## backprop to leabra

Error driven part of XCAL $\Delta w \approx \langle xy \rangle_s - \langle xy \rangle_m$

GeneRec (generalized recirculation) (equivalent to Contrastive Hebbian Learning (CHL))

$$\Delta w = (x^+ y^+) - (x^- y^-)$$

Simpler GeneRec $\Delta w = x^- (y^+ - y^-)$

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$$\Delta w_{jk} = -\frac{\partial SSE}{\partial w_{jk}} = -\frac{\partial SSE}{\partial z_k}$$

Backpropagation $SSE = \sum_k (t_k - z_k)^2 \quad z_k = \sum_j y_j w_{jk} \quad = \frac{\partial z_k}{\partial w_{jk}} = (t_k - z_k) y_j$

$$\Delta w_{ij} = -\frac{\partial SSE}{\partial w_{ij}} \qquad -\frac{\partial SSE}{\partial w_{ij}} = \sum_k (t_k - z_k) * 1 * w_{jk} * y' * x_i \qquad \Delta w = x \left( \sum_k (t_k - z_k) w_k \right) y'$$

$$= -\frac{\partial SSE}{\partial z_k} \frac{\partial z_k}{\partial \eta_k} \frac{\partial \eta_k}{\partial y_j} \frac{\partial y_j}{\partial \eta_j} \frac{\partial \eta_j}{\partial w_{ij}} \qquad = x \left( \sum_k \delta_k w_{jk} \right) y' \qquad \Delta w = x \left( \sum_k t_k w_k - \sum_k z_k w_k \right) y'$$

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Backpropagation —> Simpler GeneRec

$$y^+ = f\left( \sum_k t_k w_k \right)$$

$$f(a) - f(b) \approx f'(a)(a - b) \qquad y^- = f\left( \sum_k z_k w_k \right) \qquad y^+ - y^- \approx y' \left( \sum_k t_k w_k - \sum_k z_k w_k \right)$$

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Backpropagation —> GeneRec

$$\delta_j = -\sum_k (t_k - o_k) w_{jk} h_j (1 - h_j)$$

$$= -\sum_k (t_k - o_k) w_{kj} h_j (1 - h_j)$$

$$= -\left( \sum_k (t_k w_{kj}) - \sum_k (o_k w_{kj}) \right) h_j (1 - h_j)$$

$$= -(\eta_j^+ - \eta_j^-) h_j (1 - h_j) \qquad \delta_j = -(\eta_j^+ - \eta_j^-) \sigma'(\eta_j) \qquad \delta_j \approx -(h_j^+ - h_j^-)$$

$$\Delta w_{ij} = -\epsilon \delta_j s_i = \epsilon (h_j^+ - h_j^-) s_i^-$$

midpoint method $\Delta w_{ij} = \epsilon (y_j^+ - y_j^-) \frac{x_i^- + x_i^+}{2}$

$$\Delta w_{ij} = \epsilon \frac{1}{2} \left[ (y_j^+ - y_j^-) \frac{(x_i^+ + x_i^-)}{2} + (x_i^+ - x_i^-) \frac{(y_j^+ + y_j^-)}{2} \right]$$

preserving symmetry $= \epsilon \left[ x_i^+ y_j^+ - x_i^- y_j^- \right]$