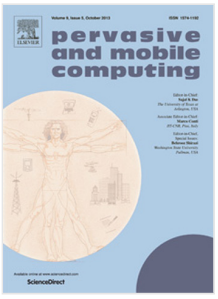
Accepted Manuscript



Gaussian Process models for ubiquitous user comfort preference sampling; global priors, active sampling and outlier rejection

Damien Fay, Liam O'Toole, Kenneth N. Brown

PII: S1574-1192(16)30165-1
DOI: http://dx.doi.org/10.1016/j.pmcj.2016.08.012
Reference: PMCJ 746

To appear in: *Pervasive and Mobile Computing*

Received date: 10 September 2015
Revised date: 16 August 2016
Accepted date: 26 August 2016

Please cite this article as: D. Fay, L. O'Toole, K.N. Brown, Gaussian Process models for ubiquitous user comfort preference sampling; global priors, active sampling and outlier rejection, *Pervasive and Mobile Computing* (2016), http://dx.doi.org/10.1016/j.pmcj.2016.08.012

Gaussian Process models for ubiquitous user comfort preference sampling; global priors, active sampling and outlier rejection.

Damien Fay[1], Liam O'Toole[2], Kenneth N. Brown[2].*

[1] *Faculty of Science and Technology, Bournemouth University, UK.*

[2] *Cork Constraint Computation Centre, Department of Computer Science, University College Cork, Ireland.*

Abstract

This paper presents a ubiquitous thermal comfort preference learning study in a noisy environment. We introduce Gaussian Process models into this field and show they are ideal, allowing rejection of outliers, deadband samples, and produce excellent estimates of a users preference function. In addition, informative combinations of users preferences becomes possible, some of which demonstrate well defined maxima ideal for control signals. Interestingly, while those users studied have differing preferences, their hyperparameters are concentrated allowing priors for new users. In addition, we present an active learning algorithm which estimates *when* to poll users to maximise the information returned.

Keywords:
Active learning, Gaussian process models, thermal preference, ASHRAE, PMV.

1. Introduction

Building energy consumption is a major factor in overall human energy consumption accounting for an estimated 20-40% of all energy consumption in the developed world [1], 43% in the US [2]. In addition, the trend appears to be increasing with this consumption in the EU rising at a rate of 1.5% each year; the rate of increase for less developed economies being far higher (4.2% in Spain for example) as their economies converge with the average [1]. Thus increase in building energy consumption has the potential to impact greatly on human energy consumption. A large part of this expenditure may be accounted for by HVAC systems (50% in the USA) designed to provide occupants with a comfortable working environment [1].

Occupant comfort is in itself an important factor effecting not just energy consumption but productivity, comfort, and the health of the occupants [3]. Indeed occupant behaviour, especially thermostat and ventilation flow usage was found to be a dominant factor in building energy demand prediction [4] outweighing structural quantities (wall conductivity, window parameters). It is important to note that an occupants comfort is a perception, *internal* to that occupant effected by, their clothing, their activity, their health and environmental factors. *External* environmental sensors alone are a poor estimator of that variable, however these are likely to remain the best measures available to us as sensing an occupants clothing index (for example) is overly intrusive. Finally, we may query the occupant themselves to get a measure of their comfort. Though a humans perception of thermal comfort is also a noisy estimator it has been found in a similar study that use of this information can yield up to a 20% saving in heating energy usage [5].

In order to assess an individuals perceived comfort level, we need to ask them how they feel. However, with the rise of ubiquitous computing individuals are now being bombarded by requests for attention and information from many sources (mobile phones, facebook, twitter etc.). As stated by York in a survey of Human Computer Interaction [6]; *Central to the concept of ubicomp* (ubiquitous computing sic.) *is that technologies should disappear*

*dfay@bournemouth.ac.uk