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Jury Member Report – Doctor of Philosophy thesis.

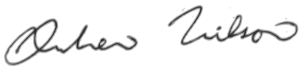
Name of Candidate: Yermek Kapushev

PhD Program: Computational and Data Science and Engineering

Title of Thesis: Gaussian process models for large-scale problems

Supervisor: Associate Professor Evgeny Burnaev

Name of the Reviewer: Prof. Andrew Gordon Wilson

I confirm the absence of any conflict of interest (Alternatively, Reviewer can formulate a possible conflict)	**Signature:**  07-02-2021 **Date: DD-MM-YYYY**

The purpose of this report is to obtain an independent review from the members of PhD defense Jury before the thesis defense. The members of PhD defense Jury are asked to submit signed copy of the report at least 30 days prior the thesis defense. The Reviewers are asked to bring a copy of the completed report to the thesis defense and to discuss the contents of each report with each other before the thesis defense.

If the reviewers have any queries about the thesis which they wish to raise in advance, please contact the Chair of the Jury.

Reviewer's Report

Reviewers report should contain the following items:

- Brief evaluation of the thesis quality and overall structure of the dissertation.
- The relevance of the topic of dissertation work to its actual content
- The relevance of the methods used in the dissertation
- The scientific significance of the results obtained and their compliance with the international level and current state of the art
- The relevance of the obtained results to applications (if applicable)
- The quality of publications

The summary of issues to be addressed before/during the thesis defense

The thesis proposes scalable algorithms for Gaussian processes, based on Kronecker structure, and random feature expansions. It then explores the application of these methods to Tensor completion, score matching, and simultaneous localization and mapping.

The thesis is well-structured, presenting methodological advances for Gaussian processes together with natural and compelling applications. The methods are complementary — one exploits existing structure for scalable exact inference, but is somewhat constrained in its applicability, while the other broadly applicable but provides approximate inference. The applications are reasonably thorough and convincing.

In Chapter 2, on Kronecker structure with missing inputs, there should be a careful discussion of the closely related work "Fast Kernel Learning for Multidimensional Pattern Extrapolation" (NeurIPS 2014), which also proposes a similar approach for Kronecker inference with GPs and missing inputs. Chapter 3 presents a natural idea. Random Fourier features are a popular class of scalable methods, derived from a simple Monte Carlo approximation to the Fourier transform of a user-specified kernel. Instead, it could be much more efficient to use a quadrature based approach. I had this idea myself many years ago, but I did not end up pursuing it due to various practical challenges. I am therefore impressed by the execution here.

While the applications are notable — and perhaps even more detailed than what one might find in a typical machine learning paper — it would have been good to have seen the quadrature approach applied to Bayesian optimization and other online learning problems. These types of approaches are most compelling, relative to alternatives like FITC, because they provide a *global* approximation, which is particularly valuable when we don't know where we are querying our Gaussian process next. It would have also been useful to have compared to scalable approximations with recent advances such as *structured kernel interpolation*, and GPU accelerated exact methods, such as in *GPyTorch*.

The writing is mostly understandable, but is rough in places. For example, at the beginning it appears as if images and audio are being used as examples of data *without* structure, when he opposite is intended. Also, it is not clear that "structure-less" problems are amenable to Bayesian approaches. This is just one representative example of some lack of clarity.

Overall, this is a nice thesis, well-structured, with a good pairing of methods and applications.

Provisional Recommendation

I recommend that the candidate should defend the thesis by means of a formal thesis defense

This is my recommendation.

I recommend that the candidate should defend the thesis by means of a formal thesis defense only after appropriate changes would be introduced in candidate's thesis according to the recommendations of the present report

The thesis is not acceptable and I recommend that the candidate be exempt from the formal thesis defense