Gating of Flow Cytometry Data via Markov Random Fields

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WP 3

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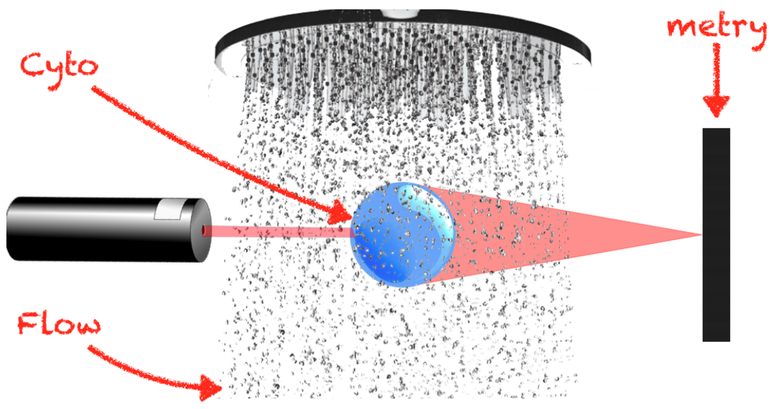
Abstract

Flow cytometry is a technology that simultaneously measures and analyses multiple physical and chemical characteristics of single cells as they flow in a stream through a beam of laser light. The gating stage of analysis, the identification of homogeneous cell populations, is performed using expert opinion rather than by employing a unified statistical framework. The increased volume and complexity of flow cytometry data resulting from advances in the technology greatly boosts the demand for reliable statistical methods and accompanying software implementations for analysis. The objective of this research is to provide a methodology which moves beyond the expert-driven approach currently employed.

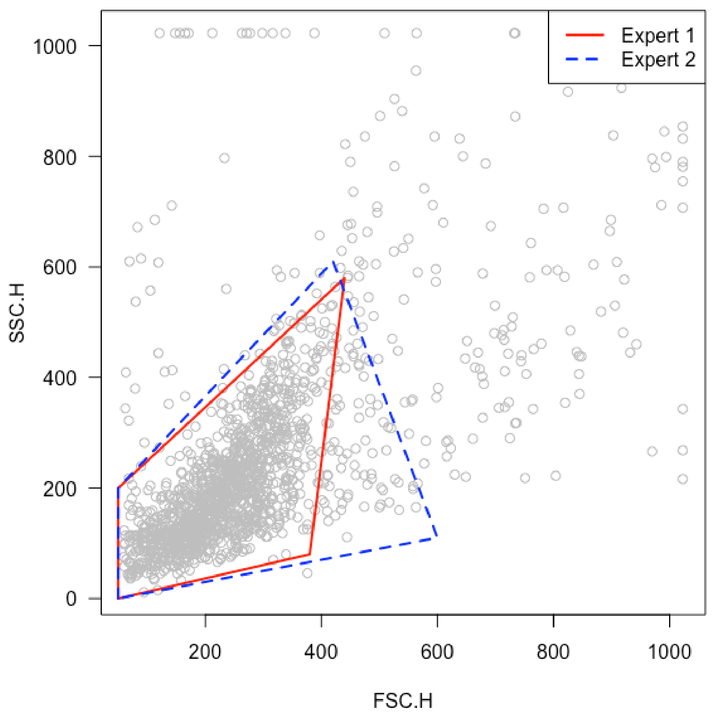
What is Flow Cytometry?



Flow – a stream of 'sticky' fluid passing through a flow cytometer
Cyto – the cells suspended in the fluid stream
metry – the measurements are recorded when a cell is excited by a laser beam

Existing Approach

- Expert-driven approach
- Non-reproducible results
- Underlying data structure ignored
- Computationally inefficient



Application Areas

- Diagnosis and monitoring of leukaemia and lymphoma patients
- Quality control in Dairy Sciences
- Food Safety

