



Why

Which tree is optimal for tree distribution approximation?

Definition

We want to choose a tree whose corresponding approximator for the given distribution minimizes the relative entropy with the given distribution among all tree distribution approximators. We call such a distribution an *optimal* tree approximator of the given distribution. We call a tree according to which an optimal tree approximator factors and *optimal* approximator tree.

Result

Proposition 1. *Let A_1, \dots, A_n be finite nonempty sets. Define $A = \prod_{i=1}^n A_i$. Let $q : A \rightarrow [0, 1]$ a distribution. A tree T on $\{1, \dots, n\}$ is an optimal approximator tree if and only if it is a maximal spanning tree of the mutual information graph of q .*

Proof. First, denote the optimal tree distribution approximator of q for tree T by p_T^* . Express

$$p_T^* = q_1 \prod_{i \neq 1} q_{i|\text{pa } i}$$

Second, express $d(q, p) = H(q, p) - H(q)$. Since $H(q)$ does not depend on T , p_T^* is a minimizer (w.r.t. T) of $d(q, p_T^*)$ if and only if it is a minimizer of $H(q, p_T^*)$.

Third, express the cross entropy of p_T^* relative to q as

$$\begin{aligned}
H(q, p_T^*) &= H(q_1) - \sum_{i \neq 1} \sum_{a \in A} q(a) \log q_{i|\text{pa } i}(a_i, a_{\text{pa } i}) \\
&= H(q_1) - \sum_{i \neq 1} \sum_{a \in A} q(a) (\log q_{i, \text{pa } i}(a_i, a_{\text{pa } i}) - \log q_{\text{pa } i}(a_{\text{pa } i})) \\
&= H(q_1) - \sum_{i \neq 1} \sum_{a \in A} q(a) (\log q_{i, \text{pa } i}(a_i, a_{\text{pa } i}) - \log q_{\text{pa } i}(a_{\text{pa } i}) - \log q_{\text{pa } i}(a_{\text{pa } i})) \\
&= \sum_{i=1}^n H(q_i) - \sum_{i \neq 1} I(q_i, q_{\text{pa } i}) \\
&= \sum_{i=1}^n H(q_i) - \sum_{\{i, j\} \in T} I(q_i, q_j)
\end{aligned}$$

where $\text{pa } i$ denotes the parent of vertex i in T rooted at vertex 1 ($i = 2, \dots, n$). For $i = 1, \dots, n$, $H(q_i)$ does not depend on the choice of tree. Therefore selecting a tree to minimize the second term in the final expression above is equivalent to choosing a maximal spanning tree from the weighted graph with mutual information edge weights; namely, the mutual information graph of q .

□

Proposition 1 says that to we should first select a maximum spanning tree of the mutual information graph of the distribution we are approximating. Then, we should pick the best approximator to q which factors according to that tree.

