
Algorithm 1: CTC Loss alpha computation

Data: $out_{m \times n}$ (result of softmax), where $m = \bar{W}_{padded}/4$,

$w = \bar{W}_{unpadded}/4$, $n = |\hat{A}|$,

label (encoded by alphabet),

bl=0 (blank index)

begin

$Loss = 0$

$l = \text{len}(\text{label})$

$L = 2 \times \text{len}(\text{label}) + 1$

$T = w$

$T_{padded} = m$

$a = \text{zeros}(T_{padded}, L)$

$a_0^0 = out_0^{bl}$

$a_0^1 = out_0^{label_0}$

$c = a_0^0 + a_0^1$

if $c > 0$ **then**

$a_0^0 = \frac{a_0^0}{c}$
 $a_0^1 = \frac{a_0^1}{c}$

else

$c = 1.0$

$Loss = Loss + \log(c)$

for $t := 1$ **to** T **do**

$start = \max(0, L - 2 \times (T - t))$

$end = \min(2 \times t + 2, L)$

for $s := start$ **to** L **do**

$i = \frac{s-1}{2}$

$red = a_{t-1}^s$

$blue = 0$

if $s > 0$ **then**

$blue = a_{t-1}^{s-1}$

if $s \bmod 2 = 0$ **then**

$a_t^s = (red + blue) \times out_t^{bl}$

else if $s = 1$ **or** $label_i = label_{i-1}$ **then**

$a_t^s = (red + blue) \times out_t^{label_i}$

else

$orange = a_{t-1}^{s-2}$

$a_t^s = (red + blue + orange) \times out_t^{label_i}$

$c = \sum_{i=start}^{end} a_t^i$

if $c > 0$ **then**

for $i := start$ **to** end **do**

$a_t^i = \frac{a_t^i}{c}$

else

$c = 1.0$

$Loss = Loss + \log(c)$

return Loss, a

Algorithm 2: CTC Loss alpha computation

Data: $out_{m \times n}$ (result of softmax), where $m = \bar{W}_{padded}/4$,

$w = \bar{W}_{unpadded}/4$, $n = |\hat{A}|$,

label (encoded by alphabet),

bl=0 (blank index)

begin

$l = \text{len}(\text{label})$

$L = 2 \times \text{len}(\text{label}) + 1$

$T = w$

$T_{padded} = m$

$b = \text{zeros}(T_{padded}, L)$

$b_{T-1}^{L-1} = out_{T-1}^{bl}$

$b_{T-1}^{L-2} = out_{T-1}^{label_{l-1}}$

$d = b_{T-1}^{L-1} + b_{T-1}^{L-2}$

if $d > 0$ **then**

$b_{T-1}^{L-1} = \frac{b_{T-1}^{L-1}}{d}$

$b_{T-1}^{L-2} = \frac{b_{T-1}^{L-2}}{d}$

for $t := T - 2$ **to** -1 **do**

$start = \max(0, L - 2 \times (T - t))$

$end = \min(2 \times t + 2, L)$

for $s := end - 1$ **to** -1 **do**

$i = \frac{s-1}{2}$

$red = b_{t+1}^s$

$blue = 0$

if $s < L - 1$ **then**

$blue = b_{t+1}^{s+1}$

if $s \bmod 2 = 0$ **then**

$b_t^s = (red + blue) \times out_t^{bl}$

else if $s = L - 2$ **or** $label_i = label_{i+1}$ **then**

$b_t^s = (red + blue) \times out_t^{label_i}$

else

$orange = b_{t+1}^{s+2}$

$b_t^s = (red + blue + orange) \times out_t^{label_i}$

$d = \sum_{i=start}^{end} d_t^i$

if $d > 0$ **then**

for $i := start$ **to** end **do**

$b_t^i = \frac{b_t^i}{d}$

return b

Algorithm 3: CTC Loss gradient computation

Data: $out_{m \times n}$ (result of softmax), where $m = \bar{W}_{padded}/4$,

$w = \bar{W}_{unpadded}/4$, $n = |\hat{A}|$,

label (encoded by alphabet),

bl=0 (blank index),

a, b

begin

$L = 2 \times \text{len}(\text{label}) + 1$

$T = w$

$T_{padded} = m$

$softmaxgrad = \text{zeros}(T_{padded}, n)$

$ab = a * b$

for $s := 0$ **to** L **do**

if $s \bmod 2 = 0$ **then**

for $t := 0$ **to** T **do**

$softmaxgrad_t^{bl} += ab_t^s$

$ab_t^s = \frac{ab_t^s}{out_t^{bl}}$

else

for $t := 0$ **to** T **do**

$i = \frac{s-1}{2}$

$softmaxgrad_t^i += ab_t^s$

$ab_t^s = \frac{ab_t^s}{out_t^i}$

$absum = \text{zeros}(T)$

for $t := 0$ **to** T **do**

$absum_t = \sum_{s=1}^L ab_t^s$

for $t := 0$ **to** T **do**

for $i := 0$ **to** n **do**

$softmaxgrad_t^i = out_t^i - \frac{softmaxgrad_t^i}{out_t^i * absum_t}$

return softmaxgrad