Probability Map – Markov Random Fields

Let L be an $N \times N$ lattice grid where

$$X_{ij} \in \{-1, +1\}$$

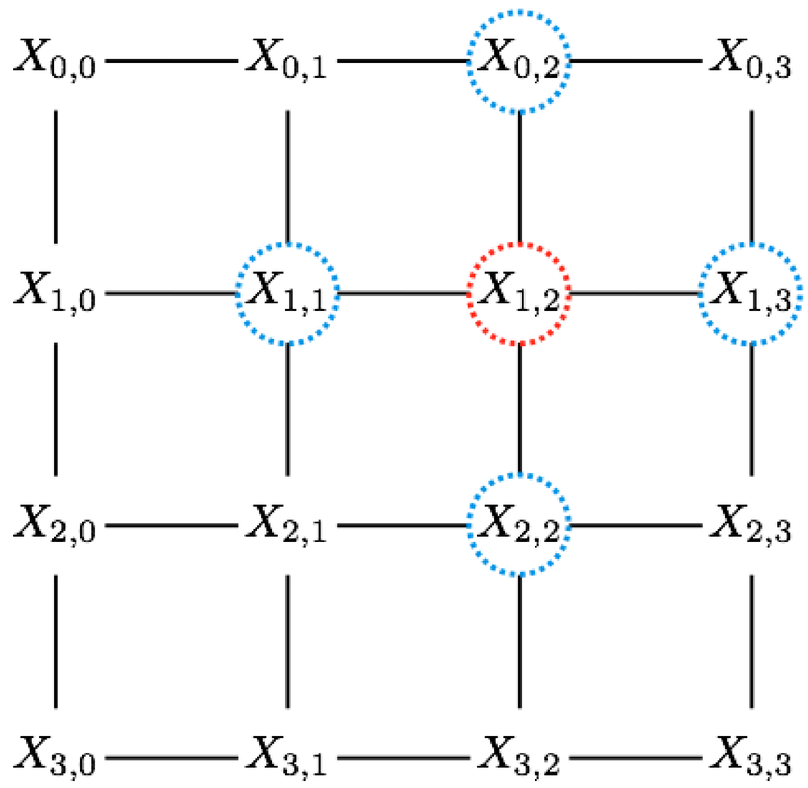
with each observation X_{ij} having first order neighbours defined by

$$\eta_{ij} = \{(\ell, m) : 0 < (i-\ell)^2 + (j-m)^2 \leq 1\}.$$

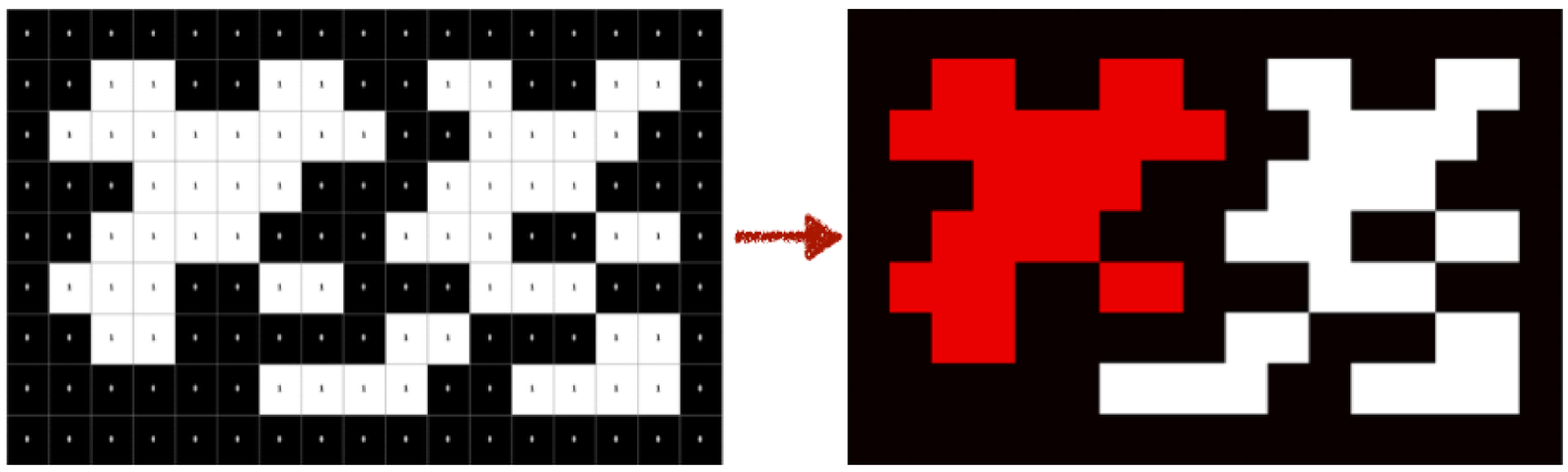
L is thus a Markov Random Field following a Gibbs Distribution with conditional probability mass function of a single node being defined as

$$\Pr(X_{ij} = x_{ij} | X_{\ell m} = x_{\ell m}, (\ell, m) \in \eta_{ij})$$

$$= \frac{\exp\left(x_{ij} \sum_{\eta_{ij}} x_{\ell m}\right)}{\exp\left(\sum_{\eta_{ij}} X_{\ell m}\right) + \exp\left(-\sum_{\eta_{ij}} X_{\ell m}\right)}$$

