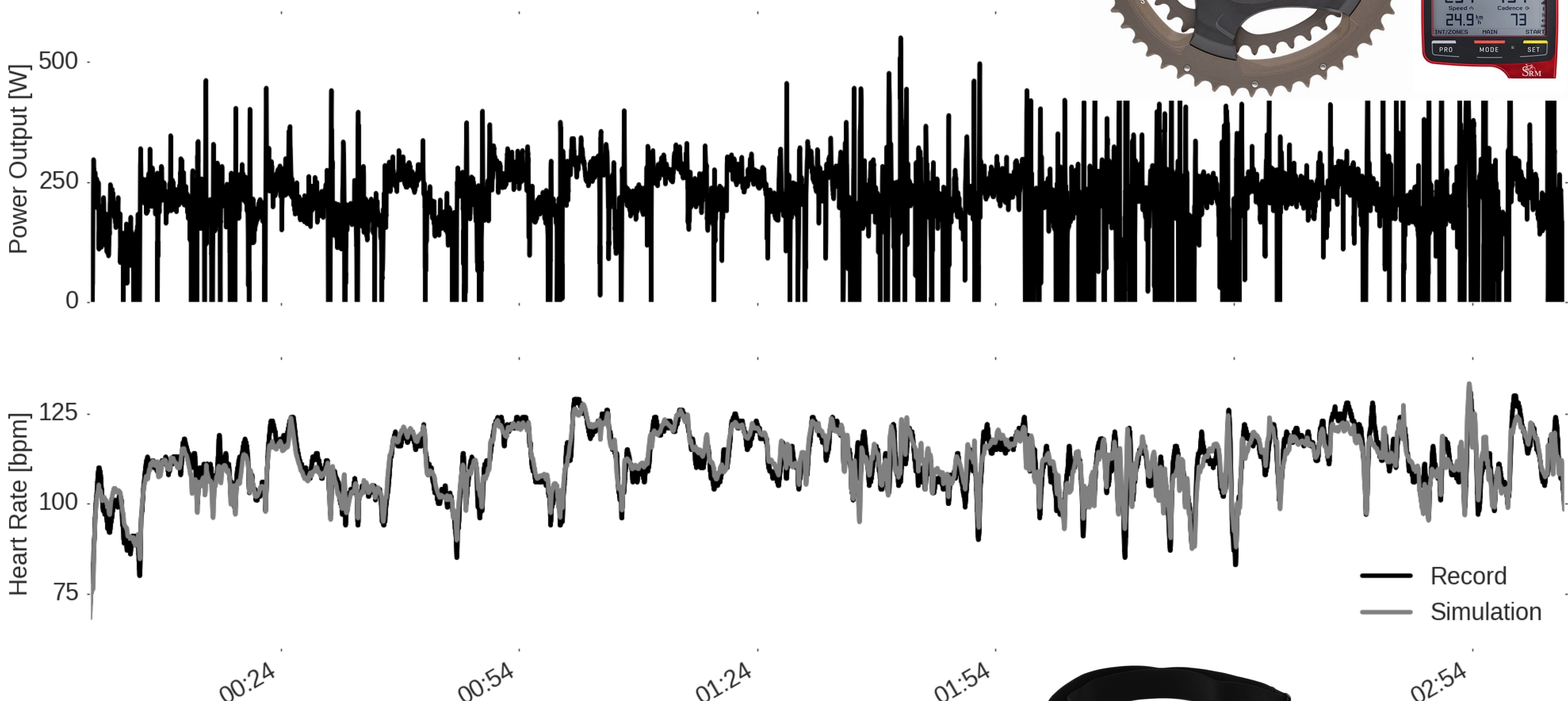
Heart rate modelling

Athlete's heart rate parameters

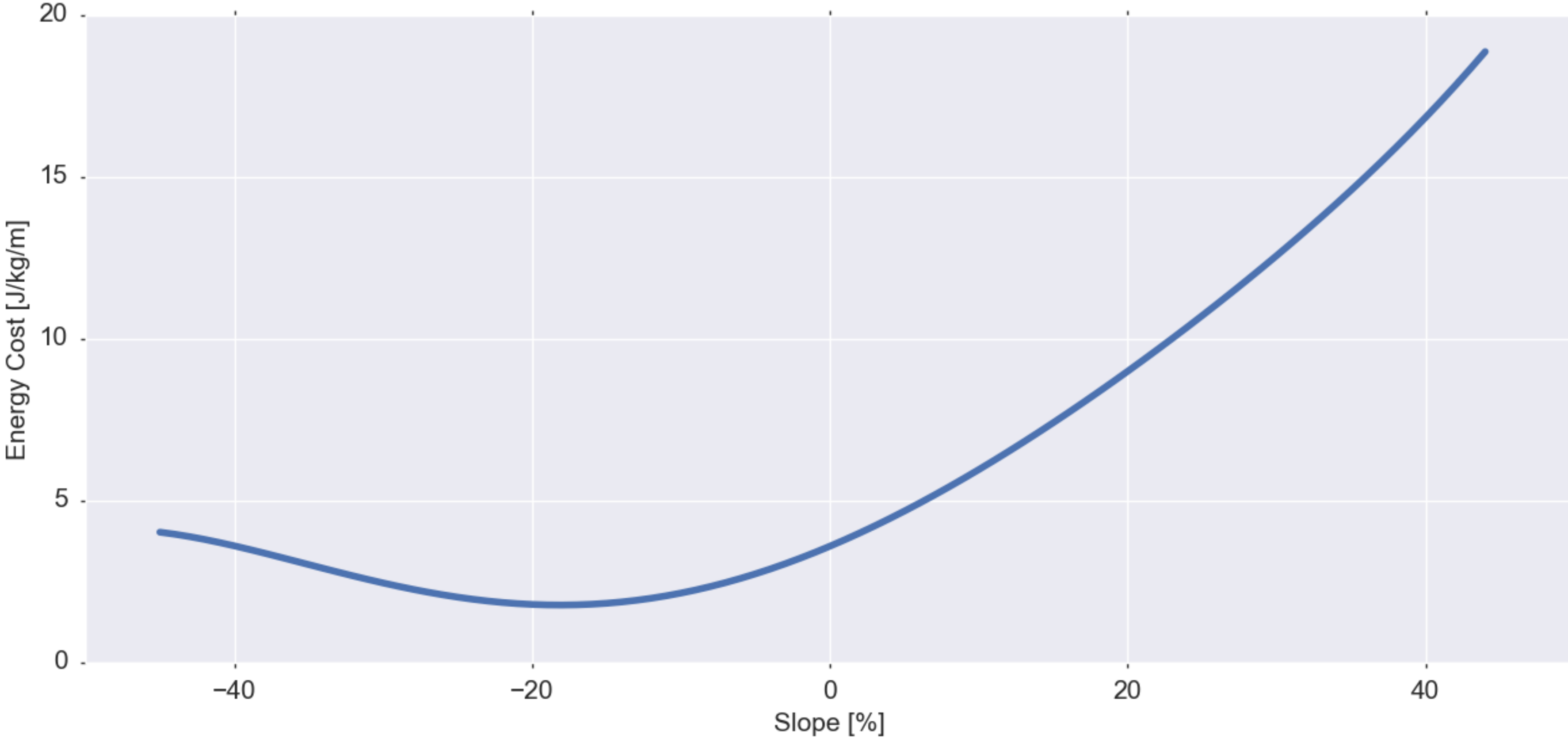
- *Resting HR [bpm]*
- *HR slope [bpm/watt]*
- *HR max [bpm]*
- *Rising time constant [s]*
- *Falling time constant [s]*
- *Sensitivity to fatigue [Watt/Joule]*



