Jens Brehm Nielsen - DTU Orbit (25/12/2017)

Jens Brehm Nielsen

Organisations

**PhD Student, Department of Applied Mathematics and Computer Science**

27/12/2012 → 10/04/2014 Former
jenb@dtu.dk
VIP

**Cognitive Systems**

18/02/2013 → 15/03/2014 Former
jenb@imm.dtu.dk
VIP

**Industrial PhD student, Department of Informatics and Mathematical Modeling**

10/12/2010 → 23/01/2014 Former
jenb@imm.dtu.dk
VIP

Publications:

**Perception-Based Personalization of Hearing Aids Using Gaussian Processes and Active Learning**

Personalization of multi-parameter hearing aids involves an initial fitting followed by a manual knowledge-based trial-and-error fine-tuning from ambiguous verbal user feedback. The result is an often suboptimal HA setting whereby the full potential of modern hearing aids is not utilized. This article proposes an interactive hearing-aid personalization system that obtains an optimal individual setting of the hearing aids from direct perceptual user feedback. Results obtained with ten hearing-impaired subjects show that ten to twenty pairwise user assessments between different settings—equivalent to 5-10 min—is sufficient for personalization of up to four hearing-aid parameters. A setting obtained by the system was significantly preferred by the subject over the initial fitting, and the obtained setting could be reproduced with reasonable precision. The system may have potential for clinical usage to assist both the hearing-care professional and the user.

General information

State: Published
Organisations: Department of Applied Mathematics and Computer Science, Cognitive Systems, Widex A/S
Authors: Nielsen, J. B. (Intern), Nielsen, J. (Intern), Larsen, J. (Intern)
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Communication, Networking and Broadcast Technologies, Computing and Processing, General Topics for Engineers, Signal Processing and Analysis, Active learning, Approximation methods, Gain, Gaussian process (GP), Gaussian processes, hearing aids, individualization, pairwise comparisons, personalization, Signal processing algorithms, Speech, Speech processing

Today, modern digital devices can be customized significantly to the individual user by adjusting or optimizing multiple parameters affecting the output of the devices. Such personal optimization of devices is referred to as personalization. In the case of hearing aids, personalization is not only a possibility offered to the user, but a requirement that must be performed carefully and precisely in order for the user to utilize the full potential of modern multi-parameter hearing aids. Today though, personalization is still based on a manual time-consuming trial-and-error approach performed by the user himself or, in case of hearing aids, by a hearing-care professional based on typically ambiguous oral feedback from the user. This often results in sub-optimal or even inappropriate settings of multi-parameter devices. This dissertation presents research on a machine-learning based interactive personalization system to improve the personalization of devices and, in particular, of hearing-aid devices. The proposed personalization system iteratively learns a non-parametric probabilistic model of a user’s assumed internal response function over all possible settings of a multi-parameter device based directly on sequential perceptual feedback from the user. A sequential design based on active learning is used to obtain the maximum of the user’s unknown internal response function in as few iterations as possible. Experiments were conducted where the proposed personalization system obtained a significantly preferred setting for individual users within ten to twenty iterations in scenarios with up to four parameters.

Following a short introduction that includes a summary of results and contributions, the first main chapter focuses on the probabilistic modeling framework in which a Gaussian process is used to model the user’s unobserved internal response function. The first main challenge addressed in this context is to account for inconsistent and thus noisy user feedback. The second main challenge addressed is to support feedback which closely reflects the user’s perception while providing maximal information about it without imposing a high cognitive load. In the second main chapter, active learning and sequential design are discussed in relation to the challenge of obtaining the setting that maximizes the user’s unobserved internal response function in as few iterations as possible. For the Gaussian process framework, an active learning criterion is proposed specifically suitable for this type of optimization. The final chapter contains an overall discussion and conclusion of the present work and research based in part on the results from eight scientific paper contributions contained in the appendices.
Bounded Gaussian process regression

We extend the Gaussian process (GP) framework for bounded regression by introducing two bounded likelihood functions that model the noise on the dependent variable explicitly. This is fundamentally different from the implicit noise assumption in the previously suggested warped GP framework. We approximate the intractable posterior distributions by the Laplace approximation and expectation propagation and show the properties of the models on an artificial example. We finally consider two real-world data sets originating from perceptual rating experiments which indicate a significant gain obtained with the proposed explicit noise-model extension.

Efficient individualization of hearing aid processed sound

Due to the large amount of options offered by the vast number of adjustable parameters in modern digital hearing aids, it is becoming increasingly daunting—even for a fine-tuning professional—to perform parameter fine tuning to satisfactorily meet the preference of the hearing aid user. In addition, the communication between the fine-tuning professional and the hearing aid user might muddle the task. In the present paper, an interactive system is proposed to ease and speed up fine tuning of hearing aids to suit the preference of the individual user. The system simultaneously makes the user conscious of his own preferences while the system itself learns the user’s preference. Since the learning is based on probabilistic modeling concepts, the system handles inconsistent user feedback efficiently. Experiments with hearing impaired subjects show that the system quickly discovers individual preferred hearing-aid settings which are consistent across consecutive fine-tuning sessions for each user.
Hearing Aid Personalization

Modern digital hearing aids require and offer a great level of personalization. Today, this personalization is not performed based directly on what the user actually perceives, but on a hearing-care professional's interpretation of what the user explains about what is perceived. In this paper, an interactive personalization system based on Gaussian process regression and active learning is proposed, which personalize the hearing aids based directly on what the user perceives. Preliminary results demonstrate a significant difference between a truly personalized setting obtained with the proposed system and a setting obtained by the current practice.

