Learning Theory and Graphical Models(B659) Interim Project Report:

Due on Thursday, March 28 , 2019

Dr.Roni Khardon

Arnav Arnav (aarnav)

March 7, 2019

Contents

Representation Learning Using Gaussian Processes

- **The Machine Learning Problem :** Representation learning is the problem of finding a latent representation from the data that is compact and can still encode important information about the data. If such a representation can be obtained, it can then be used for subsequent tasks such as regression or clustering. Obtaining such representations can be difficult and there has been much research in this field.

  The focus of this project is to understand and implement how Gaussian Process (GP) based models can be used to learn such representations.

- **Progress So Far:** I read and understood how the Bayesian GP-LVM model and the deep GP model can be used to learn latent representations. I found various implementations of the Gaussian Process models in python - scikit-learn[1], GPFlow[2] and PyMC[3]. Out of the three only GPFlow implement the Bayesian GP-LVM model to learn latent representations. The scikit-learn implementation consists only the Gaussian process Regressor and Classifier. I performed some experiments on small datasets (oil flow and subset of MNIST) using the GPFlow implementation to understand how to use these libraries.

- **Observations, Difficulties and New Opportunities:** The main observation is that, the GPFlow implementation assumes gaussian likelihoods and this can be extended to other kinds of observation likelihoods as a future project. None of the libraries mentioned above implement the Deep GP model and the library functions need to be extended for the same.

  It is important to note that training the GPLVM model can take a long time for large datasets, and this effect can be more pronounced in case of the Deep GPLVM model. Another challenge is that it is unclear how to use the learned model to find the latent representation for an unseen data point, and this needs to be explored.

  I also found some new papers that improve on the Gaussian Process learning specifically the doubly stochastic variational inference for deep Gaussian Processes [4]. In addition I also found some interesting applications of Gaussian Processes such as in Kalman filtering [5] and time series modeling and it can be interesting to see how well the deep GP model performs on those tasks.

- **Concrete Road Map:**

  1. Extend the Bayesian GP-LVM model implemented in GPFlow to develop the deep GPLVM model. (by 6th April)
  2. Replicate the results achieved in the paper [6] on MNIST, Frey Faces and oil flow datasets used in the papers. (by 10th April)
  3. Evaluate the effect of dataset size on training time of the deep GP models, and compare the effect of using sparse Gaussian processes at each layer in the deep GP model. (by 15th April)
  4. Try using the doubly stochastic method for training the deep GP-LVM [20th April]
  5. Describe the approaches used and the result clearly in the project report [26th April]

References

[1] F. Pedregosa, G. Varoquaux, A. Gramfort, V. Michel, B. Thirion, O. Grisel, M. Blondel, P. Prettenhofer, R. Weiss, V. Dubourg, J. Vanderplas, A. Passos, D. Cournapeau, M. Brucher, M. Perrot, and E. Duchesnay. Scikit-learn: Machine learning in Python. *Journal of Machine Learning Research*, 12:2825–2830, 2011.

[2] Alexander G. de G. Matthews, Mark van der Wilk, Tom Nickson, Keisuke. Fujii, Alexis Boukouvalas, Pablo León-Villagrá, Zoubin Ghahramani, and James Hensman. GPflow: A Gaussian process library using TensorFlow. *Journal of Machine Learning Research*, 18(40):1–6, apr 2017.

[3] John Salvatier, Thomas V Wiecki, and Christopher Fonnesbeck. Probabilistic programming in python using pymc3. *PeerJ Computer Science*, 2:e55, 2016.

[4] Hugh Salimbeni and Marc Deisenroth. Doubly stochastic variational inference for deep gaussian processes. In *Advances in Neural Information Processing Systems*, pages 4588–4599, 2017.

[5] Steven Reece and Stephen Roberts. An introduction to gaussian processes for the kalman filter expert. In *2010 13th International Conference on Information Fusion*, pages 1–9. IEEE, 2010.

[6] Andreas Damianou and Neil Lawrence. Deep gaussian processes. In *Artificial Intelligence and Statistics*, pages 207–215, 2013.