FELLOWSHIP PRESENTATION

Dr. Mike Smith, University of Sheffield

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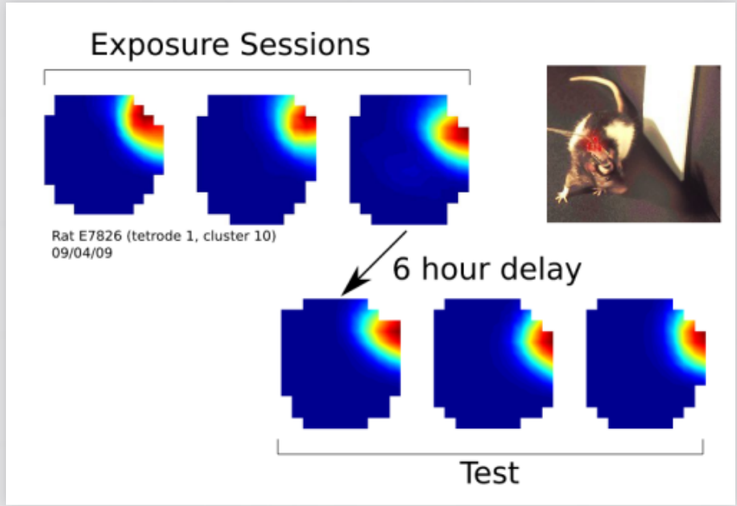
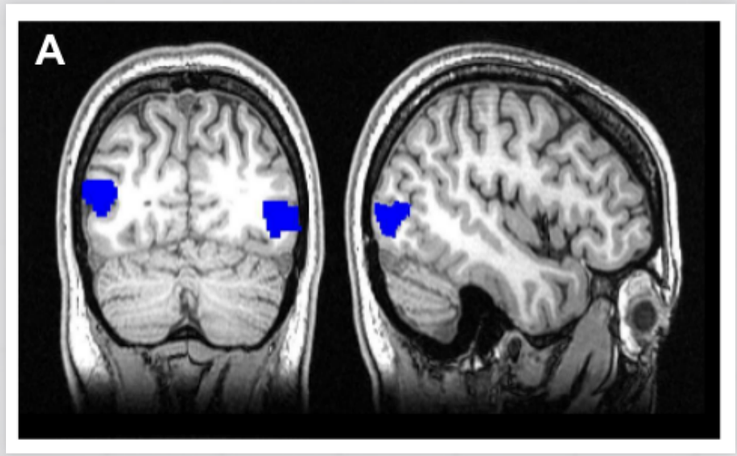
BACKGROUND

2005 BSc Computer Science, Warwick	Simulated bipedal motion
2008 MSc Informatics, Edinburgh	Synaptic charge-based noise analysis
2009 MSc Neuroinformatics, Edinburgh	Head-direction and place cell recording
2013 PhD Neuroinformatics,	Integration of self-motion cues in

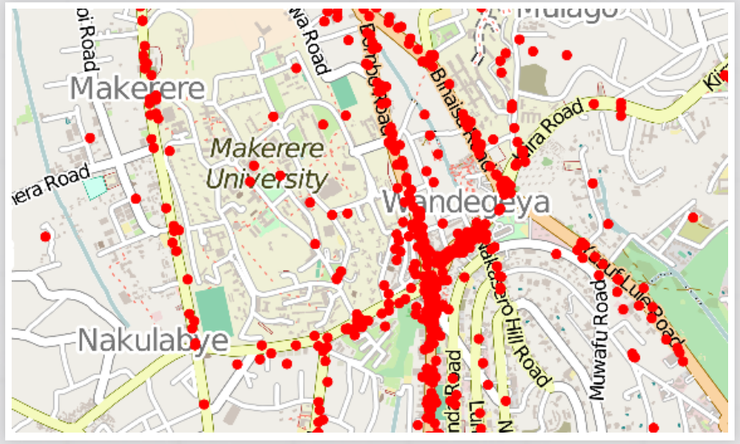




BACKGROUND

2014: Moved to Kampala to lecture at Makerere University in the computer science department.

- Crowd-sourced road crash transcription
- Air pollution monitoring
- Malaria incidence modelling



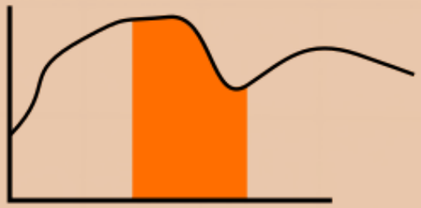
2015: InnovateUK Sheffield / CitizenMe grant. Developed scikic online Bayesian education tool & distributed DP method.