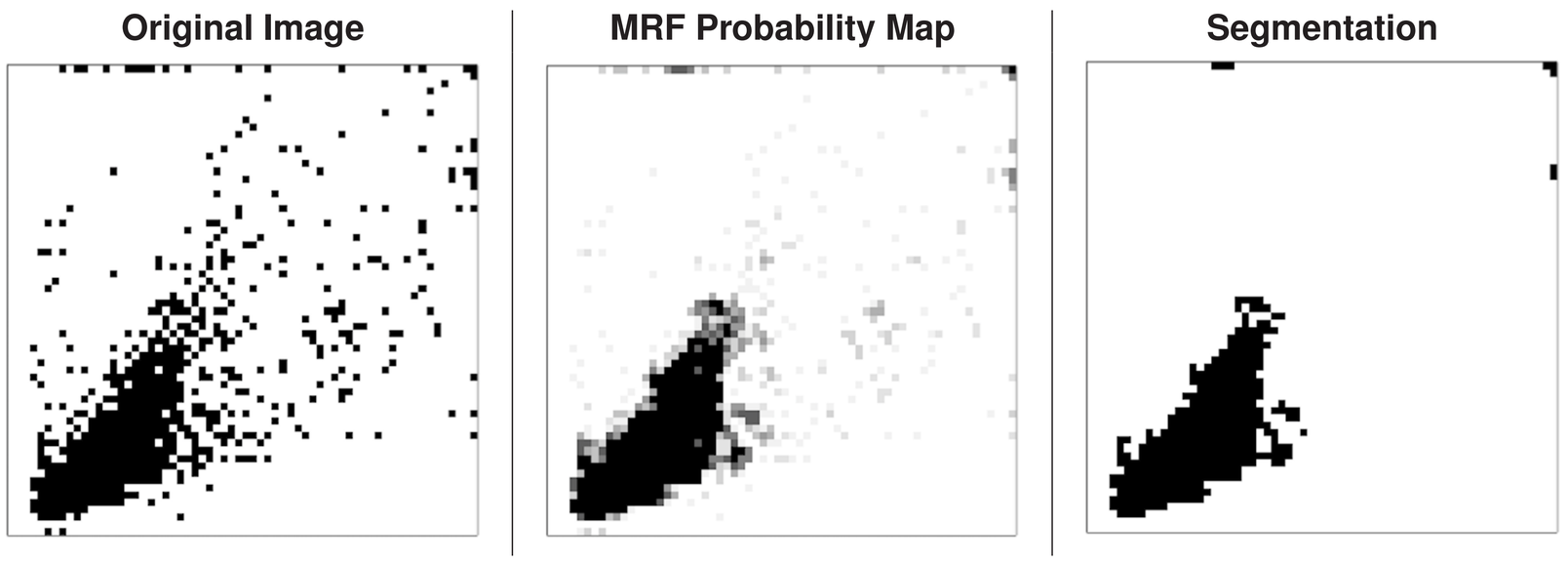


Segmentation – Connected Components Labelling



1. Begin with a realisation of the Markov Random Field Probability Map
2. Assign unique labels to each group of pixels & record label ties
3. Re-assign groups with label ties to lowest group label
4. Identification of homogeneous regions within the image

Results



Future Work

Flow Cytometry

- Gating in multiple dimensions
- Open Source Software solution

Equity Models

- Pricing of Renewable Feed-In Tariffs

Presentations

- Gating of Flow Cytometry Data via Adaptive Markov Random Fields. *Royal Statistical Society Invited Session.* University of Manchester. 8^{th} September 2016.
- A Markov Random Fields Approach to the Gating of Flow Cytometry Data. *Research Students Conference in Probability and Statistics.* University College Dublin. 15^{th} June 2016.