InferPy: Probabilistic Modeling Made Easy

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Abstract

InferPy is a high-level Python API for probabilistic modeling built on top of Edward and Tensorflow. InferPy, which is strongly inspired by Keras, focuses on being user-friendly by using an intuitive set of abstractions that make easy to deal with complex probabilistic models. It should be seen as an interface rather than a standalone machine-learning framework. In general, InferPy has the focus on enabling flexible data processing, easy-to-code probabilistic modeling, scalable inference and robust model validation.

Keywords: Probabilistic programming, Hierarchical probabilistic models, Latent variables, Tensorflow, User-friendly

1. Introduction

Machine learning (ML) [1] is a fundamental part of artificial intelligence [2], and the key of many innovative applications. Unfortunately, for a company or an institution, the development of ML models specific to their problems requires enormous efforts [3]. For this reason, probabilistic programming languages (PPLs) [4] are an active area of research. PPLs offer the same advantages to the ML community that high-level programming languages offered to software developers fifty years ago [5]. Programmers could specialize in model development while ML experts could focus their efforts on developing reusable inference engines. Thus, the number of non-experts who can create applications using a PPL could increase. Special attention requires those PPLs which exploit recent advances in probabilisitic inference for defining probabilistic models containing deep neural networks [6, 7]. These

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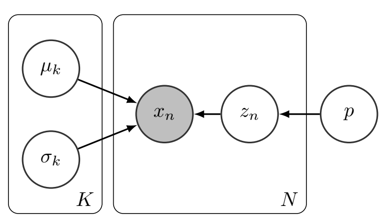
PPLs rely on deep learning libraries like Tensorflow [8]. Their main drawback is the high complexity of the abstractions, specially those centered around the definition of probability distributions over multidimensional Tensors.

InferPy[1] tries to address these issues by defining a user-friendly API which trades-off model complexity with ease of use. Complex operations over Tensor objects are hidden to the user. Similarly, Edward's flexible approach to probabilistic inference demands to provide specific details such as the variational family. Again, InferPy gives the possibility to hide all this information and make inference with a single line of code. As InferPy uses Tensorflow as computing engine, all the parallelization details are hidden to the user.

2. Background

InferPy focuses on *hierarchical probabilistic models* structured in two layers: (i) a *prior model* defining a joint distribution $p(\mathbf{w})$ over the global parameters of the model ($\mathbf{w}$ can be a single random variable or a bunch of random variables with any given dependency structure); (ii) a *data or observation model* defining a joint conditional distribution $p(\mathbf{x}, \mathbf{z}|\mathbf{w})$ over the observed quantities $\mathbf{x}$, and the the local hidden variables $\mathbf{z}$ governing the observation $\mathbf{x}$. As a running example, Figure 1 shows a model of this type.



$$p \sim Dir_K(\alpha)$$
$$z_n \sim Cat_K(p)$$
$$x_n \sim \mathcal{N}_d(\mu_{z_n}, \sigma_{z_n})$$
$$\mu_k \sim \mathcal{N}_d(0, I)$$
$$\sigma_k \sim InvGamma(0, 1)$$

Figure 1: Mixture of K d-dimensional Gaussian distributions learned from N observations.

3. Software Framework

3.1. Model Definition

In InferPy, models are specified using a simple language of random variables, which are grouped in a *probabilistic model* object (i.e., defined using the construct `with inf.ProbModel() as m:`) defining a joint distribution over observable and hidden variables $p(\mathbf{w}, \mathbf{z}, \mathbf{x})$. As an example, we provide in Figure 2 how the model of Figure 1 would be defined in InferPy.

[1]Home: inferpy.readthedocs.io; Source: github.com/PGM-Lab/InferPy

```
1  ## model definition ##
2  with inf.ProbModel() as model:
3
4      # prior distributions
5      with inf.replicate(size=K):
6          mu = inf.models.Normal(loc=0, scale=1, dim=d)
7          sigma = inf.models.InverseGamma(1, 1, dim=d)
8      p = inf.models.Dirichlet(np.ones(K)/K)
9
10     # define the generative model
11     with inf.replicate(size=N):
12         z = inf.models.Categorical(probs = p)
13         x = inf.models.Normal(mu[z], sigma[z],
14                               observed=True, dim=d)
```

Figure 2: InferPy code for the Mixture of Gaussians model of Figure 1.