RESEARCH NOW

Adversarial Bound

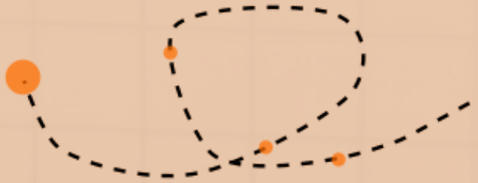
Differential Privacy

Integral Kernel



Pollution Model

Insect Tracking

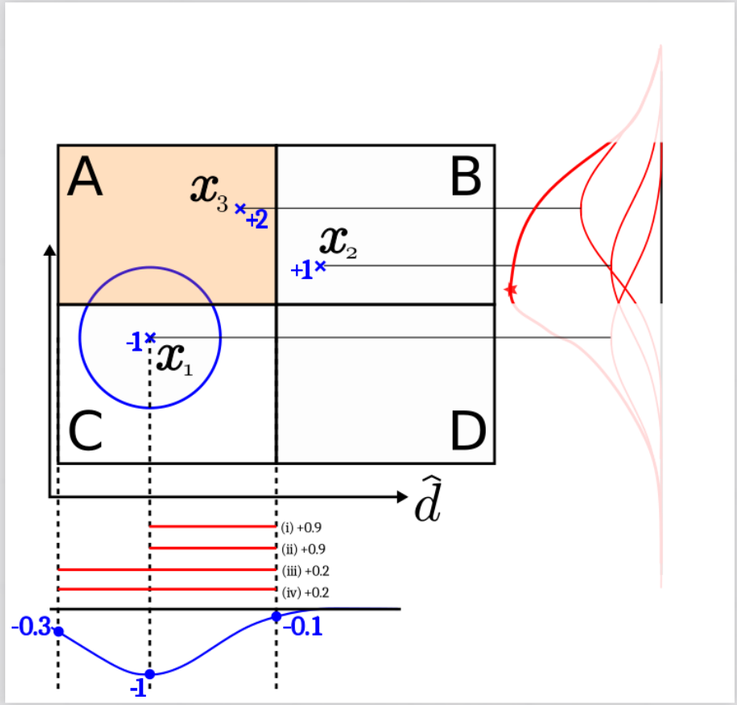


Dialysis

ADVERSARIAL BOUND

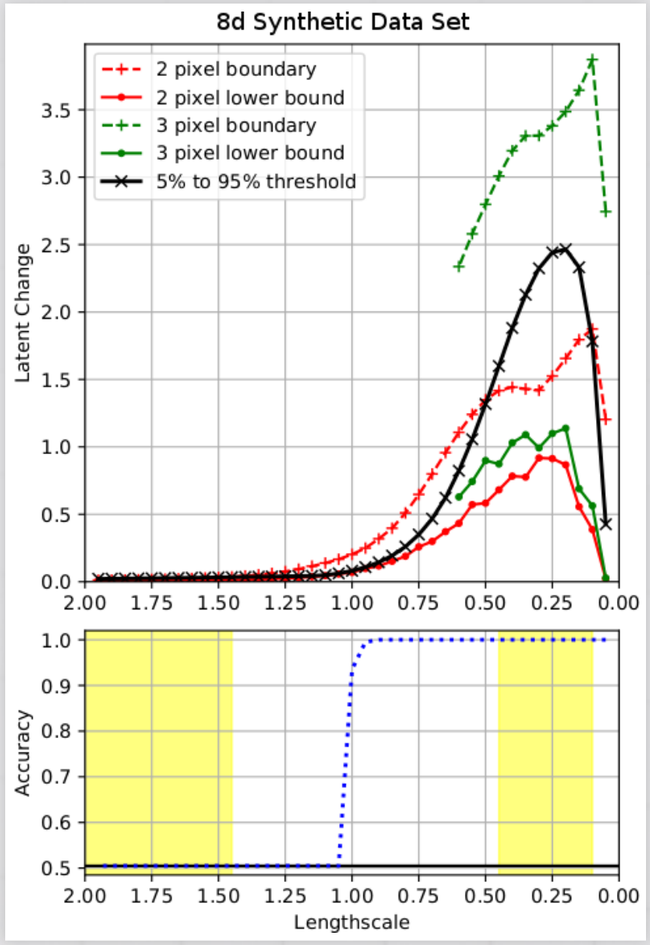
Collaborators: Kathrin Grosse & David Pfaff of CISPA, Saarland.

