TTIC 31230 Fundamentals of Deep Learning

RL Problems.

Problem 1. Consider training machine translation on a corpus of translation pairs (x, y) where x is, say, an English sentence $x_1, \ldots, \mathrm{EOS}$ and y is a French sentence $y_1, \ldots, \mathrm{EOS}$ where EOS is the "end of sentence" tag.

Suppose that we have a parameterized model defining $P_\Phi(y_t|x, y_1, \ldots, y_{t-1})$ so that $P_\Phi(y_1, \ldots, y_T|x) = \prod_{t=1}^{T'} P_\Phi(y_t|x, y_1, \ldots, y_{t-1})$ where y_T is EOS.

For a sample $\hat{y}$ from $P_\Phi(y|x)$ we have a non-differentiable BLEU score $\mathrm{BLEU}(\hat{y}, y) \geq 0$ that is not computed until the entire output y is complete and which we would like to maximize.

(a) Give an SGD update equation for the parameters Φ for the REINFORCE algorithm for maximizing $E_{\hat{y} \sim P_\Phi(y|x)}$ for this problem.

Solution: For $\langle x, y \rangle$ samples form the training corpus of translation pairs, and for $\hat{y}_1, \ldots, \hat{y}_T$ sampled from $P_\Phi(\hat{y}|x)$ we udate Φ by

$$\Phi \mathrel{+}= \eta \mathrm{BLEU}(\hat{y}, y) \sum_{t=1}^{T} \nabla_\Phi \; \ln P_\Phi(\hat{y}_t|x, \hat{y}_1, \ldots, \hat{y}_{t-1})$$

Samples with higher BLEU scores have their probabilities increased.

(b) Suppose that somehow we reach a parameter setting Φ where $P_\Phi(y|x)$ assigns probability close enough to 1 for a particular translation $\hat{y}$ that in practice we will always sample the same $\hat{y}$. Suppose that this translation $\hat{y}$ has less than optimal BLEU score. Can the REINFORCE algorithm recover from this situation and consider other translations? Explain your answer.

Solution: No. The REINFORCE algorithm will not recover. The update will only increase the probability of the single translation which it always selects. A deterministic policy has zero gradient and is stuck.

(c) Show that for any function $V(x)$ we have

$$E_{\hat{y} \sim P_\Phi(\hat{y}|x)} \quad V(x) \nabla_\Phi \ln P_\Phi(\hat{y}_t|x, y_1, \ldots, y_{t-1}) = 0$$

Solution:

$$
\begin{aligned}
& E_{\hat{y}}\ V(x) \nabla_\Phi \ln P_\Phi(\hat{y}_t | x, y_1, \ldots, y_{t-1}) \\
= \;& V(x) E_{\hat{y}_1 \ldots, \hat{y}_{t-1}} \sum_{\hat{y}_t} P_\Phi(\hat{y}_t | x, \hat{y}_1, \ldots, \hat{y}_{t-1}) \frac{\nabla_\Phi\ P_\Phi(\hat{y}_t | x, \hat{y}_1, \ldots, \hat{y}_{t-1})}{P_\Phi(\hat{y}_t | x, \hat{y}_1, \ldots, \hat{y}_{t-1})} \\
= \;& V(x) E_{\hat{y}_1 \ldots, \hat{y}_{t-1}} \sum_{\hat{y}_t} P_\Phi(\hat{y}_t | x, \hat{y}_1, \ldots, \hat{y}_{t-1}) \frac{\nabla_\Phi\ P_\Phi(\hat{y}_t | x, \hat{y}_1, \ldots, \hat{y}_{t-1})}{P_\Phi(\hat{y}_t | x, \hat{y}_1, \ldots, \hat{y}_{t-1})} \\
= \;& V(x) E_{\hat{y}_1 \ldots, \hat{y}_{t-1}}\ \nabla_\Phi \sum_{\hat{y}_t} P_\Phi(\hat{y}_t | x, \hat{y}_1, \ldots, \hat{y}_{t-1}) \\
= \;& 0 she
\end{aligned}
$$

(d) Modify the REINFORCE update equations to use a value function approximation $V_\Phi(x)$ to reduce the variance in the gradient samples and where V_Φ is trained by Bellman Error. Your equations should include updates to train $V_\Phi(x)$ to predict $E_{\hat{y} \sim P(y|x)}$ BLEU$(\hat{y}, y)$. (Replace the reward by the "advantage" of the particular translation).

Solution: For $\langle x, y \rangle$ sampled form the training corpus of translation pairs, and for $\hat{y}_1, \ldots, \hat{y}_T$ sampled from $P_\Phi(\hat{y}|x)$ we udate Φ by

$$
\begin{aligned}
\Phi \quad \texttt{+=} \quad & \eta(\mathrm{BLEU}(\hat{y}, y) - V_\Phi(x)) \sum_{t=1}^{T} \nabla_\Phi\ \ln P_\Phi(\hat{y}_t | x, \hat{y}_1, \ldots, \hat{y}_{t-1}) \\
\Phi \quad \texttt{-=} \quad & \eta \nabla_\Phi (V_\Phi(x) - \mathrm{BLEU}(\hat{y}, y))^2 \;=\; 2\eta(V_\Phi(x) - \mathrm{BLEU}(\hat{y}, y)) \nabla_\Phi V_\Phi(x)
\end{aligned}
$$