InferPy allows to specify our model in a single sample-basis, resembling the standard *plateau notation*, with the `with inf.replicate(size=N)` construct (Line 5). The dimension N is the number of *replicas*. The dimension of each variable can be specified either using the input parameter `dim` (Line 6), or by the length of the distribution parameters (e.g., other InferPy variable, NumPy's ndarray [9], a tensor or a Python list). For example, variable `x` in the previous code contains N replicas of d independent Gaussian distributions and, in consequence, has two dimensions (i.e., $\textit{shape} = [N, d]$). Like in Edward, each random variable y is associated to a tensor y^* representing a sample from its distribution. Note that when operating on y, the operation is indeed done on y^*. In the previous code, the mean (i.e., loc) of `x` is a sample from the distribution obtained by indexing `mu` with a sample from `z`. Any variable defined in InferPy encapsulates an equivalent one in Edward, which can be obtain by accessing the property `dist`. The user does not deal with tensor objects unless it is explicitly specified, e.g.: `z.sample()` returns an array of samples while `z.sample(tf_run=False)` allows to obtain the equivalent (lazily evaluated) Tensor object.

3.2. Approximate Inference

InferPy directly relies on top of Edward's inference engine. In particular, InferPy inherits Edward's approach and considers approximate inference solutions in which the task is to approximate the posterior with a simpler distribution q. Unlike Edward, InferPy offers the possibility to hide all these details about the definition of this q distribution, making the inference more simple for non-advanced users. Figure 3 shows the code for making inference in the model defined in the previous section.

```
# compile and fit the model with training data
data = {x: x_train}
model.compile(infMethod="MCMC")
model.fit(data)
# print the posterior
print(model.posterior(mu))
```

Figure 3: Code for making inference in the Mixture of Gaussian model of Figure 2.

4. Comparison with Edward

The analogous Edward code for making inference in a mixture of Gaussians, which can be found in our online documentation[2], has some drawbacks compared to the code in InferPy (Figures 2 and 3). First, the model definition is more complex because this is not done in a single-sample basis. This can be specially problematic when defining the dependencies among variables. For example, the mean of `x` is specified using the function `tf.gather` which is not always intuitive, i.e. `loc=tf.gather(mu,z)`. Secondly, Edward requires to have a strong knowledge about the inference algorithms for specifying all its parameters. For the running example, a q and g variable is defined for each latent variable in the model. For variable `mu`, this is done as follows.

```
qmu = ed.models.Empirical(params=tf.get_variable(
    "qmu/prm", [T,K,d],
    initializer=tf.zeros_initializer()))
gmu = ed.models.Normal(loc=tf.ones([K,d]),
                       scale=tf.ones([K,d]))
```

Figure 4: Edward's code for defining the q distribution for the model of Figure 2.

5. Conclusions

We have briefly presented InferPy, a high-level API for probabilistic modeling built on top of Edward and Tensorflow. The use of intuitive abstractions such as the *plateau notation* simplifies the task of defining complex hirearchical probabilistic models. In the future, we aim to fully integrate InferPy with Keras, allowing simple probabilistic modeling with deep neural networks.

[2] https://inferpy.readthedocs.io/en/latest/notes/inf_vs_ed.html

Acknowledgements

Authors have been jointly supported by the Spanish Ministry of Science, Innovation and Universities and by the FEDER under the projects TIN2015-74368-JIN, and TIN2016-77902-C3-3-P.

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Metadata

Current executable software version

Nr.	**(executable) Software metadata description**	
S1	Current software version	0.2.1
S2	Permanent link to executables of this version	https://pypi.org/project/inferpy/0.2.1/
S3	Legal Software License	Apache 2.0
S4	Computing platform/Operating System	for example Linux, OS X, Microsoft Windows, Unix-like
S5	Installation requirements & dependencies	Pip, Python 2.7-3.6, Edward 1.3.5, Tensorflow 1.5-1.7, Numpy 1.14 or higher, Pandas 0.15.0 or higher.
S6	Link to user manual	https://inferpy.readthedocs.io/
S7	Support email for questions	inferpy.api@gmail.com

Table 1: Software metadata

Current code version

Nr.	**Code metadata description**	
C1	Current code version	0.2.1
C2	Permanent link to code/repository used of this code version	https://github.com/PGM-Lab/InferPy/tree/0.2.1
C3	Legal Code License	Apache 2.0
C4	Code versioning system used	github
C5	Software code languages, tools, and services used	Python
C6	Compilation requirements, operating environments	Python 2.7-3.6, Edward 1.3.5, Tensorflow 1.5-1.7, Numpy 1.14 or higher, Pandas 0.15.0 or higher.
C7	Link to developer documentation/manual	https://inferpy.readthedocs.io/
C8	Support email for questions	inferpy.api@gmail.com

Table 2: Code metadata