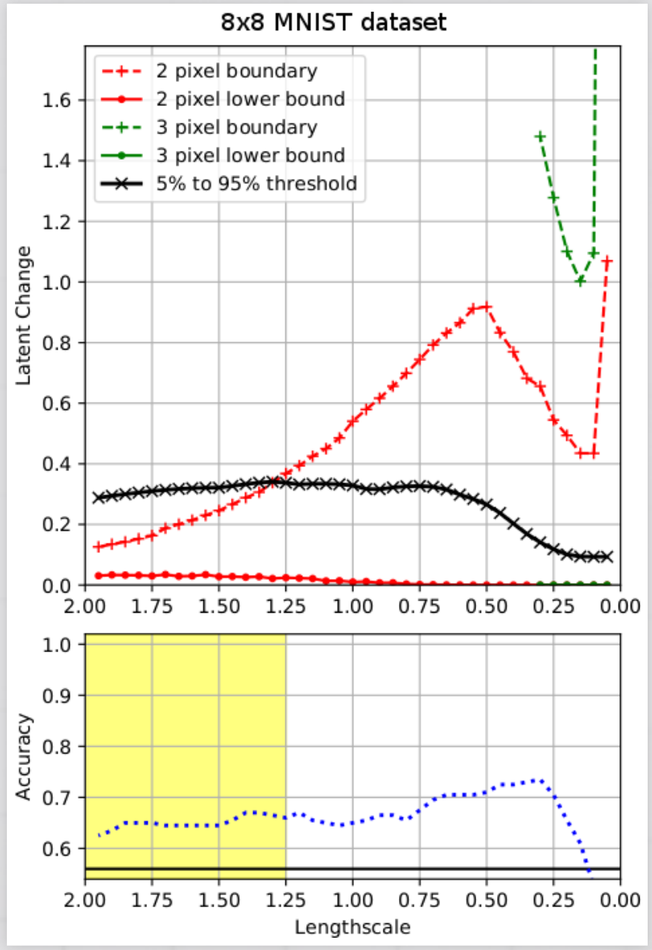
Adversarial Examples using Gaussian Process classification. In particular can we find a **lower bound** on the number of pixels one needs to perturb to get a **confident misclassification**?



Next: deepGPs?

ADVERSARIAL BOUND





ADVERSARIAL BOUND

Papers:
Kathrin Grosse, David Pfaff, Michael T. Smith, Michael Backes. (2019). The Limitations of Model Uncertainty in Adversarial Settings (*in review* on 5th Feb to CCS).

Kathrin Grosse, Michael T. Smith, Michael Backes. (2019). Killing Three Birds with one Gaussian Process: Analyzing Attack Vectors on Classification (*in review* at Euro S&P).

The bounds method is *in prep*.

DIFFERENTIAL PRIVACY

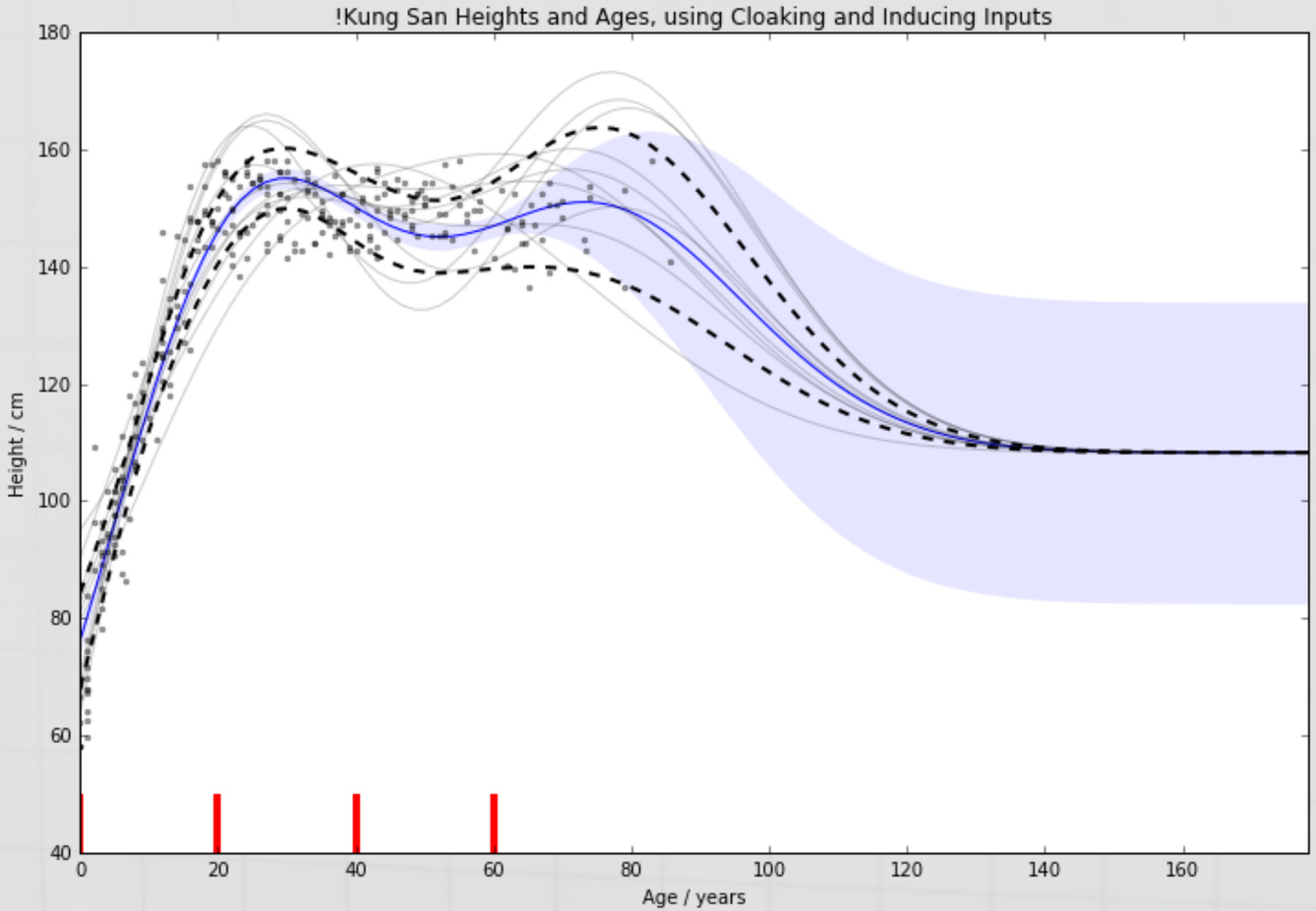
Finding practical bounds on the scale of DP noise required for GP regression and classification.