Cycling activities results

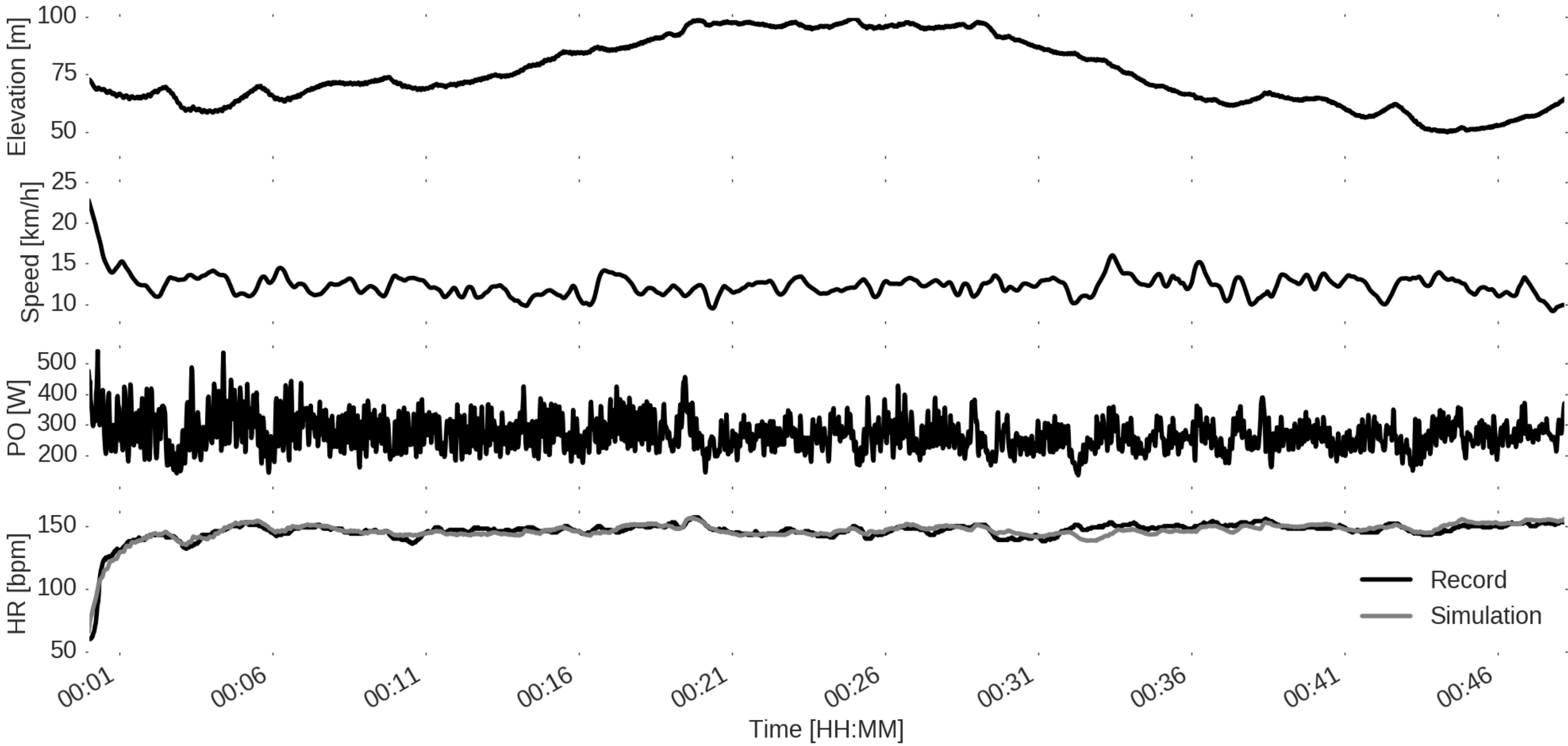


Energy cost of running

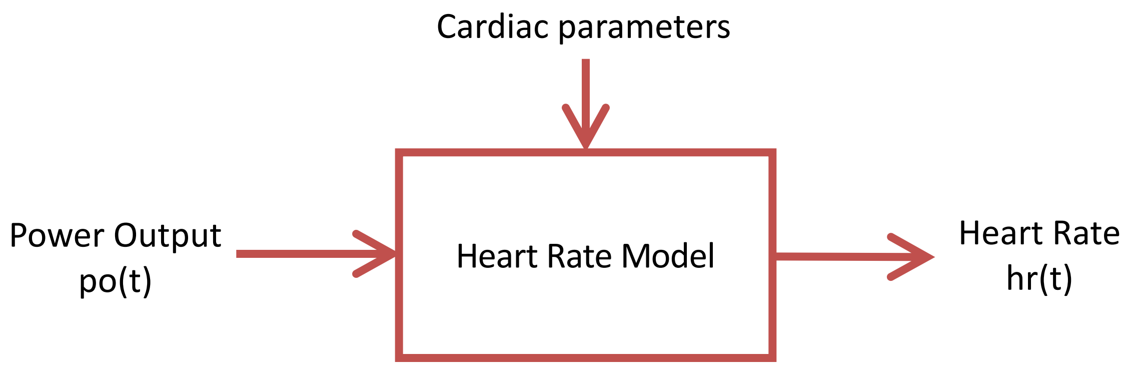


Minetti, A. E., Moia, C., Roi, G. S., Susta, D., & Ferretti, G. (2002).
Energy cost of walking and running at extreme uphill and downhill slopes.
Journal of applied physiology, *93*(3), 1039-1046.

Running activities results



Validation



- 72 Cycling activities (3 cyclists) average rmse : 4 bpm
- 234 Running activities (2 runners) average rmse : 6 bpm

Conclusion

- Pressing need for continuous fitness assessment
- Our identified parameters allow for accurate heart rate simulation
- Ongoing research
  - Our parameters Vs Laboratory measurements
  - Performance prediction (like race times)

Questions ?