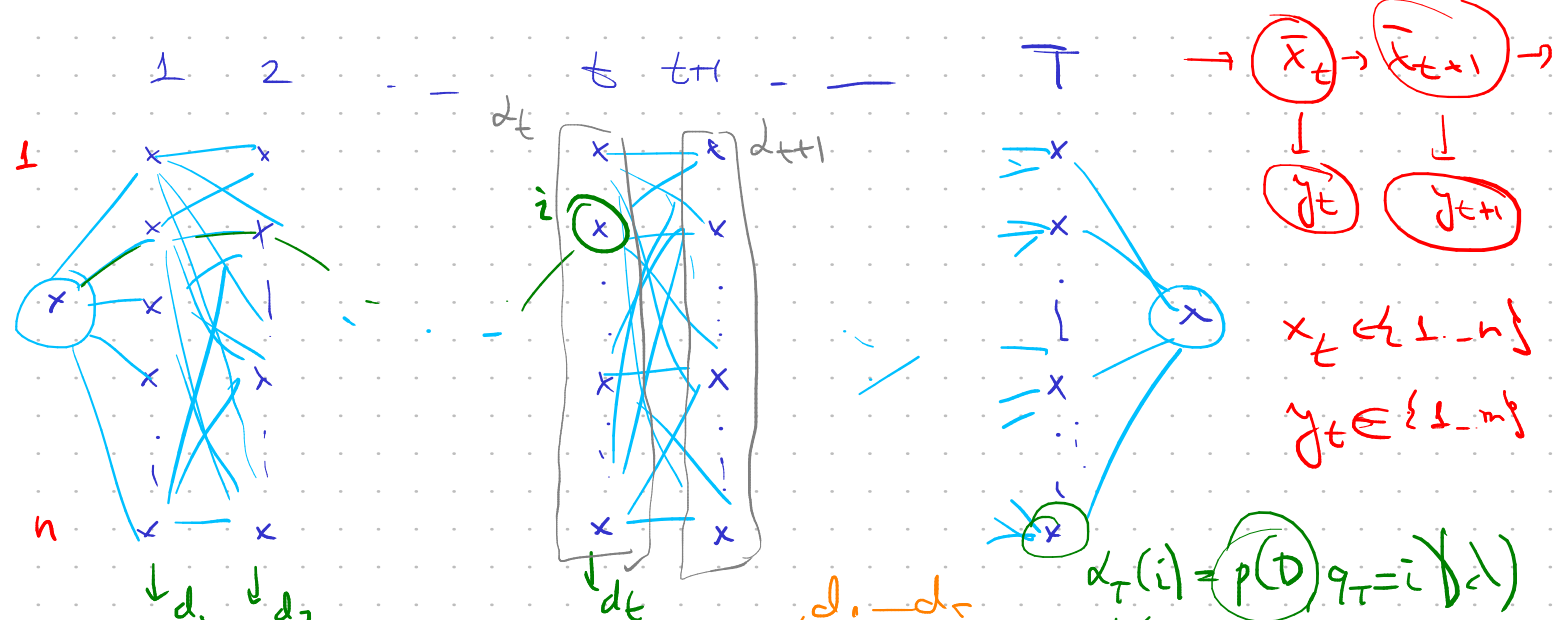




$$p(D | \lambda = (\pi, A, B)) = \sum_{Q} p(D, Q | \lambda) = \sum_{Q} \underbrace{p(x_1)}_{\pi_{q_1}} \underbrace{p(q_1 | x_1)}_{b_{q_1}(d_1)} \underbrace{p(x_2 | x_1)}_{a_{q_1 q_2}} \underbrace{p(y_2 | x_2)}_{b_{q_2}(d_2)} \dots p(x_T | x_{T-1}) \underbrace{p(y_T | x_T)}_{b_{q_T}(d_T)}$$

$$\alpha_t(i) = p(d_1, d_2, \dots, d_t, q_t = i | \lambda)$$

$$\alpha_{t+1}(j) = p(d_1, d_2, \dots, d_t, d_{t+1}, q_{t+1} = j | \lambda) =$$

$$= \sum_{i=1}^n p(\underbrace{d_1, \dots, d_t}_{\alpha_t(i)}, \underbrace{d_{t+1}}_{b_j(d_{t+1})}, q_t = i, q_{t+1} = j | \lambda) =$$

$$= \sum_{i=1}^n p(d_1, \dots, d_t, q_t = i | \lambda) p(q_{t+1} = j, d_{t+1} | d_1, \dots, d_t, q_t = i, \lambda)$$

$$a_{ij} \cdot b_j(d_{t+1})$$

$$\alpha_{t+1}(j) = \sum_{i=1}^n \alpha_t(i) \cdot a_{ij} \cdot b_j(d_{t+1})$$

Viterbi

$$\max_Q p(Q | D, \lambda) = \max_Q p(Q, D | \lambda)$$