probability $\gamma_{r,r-r'}$ and the attractiveness probability $\alpha_{q,d}$. Both $\gamma_{r,r-r'}$ and $\alpha_{q,d}$ are the parameters of the function $\mathcal{F}(\cdot)$.

Overall, UBM can be formalized as follows.

$$\begin{aligned}
\mathcal{I}(q) &= (\text{QUERY_ID}(q), 0, 0, 0) \\
\mathcal{U}(\mathbf{s}_r, i_t, d_{r+1}) &= (\mathbf{s}_r[1], \text{DOC_ID}(d_{r+1}), \mathbf{s}_r[3]+1, h(\mathbf{s}_r, i_r)) \\
h(\mathbf{s}_r, i_r) &= \begin{cases} \mathbf{s}_r[3] & \text{if } \ i_r = 1 \\ \mathbf{s}_r[4] & \text{otherwise} \end{cases} \\
\mathcal{F}(\mathbf{s}_{r+1}) &= \gamma_{\mathbf{s}_{r+1}[3], \mathbf{s}_{r+1}[3]-\mathbf{s}_{r+1}[4]} \cdot \alpha_{\mathbf{s}_{r+1}[1], \mathbf{s}_{r+1}[2]}
\end{aligned}$$

DBN. The vector state $\mathbf{s}_r$ can be represented with a tuple of two integer and one floating-point values (q, d, ϵ), where the first component q denotes a query ID, the second component d denotes the ID of a currently examined document, and the third component ϵ denotes the probability of examining the current document.

The mapping $\mathcal{I}(\cdot)$ initializes $\mathbf{s}_0$ by setting the first component to the ID of a user's query, the second component to zero and the third component to one. The mapping $\mathcal{U}(\cdot)$ updates the previous state $\mathbf{s}_r$ to the next state $\mathbf{s}_{r+1}$ as follows: the second component is set to the ID of the next document d_{r+1}, and the third component is updated according the function $g(\mathbf{s}_r, i_r)$:

$$g(\mathbf{s}_r, i_r) = \begin{cases} (1 - \beta_{\mathbf{s}_r[0], \mathbf{s}_r[1]})\gamma & \text{if } \ i_r = 1 \\ \dfrac{(1 - \alpha_{\mathbf{s}_r[0], \mathbf{s}_r[1]})\mathbf{s}_r[3]\gamma}{1 - \alpha_{\mathbf{s}_r[0], \mathbf{s}_r[1]}\mathbf{s}_r[3]} & \text{otherwise} \end{cases}$$

where γ, $\beta_{q,d}$, and $\alpha_{q,d}$ are the parameters of the mapping $\mathcal{U}(\cdot)$.

The above formula can be interpreted as follows (see [10, Chapter 3] for more details). If a user clicks on the current document ($i_r = 1$), then according to DBN she continues examining other documents if she is not satisfied with the current one $(1 - \beta_{q,d})$ and explicitly decides to continue (γ). The user skips the current document ($i_r = 0$) with probability $(1 - \alpha_{q,d})\epsilon/(1 - \alpha_{q,d}\epsilon)$, i.e., the user examines the current document (ϵ), but is not attracted by it $(1 - \alpha_{q,d})$, normalized by the total probability of no click $(1 - \alpha_{q,d}\epsilon)$. In the case of a skip, the user continues examining other documents with probability γ.

The function $\mathcal{F}(\cdot)$ computes the probability that a user clicks on the currently examined document as a product of the examination probability ϵ and attractiveness probability $\alpha_{q,d}$. Here, $\alpha_{q,d}$ is the parameter of $\mathcal{F}(\cdot)$, which is shared with the mapping $\mathcal{U}(\cdot)$.

Overall, DBN can be formalized as follows.

$$\begin{aligned}
\mathcal{I}(q) &= (\text{QUERY_ID}(q), 0, 1) \\
\mathcal{U}(\mathbf{s}_r, i_t, d_{r+1}) &= (\mathbf{s}_r[1], \text{DOC_ID}(d_{r+1}), g(\mathbf{s}_r, i_r)) \\
\mathcal{F}(\mathbf{s}_{r+1}) &= \mathbf{s}_{r+1}[3] \cdot \alpha_{\mathbf{s}_{r+1}[1], \mathbf{s}_{r+1}[2]}
\end{aligned}$$