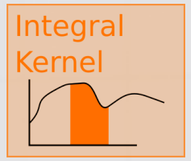
- Developed the **cloaking method**
- Used **inducing inputs** to reduce sensitivity
- Extended to work with **classification** (using the Laplace approximation)

Papers: Smith, M.T., Álvarez, M. A., Zwiessele, M., Lawrence, N. D. (2018). Differentially Private Gaussian Processes, AI STATS 2018.
We have a second paper covering the inducing inputs, classification, hyperparameter selection, etc, *in review*, JMLR.

Next: Input privacy for GPs. DP for deepGP?

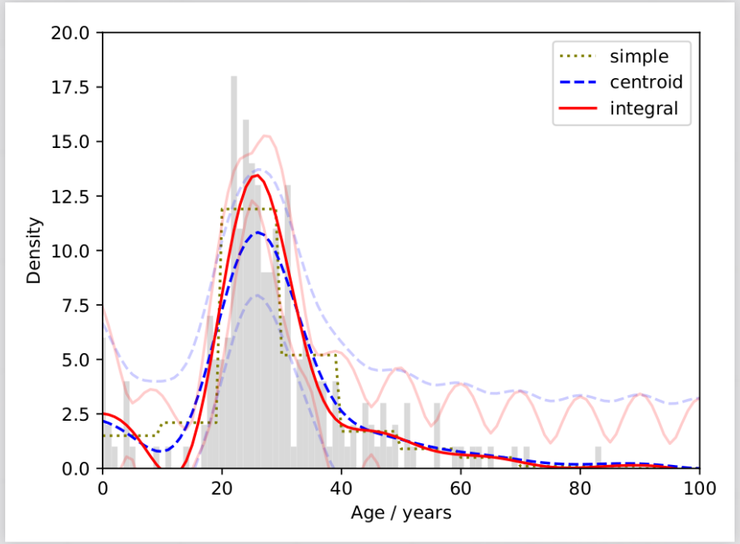
DIFFERENTIAL PRIVACY





INTEGRAL KERNEL

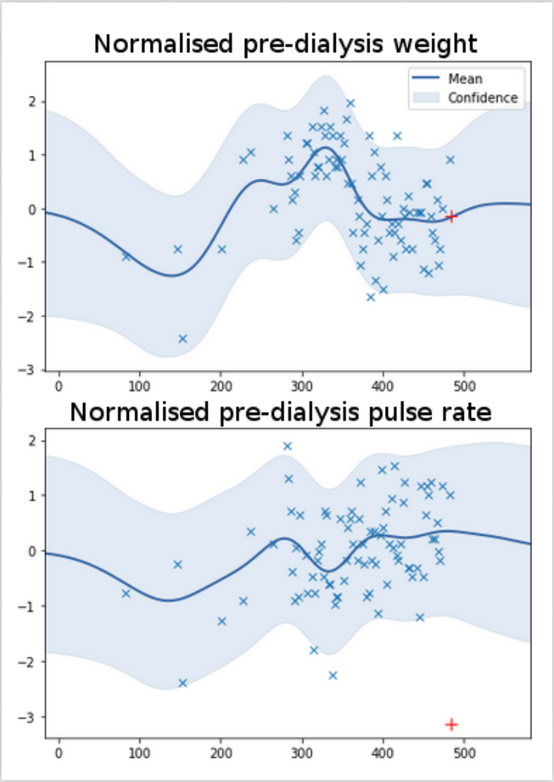
A spin-off from the DP work. Based on GP latent-force models. Uses the observation that one can integrate over a kernel to allow the **observations** to be of the **integral of the latent function**. Examples: ecological hectad data, annual financial reports, census aggregations for privacy, camera pixels, fMRI, etc.



