

Functional Data Analysis in Sports Biomechanics

Over the past 20 years, Functional Data Analysis has emerged as an important and natural framework for analysis of biomechanical data sets in both sports and rehabilitation applications.

Despite its inherent suitability, the uptake of this approach in sports biomechanics has been limited by the lack of by the availability of user-friendly code and professional development tutorials for researchers. Additionally, the applications of FDA in biomechanics have been limited to the use of elementary techniques (e.g., FPCA) and have not leveraged the full suite of techniques available in FDA toolkit.

This workshop will provide a practical introduction to a broad range of FDA techniques and their applications in biomechanics, focusing on the following themes:

- **Data Smoothing with Basis Expansions:** How to convert noisy, sampled data into smooth functions for analysis. We will cover the conventional approach of using Fourier and B-spline basis functions as well as other approaches such as the wavelet basis for less smooth data (e.g., EMG).
- **Registration of Functional Data:** How to align functions that exhibit variation in both amplitude (e.g., peak heights) and phase/ timing (e.g., peak timings). We will discuss the well-studied landmark registration method as well as more modern, sophisticated techniques.
- **Functional Principal Components Analysis (FPCA):** FPCA is the most widely-used technique in FDA, both in biomechanics applications and more generally. It is a dimension reduction tool that can be used to explore variation in functional data. We will discuss the computation and application of FPCA, as well as modern developments for more advanced analyses.
- **Inference and Prediction with Functional Data:** Regression models using functional variables as outcomes and/ or predictors, linking with hypothesis and inferential tests for functional data.

$$\begin{matrix} \underbrace{y(t)} \\ \left[\begin{array}{c} \text{green wave} \\ \vdots \\ \text{blue wave} \end{array} \right] \end{matrix} = \begin{matrix} \underbrace{X} \\ \left[\begin{array}{cc} 1 & x_{11}=1 \\ \vdots & \vdots \\ 1 & x_{IN}=0 \end{array} \right] \end{matrix} \begin{matrix} \underbrace{\beta(t)} \\ \left[\begin{array}{c} \text{black wave} \\ \vdots \\ \text{red curve} \end{array} \right] \end{matrix} + \begin{matrix} \underbrace{\varepsilon(t)} \\ \left[\begin{array}{c} \text{green wave} \\ \vdots \\ \text{blue wave} \end{array} \right] \end{matrix}$$

- **Visualisation and Presentation of Functional Data:** Perhaps the most under-utilised aspect of FDA is its ability to describe data in a principled, coherent and interpretable manner. We will discuss visualisation and summary tools for functional data such as the functional boxplot.

Workshop Organisers

Dr Edward Gunning



Ed Gunning is a postdoctoral researcher at the Department of Biostatistics, Epidemiology and Informatics in the Perelman School of Medicine at the University of Pennsylvania. He is mentored by Prof. Jeffrey Morris and Prof. Giles Hooker, who are both prolific researchers in the field of Functional Data Analysis. Ed's postdoctoral research focuses on the development of functional data analysis methodology,

driven by applications in the biomedical sciences (e.g., wearable device data, radiomic data and climate data).

Ed completed his Ph.D. '[*Statistical Modelling of Second-Generation Functional Data with Application in Biomechanics and Human Movement Research*](#)' in the Dept. of Mathematics and Statistics at the University of Limerick, Ireland, where he was part of the SFI Centre for Research Training in Foundations of Data Science. He was advised by Prof. Norma Bargary and collaborated with leading sports and exercise biomechanists such as Prof. Kieran Moran, Dr Shane Gore, Dr John Warmenhoven and Prof. Drew Harrison.

Prof Drew Harrison



Drew Harrison is an Emeritus Professor in the Department of Physical Education and Sports Sciences at University of Limerick, Ireland. He served as Department Head from 2006 to 2012 and established and co-directed the Sport and Human Research Centre and the Biomechanics Research Unit at the University of Limerick. Drew served as President of the International Society of Biomechanics in Sport (2011-2013), received the Geoffrey Dyson award of ISBS in 2014 and was made an honorary life member of ISBS in 2015. Drew is an Associate Editor for *Sports Biomechanics*

and is a regular reviewer for many peer reviewed journals in sports science, sports medicine, exercise and rehabilitation. In addition to his academic and research activity, Drew is a high-performance athletics coach and has coached many track and field athletes at all levels including, National, European, World and Olympic Games.

Workshop Schedule: 09:00 to 16:00 with 1-hour lunch break and 20-minute coffee break. The workshop will comprise a mix of lecture-style presentations, group break-out discussions and practical coding exercises.

Fees: €70 (student) €90 (staff);

Requirements: Attendees must bring their own laptop with the R software for Statistical Computing and the RStudio IDE installed. Further details on software to follow.