PhD Thesis Proposal (2019)

Laboratoire de Physique Théorique
et Modèles Statistiques (LPTMS)

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Location: Orsay

Models and Time Series Analysis for Human Sports Performance

This project is directed to students with a strong background in quantitative methods from statistical physics, and ideally some knowledge of machine learning, computational physiology and statistical analysis of large data. Interest in sports performance would be useful. Expected are both analytical and computer programming skills.

Models for human sports performances of various complexities and underlying principles have been proposed, often combining data from world record performances and bio-energetic facts of human physiology. For running, we were the first to derive an observed logarithmic scaling between world record running speeds and times from basic principles of metabolic power supply. We showed that various female and male record performances (world, national) and also personal best performances of individual runners for distances from 800m to the marathon are excellently described by our approach, with mean errors of (often much) less than 1%.

Main goal of this thesis project is the data-driven modeling of physiological and biomechanical processes in endurance sports, in particular running. The physiological and mechanical response of humans to exercise constitutes a complex system that involves many dynamical variables. Examples are the beat-to-beat intervals between heart beats, oxygen uptake, and stride frequency to name a few. These variables show inherent fluctuations that can be correlated.

Time series analysis can be used to detect these correlations which can show fractal scaling. This has been demonstrated for patients with cardiac diseases by Goldberger (see references below). Methods include detrended fluctuation analysis (DFA), multifractal DFA, EMD, multiscale entropy, and transfer entropy.

Models for complex physiological systems shall be constructed by learning from data. For example, running performance has been studied using recent advances in machine learning (see reference by Blythe and Kiraly). One aspect of this project is to apply machine learning to complex physiological data for endurance exercise and compare the so obtained results to findings from other methods.

Some relevant literature and online resources:

- Workshop in April 2018 at MIT (talks are online):
  http://running.mit.edu/workshop/
- M. Mulligan, G. Adam, T. Emig, A Minimal Power Model for Human Running Performance, PLoS ONE 13: e0206645 (2018),
  https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0206645.
- P. Ch. Ivanov et al, Multifractality in human heartbeat dynamics, Nature 399, 461 (1999).
- D.A.J. Blythe and F.J. Kiraly, Prediction and Quantification of Individual Athletic Performance of Runners. PLoS ONE 11: e0157257 (2016),
  https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0157257.

This project potentially involves collaborations with Prof. A. Goldberger (Harvard Medical School) and Prof. E. Räsänen (TUT, Finland).

The official application can be found on the web site of Ecole Doctorale at
https://www.edpif.org/fr/recrutement/prop.php
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