Paper: Gaussian Process Regression for Binned Data (Stats and Computing) being revised for resubmission in February.

DIALYSIS ANALYSIS

Collaborator: James Fotheringham, Consultant Nephrologist and Honorary Lecturer, ScHARR.



Predict clinical variables over 2-4 days. ICM coregionalisation improved over simple GP fit for a subset of patients (RMSE down 15%, $p<0.05$). Hierarchical model to incorporate rare events from all patients.

Paper: Drafting a paper looking at where the method works but also what improvements are needed in data quality.

CONTINUING RESEARCH

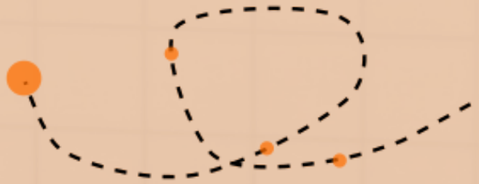
Adversarial Bound

Differential Privacy

Integral Kernel

Pollution Model

Insect Tracking

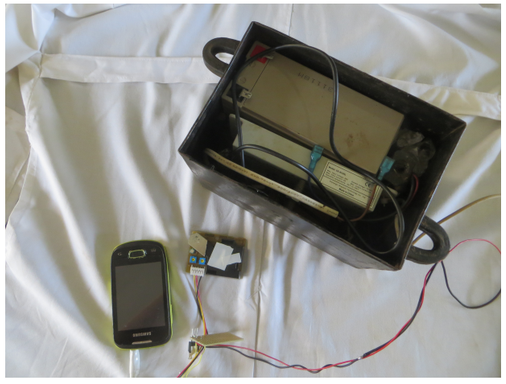


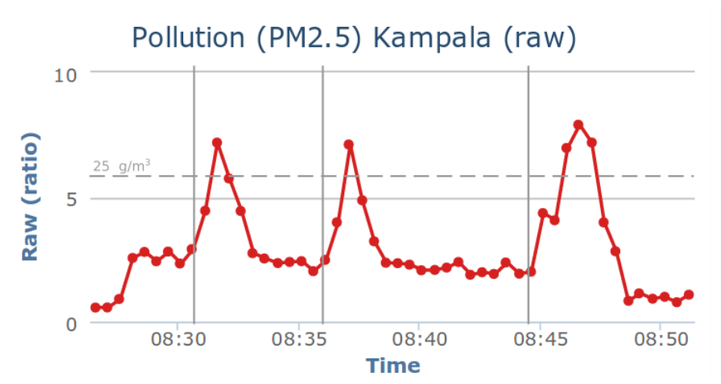
Dialysis

Pollution Model

KAMPALA AIR POLLUTION

I began the project while working in Kampala. No one was collecting air quality data in the city at the time.





Pollution Model

KAMPALA AIR POLLUTION

First collaborator was **Prof. Engineer Bainomugisha**. We won funding from the UC Berkeley's Development Impact Lab (2016, $56k) to develop the hardware. Recruited Joel Ssematimba.

