

# Bayesian Inference Using Sequential Monte-Carlo Algorithm for Dynamic System Models

Chaolin Han

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## **Abstract**

This is the bit where you summarise what is in your thesis.

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## **Acknowledgements**

This template is a slightly modified version of the one developed by Prof. Charles Duncan for MSc students in the Dept. of Meteorology. His acknowledgement follows:

*This template has been produced with help from many former students who have shown different ways of doing things. Please make suggestions for further improvements.*

# Chapter 1

## Introduction

This should contain a description of your project and the problem you are trying to solve. Where appropriate you should also include references to work which has already been done on your topic and anything else which lets you set your work in context.

One of the things you will need to do is to ensure that you have a suitable list of references. To do this you should see [1] or some other suitable reference. Note the format of the citation used here is the style favoured in this department. Here is another reference [2] for good measure.

You will also want to make sure you have no spelling or grammatical mistakes. To help identify spelling mistakes you can use the commands *ispell* or *spell*. See the appropriate manual pages. Remember that spelling mistakes are not the only errors which can occur. Spelling checkers will not find errors which are, in fact, valid words such as *there* for *their*, nor will they find repeated words which sometimes occur if your concentration is broken when typing. **There is no substitute for thorough proof reading!**

# Background

[illegible]

Some bits are hard.

Here is a padding paragraph. Rhubarb. More rhubarb. Yet more rhubarb. Rhubarb. More rhubarb. Yet more rhubarb. Rhubarb. More rhubarb. Yet more rhubarb. Rhubarb. More rhubarb. Yet more rhubarb. Rhubarb. More rhubarb. Yet more rhubarb. Rhubarb.



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### 2.2.1 Hard bits

You might want to include an equation here:

$$\delta N_\nu = (\delta N_\nu)_{ex} + (\delta N_\nu)_{au} \quad (2.1)$$

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### 2.2.2 Even harder bits

This might be one of the places where you might want to refer to equation 2.1. You will usually need to use the Latex command twice to make cross-references like this work properly. The cross-reference information is stored in the *.aux* file so don't delete it.

## Numbering

You can keep subdividing but eventually you get to a level where numbering stops. This text is in a subsubsection which is not numbered by default.

**More on numbering:** This text is in a paragraph which is also not numbered by default and the “title” of the paragraph is not on a separate line. If you want to increase the depth to which sections are numbered you should see the section on setting the secnumdepth counter in the manual.

## 2.3 Bayesian inference

## Chapter 3

# Mathematical modelling

You might sometimes want to include equations without numbering them.

$$E = mc^2$$

You might also want to include diagrams. The example shows the use of the special command which allows existing postscript files to be included. You would normally keep your figures separate from the text. These pictures might be satellite images or postscript output from some program such as IDL, PV-WAVE, Uniras or xpaint.

Below I create a figure which is centred and stretched to 30% of the width of the page `{0.30\hsize}` and with the height stretched by the same amount `{!}` to preserve the aspect ratio. If you omit the extension (ie .eps, .ps or .pdf) on the file name then latex will pick up the postscript copy whereas pdflatex will automatically pick up the PDF version.

You can use a label on a figure to refer to it later. The university crest is in 3.1. Note that you should not use phrases like “the figure above” or “the following figure” since Latex may move the figure relative to the text if it cannot be fitted onto the current page.



Figure 3.1: The University Crest

# Chapter 4

## Implementations and Experiments

### 4.1 Parameter estimation

Here are some results.

### 4.2 Model comparison

Here are some results.

### 4.3 Performance experiments

The performance experiments are designed to explore the parallel performance of ABC SMC implementations. Usually ABC SMC is a time-consuming and computation intensive task and usually is executed on large clusters. The scheduling strategy, implementation details and many other factors can affect the parallel efficiency.

First experiments are designed to illustrate the scaling-up performance. The program used here is an implementation of ABC SMC on model 5. The details of the ABC SMC settings is listed below

- Prior distribution: default to log-uniform distribution  $[1 \times 10^{-6}, 50]$  for all the 12 parameters
- threshold schedule: median epsilon
- No factors, no adaptive distance or adaptive population applied
- Population size is 2000, with 20 generations

## HOW PYABC parallelise the sampling

For HPC systems like Cirrus, `pyabc` uses `multiprocessing` for multi-core parallel sampling. By default if the number of cores is not specified, it will automatically read the number of available cores and use them all. Cirrus has a 36-core CPU which support hyperthreading, such that the maximal number of cores available to `multiprocessing` is 72.

The program is executed on Cirrus, using 8, 12, 16, 24, 36, 54, 72 cores respectively. Each run is repeated 5 times. The average execution time, required sampling numbers are recorded. Hyperthreading is enabled when using 54 and 72 cores. The access to the node that contains computation cores is exclusive, such that the execution would not be affected by other programs of operations.

The implementation of ABC SMC in `pyabc` enables the parallelisation of sampling, which is the most time-consuming part. The rest part of the program is mostly not parallelised, e.g. database I/O and reductions operations. The sampling process involves sampling, perturbation and test of the acceptance criteria, all of which are computation-intensive.

In practice, using ABC SMC to estimate the parameters of a given model could cost up to several hundred of hours if the computational resources is limited[REF]. The performance experiment result could provide a reference that illustrate that how the efficiency changes when scaling-up or the trade-offs in computational resources' cost and their benefit.

The performance could also be analysed given a profiling report. The second experiment profiles the program to reveal the detailed time consumption for each operation and the possible bottleneck. according to which we could

# **Chapter 5**

## **Results Analysis**

### **5.1 ABC SMC results**

### **5.2 Performance experiments**

### **5.3 Discussions**

This is the place to put your conclusions about your work. You can split it into different sections if appropriate. You may want to include a section of future work which could be carried out to continue your research.

## **Chapter 6**

### **Future works**

## **Chapter 7**

## **Conclusions**



# **Appendix A**

## **Stuff which is too detailed**

Appendices should contain all the material which is considered too detailed to be included in the main bod but which is, nevertheless, important enough to be included in the thesis.

## **Appendix B**

### **Stuff which no-one will read**

Some people include in their thesis a lot of detail, particularly computer code, which no-one will ever read. You should be careful that anything like this you include should contain some element of uniqueness which justifies its inclusion.

# Bibliography

- [1] L.Lamport. *1986 Latex User's Guide and Reference Manual*. Addison Wesley.  
pp242.
- [2] F.Bloggs. *1993 Latex Users do it in Environments* Int. Journal of Silly Findings.  
pp 23-29.