# Inference for Change Points and Related Processes Programme Final Report

John Aston, Idris Eckley, Paul Fearnhead and Georgy Sofronov

May 28, 2014

## Rationale

Change points and related areas, such as non-stationary time series analysis, are undergoing a renaissance. In the age of "Big Data", it is no longer reasonable to assume that long time series of complex data are stationary, and as such changes in the data are to be expected. Often such changes are the features of primary interest, as is seen with high-profile applications such as climate change and the recent financial crisis. Issues of detecting such changes, or allowing for the uncertainty about future changes in predictions, are important practical problems that often require novel statistical methods. In addition, there have also been recent promising developments in statistical theory for change points, from the theoretical underpinnings for high dimensional data to the algorithmic implementations of change point routines which can be utilised on massive data.

The focus of this programme was to bring together researchers from two methodological areas, namely change point analysis and locally stationary time series analysis, as well as to highlight a wide variety of application areas where the methodology is becoming increasingly relevant. Many researchers in these areas are working on related or even highly similar problems, but due to the somewhat disconnected literature, the programme aimed to enhance contact between the areas and to build links between those working in them.

With this in mind, the programme was structured into four distinct weeks. The first week contained the workshop which focussed on methodological aspects. The final three weeks each concentrated on a broad area of application; Economics and Social Science (week 2), Energy and Environment (week 3); and Biomedical (week 4).

## Week 1: Workshop

The most intensive week from the point of view of presentations was the first workshop week. Thirty four researchers gave presentations on aspects of change point analysis and non-stationary time series analysis, with a roughly 50/50 split between the two areas. Three keynote talks were presented on the first day, giving all present the opportunity to learn about the state of the art in terms of locally stationary and change point analysis. These presentations were given by three world reknowned experts in the areas; Prof. Rainer Dalhaus (Heidelberg) on Locally Stationary Processes; Prof. David Siegmund (Stanford) on Change Point Analysis; and Prof Guy Nason (Bristol) on Wavelet Analysis for Non-stationary Time Series.

The presentations during the rest of the week covered a huge range of theoretical, methodological and applied statistical areas. The talks ranged from mathematical statistical analysis of the asympotitic properties of change point estimators, through developing computationally and statistically efficient methods for detecting changes that scale to big data applications, to applications of locally stationary time series analysis in areas such as oceanography and neuro-

science. The presentations were from a mixture of world leading and established researchers as well as some from more junior up and coming researchers in the areas.

## Week 2: Economic and Social Science Applications

Week two focussed on applications of change points methods and non-stationary time series analysis in Economic, Financial and Social Science application areas. There were six, more in depth, seminars during the week. These ranged in application areas, including finance, demography, and social network analysis. Indeed, the final one of these became somewhat of a recurring theme during this week with many people indicating that the analysis of change points and local stationarity of graphs may well be an important problem to address. This lead to a formal discussion session late on in the week specifically based on exploring connections between participants and interests in change points on graphs and in networks. This was indicated by several participants as one of the highlights of the programme, as it allowed several promising connections to be made.

## Week 3: Energy and Environmental Applications

The third week of the programme considered the application of these methods to energy and environmental applications. Talks focussed on the application of changepoint and related methods to a variety of areas including wind energy, climate change and emissions monitoring. One particular feature common to these talks was to raise awareness of both the diverse and challenging changepoint and time series questions which occur in these disciplines. As such they provide statisticians with both challenging methodological and theoretical questions, whilst also potentially enabling significant impact to be realised. Many discussions occurred following these presentations and several research avenues were identified. These have resulted in new collaborations and, in time, we hope several important new developments will be published.

## Week 4: Biomedical Applications

Week four was devoted to biomedical applications of change point detection methods and non-stationary time series analysis. There were six one-hour seminars presented by world leading experts in bioinformatics and signal processing. Applications within these areas covered important issues such as detecting changes in DNA copy number variation and structural analysis of EEG signals. A number of participants attended only this week of the programme, which emphasised the significance of the practical applications discussed during the week.

## Outcomes and Achievements

From our point of view, the programme was very successful, bringing together many people from different areas who had little or no previous connection, but who at the end were establishing collaborations and sharing ideas. This was facilitated by several interesting initiatives during the programme. These included virtual seminars which allowed participants who were unable to travel to still present their work at the programme, and "Ideas Lunches", where individuals who had connections in their work but might not necessarily be known to each other were identified and given the opportunity to go to lunch together. We know of at least six different collaborations that have been initiated from the programme, and it may well be even more than this. Many people indicated that the programme was an ideal starting point for further development of the area and that while the month programme began these ideas, a longer programme in a few years time might well be the natural next step.