Pollution Model

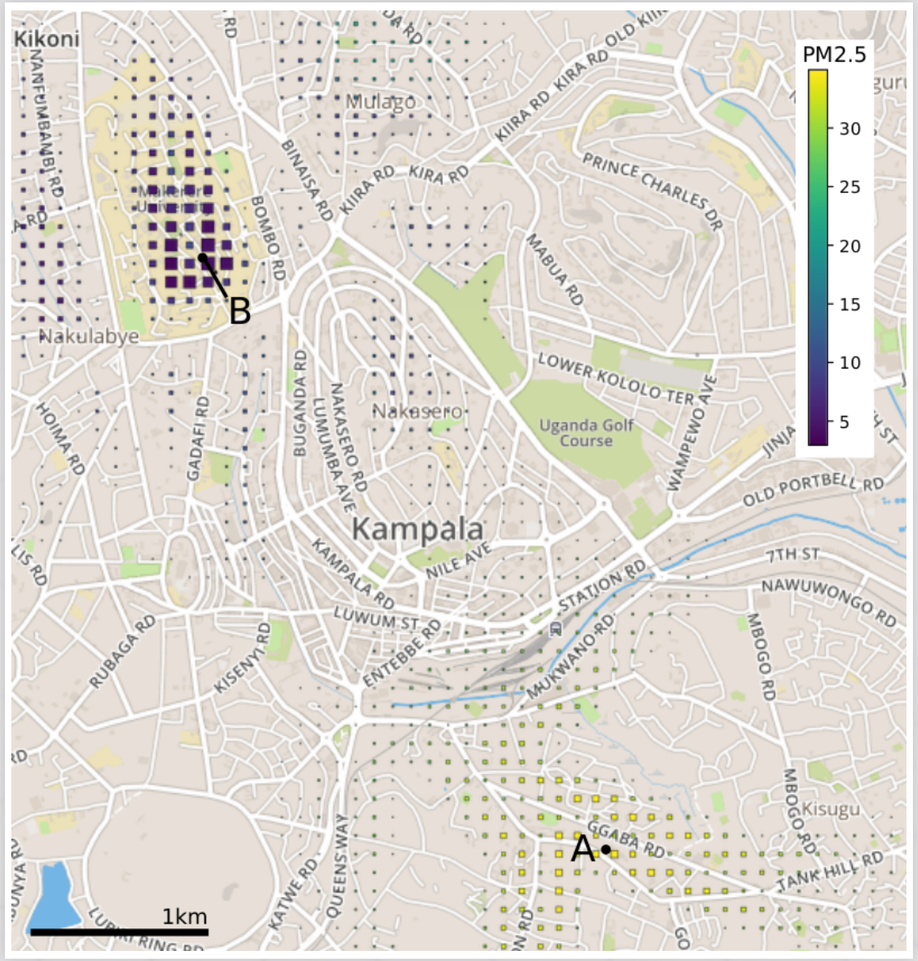
EXAMPLE DATA STREAM

Pollution Model

COMBINING SENSORS

Current model is a simple GP with inputs:

- latitude, longitude, date
- time-of-day
- distance from large roads



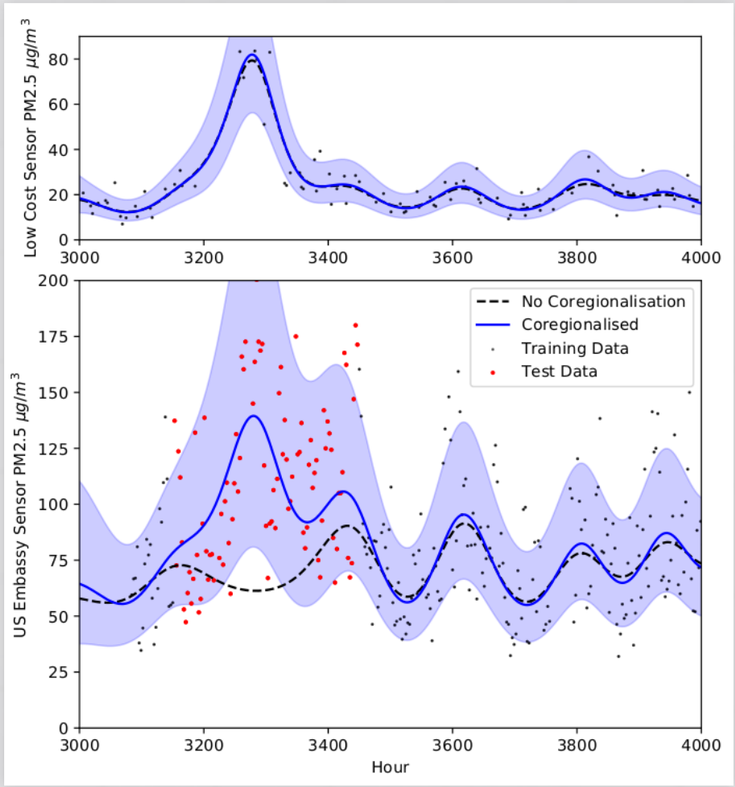
Output: Presentations and posters at workshops

Map: Replaced with a map developed by Irene Michalaki. Server model currently offline, sorry!

Pollution Model

COMBINING SENSORS

Testing coregionalisation. Collaborating with **Prof. Martin Mayfield** of the Urban Observatory, who has lent the project the equipment to validate our methods. **Rohit Chakraborty**, his PhD student, will be visiting Kampala.

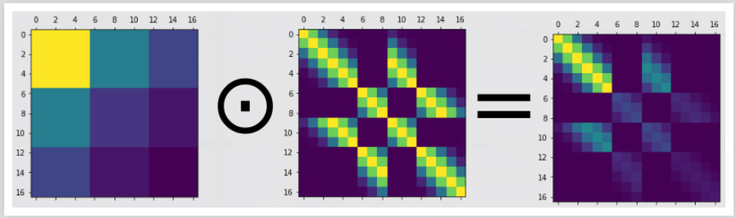


Output: Extended abstract and talk, Advances in Data Science 2018, Manchester.

