Operational classifier development using quasi-open set semi-supervised training and GANs

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1 Extended Abstract

Deep learning methods for classifier development have been found wanting when translated to real-world applications. The most notable drawbacks of deep learning is the cost associated with gathering annotated samples and the assumption that all is known about the domain. Within this work we study and alter deep learning techniques to develop operational-grade classifier models whilst addressing these two limitations.

For classification, it is assumed that each data sample encountered by the model will belong to some category/class in the domain which can be determined through studying of the input samples. Some classification examples are:

- The introductory machine learning MNIST digit data-set contains images of hand-written digits from 0 - 9. A classifier model would be required to study an input image and determine its corresponding digit (0, 1, 2 ..., 8 or 9).
- Symptoms of patients are used to determine their corresponding disease. A classifier model could be built to study symptoms and predict diseases automatically.

In the developing world where the majority of the population cannot afford doctor visits due to lack of doctors and/or money, having a classification system capable of quick free diagnoses is of immense benefit. This example is one of many which shows the potential of the 4^{th} industrial revolution.

Deep learning has in recent years seen growing success in training classifier models. Typically deep models are developed/trained using two learning regimes, supervised or semi-supervised learning.

Supervised learning requires that each input sample used to train the model has to be annotated/labelled to indicate which class it belongs to. Models then study (many) labelled samples and learn the differences between the various classes in the domain. Given that the model trained well, new never-before seen input data can be accurately classified during the operation/testing phase. Supervised learning has shown high accuracy scores with deep neural networks given that a large number of annotated samples are provided [1] [2]. Manually annotating samples within applications, however, is expensive which lead to the development of the second learning regime, namely semi-supervised learning.

Semi-supervised learning research has achieved similar accuracy results to supervised learning while requiring much less labelled data [3]. This is due to models learning from both labelled and unlabelled data simultaneously. Labelled data samples make known the various classes to the system, whilst unlabelled data aids in learning class properties. Semi-supervised learning consequently addresses the cost issue relative to manually annotating data samples. For both supervised and semi-supervised learning, however, it is still required that all classes in the domain be known by the system.

Within real-world application domains there might be (many) classes which are not known to designers. For the symptoms/disease example above, unknown classes might be the symptom-disease correlations yet to be discovered by doctors. In such cases there is no certainty as to whether an unlabelled sample corresponds to one of the classes known to the system or not. This violates the assumption of semi-supervised training, causing it to break down. It still, however, remains fundamental for operative classifiers to classify over all classes in the domain, known or unknown, as samples from all classes will be encountered.

To the best of our knowledge, no work has addressed a semi-supervised learning scenario where unlabelled samples might also belong to categories outside of those known to the classification system. We therefore first formally define this setting, which we coin a quasi-open set, after which we propose a learning regime to handle quasi-open sets. This learning regime is called quasi-open set semi-supervised training and requires known classes be correctly classified whilst simultaneously requiring unknown classes (only seen in the unlabelled data) be classified as 'other'.

Training under quasi-closed semi-supervised learning develops a model capable of classifying over all classes in the domain even though each class might not be explicitly expressed to the system. Models are therefore able to train using vast unfiltered and unrestricted unlabelled sets (as would be available in application) which was previously un-attainable using deep neural networks.

Our proposed method for quasi-closed semi-supervised learning uses generative adversarial networks (GANs) in a similar fashion to general semi-supervised learning using GANs [3]. An additional framework is, however, added to handle unknown classes. Experiments are done using MNIST by providing labelled samples for some classes and unlabelled samples for the same and different classes. Example accuracy scores reach upward of 96.23% when 500 labelled samples were provided for 7 classes whilst unlabelled data was provided for all 10 classes. Our method is ensured to remain non-domain specific to allow ease of translation to any application.

With this new learning regime and our proposed method, we are able to build operational classifiers (capable of classifying over all classes in the domain) without requiring each individual class be made known to the system. This approach greatly extends the range of automated classification tasks that can be addressed in a cost effective manner.

References

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