General information

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Authors: Nielsen, J. B. (Intern), Nielsen, J. (Ekstern), Jensen, B. S. (Intern), Larsen, J. (Intern)
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Personalized Audio Systems - a Bayesian Approach

Modern audio systems are typically equipped with several user-adjustable parameters unfamiliar to most users listening to the system. To obtain the best possible setting, the user is forced into multi-parameter optimization with respect to the user's own objective and preference. To address this, the present paper presents a general inter-active framework for personalization of such audio systems. The framework builds on Bayesian Gaussian process regression in which a model of the user's objective function is updated sequentially. The parameter setting to be evaluated in a given trial is selected by model-based sequential experimental design. A Gaussian process model is proposed which incorporates correlation among particular parameters providing better modeling capabilities compared to a standard model. A ve-band equalizer is considered for demonstration purposes, in which the parameters are optimized using the proposed framework. Twelve test subjects obtain a personalized setting with the framework, and these settings are significantly preferred to those obtained with random experimentation.

General information

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Organisations: Department of Applied Mathematics and Computer Science, Cognitive Systems
Authors: Nielsen, J. B. (Intern), Jensen, B. S. (Intern), Hansen, T. J. (Intern), Larsen, J. (Intern)
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Modeling Expressed Emotions in Music using Pairwise Comparisons

We introduce a two-alternative forced-choice experimental paradigm to quantify expressed emotions in music using the two well-known arousal and valence (AV) dimensions. In order to produce AV scores from the pairwise comparisons and to visualize the locations of excerpts in the AV space, we introduce a flexible Gaussian process (GP) framework which learns from the pairwise comparisons directly. A novel dataset is used to evaluate the proposed framework and learning curves show that the proposed framework needs relative few comparisons in order to achieve satisfactory performance. This is further supported by visualizing the learned locations of excerpts in the AV space. Finally, by examining the predictive performance of the user-specific models we show the importance of modeling subjects individually due to significant subjective differences.

General information
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Organisations: Department of Informatics and Mathematical Modeling, Cognitive Systems
Authors: Madsen, J. (Intern), Nielsen, J. B. (Intern), Jensen, B. S. (Intern), Larsen, J. (Intern)
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Source: dtu
Source-ID: u::5376
Publication: Research - peer-review › Article in proceedings – Annual report year: 2012

Pseudo inputs for pairwise learning with Gaussian processes

We consider learning and prediction of pairwise comparisons between instances. The problem is motivated from a perceptual viewpoint, where pairwise comparisons serve as an effective and extensively used paradigm. A state-of-the-art method for modeling pairwise data in high dimensional domains is based on a classical pairwise probit likelihood imposed with a Gaussian process prior. While extremely flexible, this non-parametric method struggles with an inconvenient $O(n^3)$ scaling in terms of the $n$ input instances which limits the method only to smaller problems. To overcome this, we derive a specific sparse extension of the classical pairwise likelihood using the pseudo-input formulation. The behavior of the proposed extension is demonstrated on a toy example and on two real-world data sets which outlines the potential gain and pitfalls of the approach. Finally, we discuss the relation to other similar approximations that have been applied in standard Gaussian process regression and classification problems such as FI(T)C and PI(T)C.

General information
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Series: Machine Learning for Signal Processing
ISSN: 1551-2541
Main Research Area: Technical/natural sciences
Towards Predicting Expressed Emotion in Music from Pairwise Comparisons

We introduce five regression models for the modeling of expressed emotion in music using data obtained in a two alternative forced choice listening experiment. The predictive performance of the proposed models is compared using learning curves, showing that all models converge to produce a similar classification error. The predictive ranking of the models is compared using Kendall's tau rank correlation coefficient which shows a difference despite similar classification error. The variation in predictions across subjects and the difference in ranking is investigated visually in the arousal-valence space and quantified using Kendall's tau.

Efficient preference learning with pairwise continuous observations and Gaussian Processes

Human preferences can effectively be elicited using pairwise comparisons and in this paper current state-of-the-art based on binary decisions is extended by a new paradigm which allows subjects to convey their degree of preference as a continuous but bounded response. For this purpose, a novel Betatype likelihood is proposed and applied in a Bayesian regression framework using Gaussian Process priors. Posterior estimation and inference is performed using a Laplace approximation. The potential of the paradigm is demonstrated and discussed in terms of learning rates and robustness by evaluating the predictive performance under various noise conditions on a synthetic dataset. It is demonstrated that the learning rate of the novel paradigm is not only faster under ideal conditions, where continuous responses are naturally more informative than binary decisions, but also under adverse conditions where it seemingly preserves the robustness of the binary paradigm, suggesting that the new paradigm is robust to human inconsistency.
On Sparse Multi-Task Gaussian Process Priors for Music Preference Learning

In this paper we study pairwise preference learning in a music setting with multitask Gaussian processes and examine the effect of sparsity in the input space as well as in the actual judgments. To introduce sparsity in the inputs, we extend a classic pairwise likelihood model to support sparse, multi-task Gaussian process priors based on the pseudo-input formulation. Sparsity in the actual pairwise judgments is potentially obtained by a sequential experimental design approach, and we discuss the combination of the sequential approach with the pseudo-input preference model. A preliminary simulation shows the performance on a real-world music preference dataset which motivates and demonstrates the potential of the sparse Gaussian process formulation for pairwise likelihoods.

General information
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Projects:

Systemer til personalisering af høreapparater

Department of Applied Mathematics and Computer Science
Period: 01/01/2011 → 20/03/2014
Number of participants: 6
Phd Student:
Nielsen, Jens Brehm (Intern)
Supervisor:
Nielsen, Jacob (Ekstern)
Main Supervisor:
Larsen, Jan (Intern)
Examiner:
Winther, Ole (Intern)
Murray-Smith, Roderick (Intern)
Zacharov, Nick (Ekstern)

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