Pollution Model

IMPACT AND COLLABORATION

The **KCCA (Kampala Authority)** are heavily involved in the project, giving us confidence of **impact** (particularly important for funders too). The low-cost network makes it suitable for low-income cities, but requires sophisticated mathematical methods to quantify uncertainty and for calibration.



FUNDING

Besides the Impact Lab funding (2016), we just won the internal **QR GCRF** funding (£40k). I've allocated this mainly for post-doc time in Kampala to build and deploy the network, also part-time post-doc time (here) for developing the model.

Two months Sheffield based post-doc time from **Urban Observatory** to translate the method for Sheffield's sensor network.

FUTURE FUNDING

Currently applying for the **EPSRC GRCF** Mathematical Sciences fund (£450k) to pay for post-docs both here and in Kampala for two years. Deadline: 14th February.

This would go beyond correlations and will introduce **causality** and a rudimentary **physical-basis** to improve model accuracy, but also to allow the KCCA to ask "**what if?**" questions.

We will incorporate anomaly detection. Active Learning.
Lots of interest in mathematical methods for development, air pollution, smart-cities, impact and IoT, etc.

FURTHER COLLABORATIONS

We have an effective network of collaborations. Other links are with **Dr. Pete Edwards** (Chemistry, York) who has provided considerable support on pollution questions and the low-cost sensors. **Dr. Bruce Kirenga** (Lung Institute, Kampala) will be using our data to answer epidemiological questions. **Prof. Richard Wilkinson** and **Dr. Mauricio A Alvarez** are supporting the development of the causal probabilistic model.

Initial planned outputs (next seven months): (1) calibration kernel paper, (2) low-cost sensor designs, (3) results of calibration across city/validate low-cost method.

John Quinn and the UN pulse lab. **DSA** & last year's air pollution IoT. **Dr Shamanthi Jayasooriya**, (ScHARR) indoor air pollution. **Stephan Schwander** (School of Public Health, Rutgers, NJ) gravimetric data collection.

VISION

- Development is increasingly based on **integrating** multiple sources of real-time, **low-cost**, large-scale data.
- Suffer from **biases** and unquantified **uncertainty**.
- May allow Global South to '**leap-frog**' current systems.
- Unfortunately using such data depends on more **sophisticated methods**.
- Need to develop robust **mathematical tools** for its analysis and integration.
- Ensure this development is conducted **in partnership** with research groups who will **need to apply it locally.**

STRATEGIC FIT

- ML group has **long-standing strategic collaboration** with **Makerere** (reciprocal PhD placements, research, DSA, etc) & a commitment to the values of ODA and the GCRF.
- The project also bolsters the **Open Data Science Initiative**; providing education and support in ML.
- **IoT** is a priority for the faculty (e.g. Urban Flows & MindSphere).
- Developing the group's international collaborations in **ODA eligible** countries provides **applications** for our methods and strengthens our position as a leading, outward-looking CS department.

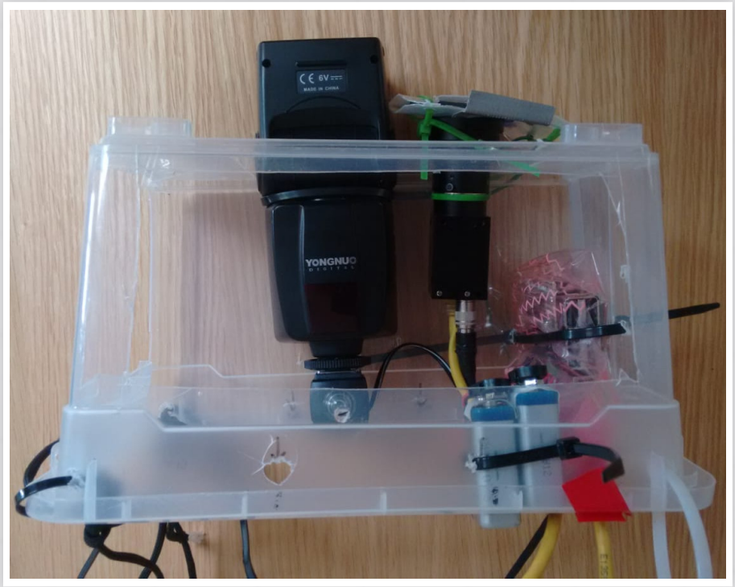
INSECT TRACKING

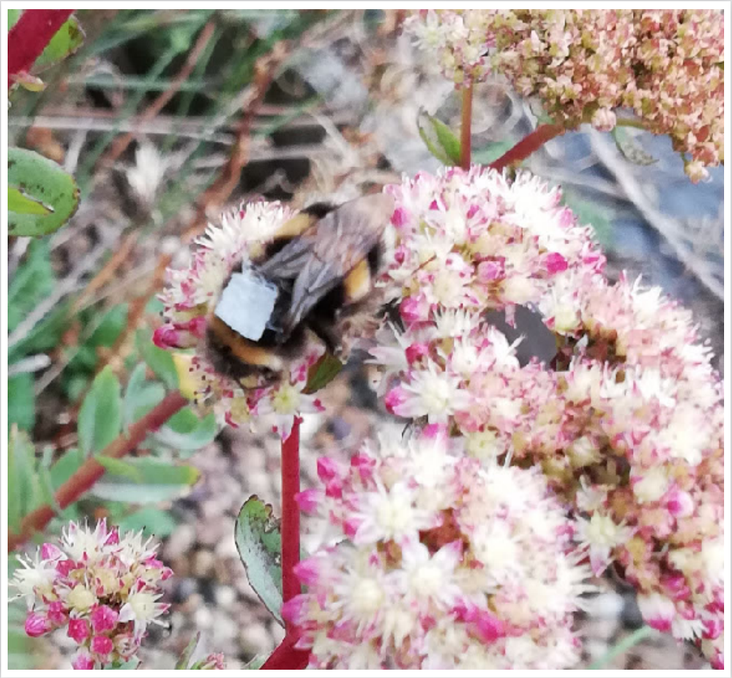
Motivation: Finding nests and understanding foraging and mating behaviour are vital for conservation. Provision of training data for **brainsonboard**.

The problem: Tracking insects in the field currently necessitates the use of electronic tags and expensive radar equipment, making it largely inaccessible to most researchers and inappropriate for smaller insects.

INSECT TRACKING

The solution: Simple retroreflective tags (<5mg) and a camera with a flash in the sky.





Insect Tracking

INSECT TRACKING

INSECT TRACKING

INSECT TRACKING

COLLABORATIONS

Mike Livingstone (Department of Landscape Architecture) supporting with insect, site and plant expertise.
Dr. Richard Comont (Bumblebee conservation trust) has been advising on relevant research questions.
Dr. Michael Mangan and the **brainsonboard** multiyear project will be conducting honey bee experiments. Tracking them as they navigate is currently challenging. The system will slot into this perfectly, providing behavioural data to help with model constraint.
Prof. Jeremy Field has contacted me about using the system for investigating paper wasp workers.

FUNDING

Previously:

Won two rounds of Sheffield University Socially Enterprising Researcher grant (2016 & 2017).

Applied for BES small-grants, but with insufficient ecological research experience.

Future:

Will resubmit to the BES with ecologist as co-I, with specific biological research question in mind (deadline 20th March).

Also will apply to the C.B. Dennis trust (1st March).

STRATEGIC FIT

- This project integrates perfectly with the **brainsonboard project**, strengthening collaborations within Engineering.
- The ML group already is embedded in the field of **neuroinformatics** and modelling animal behaviour.
- These results provide valuable constraints on these models.
- **Ecology**: Its low cost and relative simplicity would make it amenable for deployment in **East Africa** (e.g. with one of our DSA collaborators, e.g. Ciira wa Maina, who is working on the interface between engineering and ecological research).

RESEARCH SUMMARY

The **insect tracking** and **air pollution** projects both have **high impact potential** and **strong collaborative networks**, with partnerships both inside the university and beyond. The **air pollution** project in particular has the potential to accrue funding (e.g. for future expansion to other domains).
Insect tracking: The recent attention to the massive decline in insect populations has focused interest on this field and the urgent need to develop more advanced methods.

TEACHING

Edinburgh 2008-13: Tutoring, demonstrating & marking for several courses. Developed practicals and mark schemes.

Makerere 2014: Lecturing AI & Advanced Programming (course materials, exams, course-work, marking, etc). Supervised MSc students.

Sheffield 2015-: Supervising student projects & some marking.

Have led the MLnet book-group and help organise the annual Data Science Africa and the Gaussian process summer school. GPy support. Helped with GEC.

APPROACH

The Makerere lectures were two hours, so split it up with exercises to do with neighbours.

Linked with real life/fun: E.g. teaching internet protocols in Edinburgh, encourage students to 'hack' each others implementations.

Starting thesis mentoring in July (after SPL is over) & will work towards the Learning and Teaching Professional Recognition Scheme.

COURSE TOPICS

Modules from the UG course that would best fit my background include any ML related courses, or those in the fields related to neuroinformatics.

E.g. Data Driven Computing, Automata, Modelling Brain and Mind, Neural Bases, Adaptive Intelligence, Natural Systems.

Ideas for new modules or topics to bring into current modules: Algorithmic privacy & adversarial vulnerability, Neuroscience of vision, Neuro-information processing/neural coding (& Bayesian appoaches to cognition).

THANK YOU