Fairness on the Web

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Fairness in Ranking

- There is hardly anything that is *not* being ranked today
  - Products
  - Jobs
  - Opinions
  - Potential romantic partners
- Current ranking systems can be **unfair**

Search for "CEO"

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[1] Fairness of Exposure in Rankings. A. Singh, T. Joachims. KDD 2018

Fairness in Ranking

- **Goal:** Given query *q*, choose a fair ranking *r* that maximise $U(r|q)$ where *U* is the utility function

- In many cases $U(r|q) = \sum_{d \in D} v\big(rank(d|r)\big)u(d|q)$, where D is the collection of document, v models how much attention document d gets at a certain rank, and $u(d|q)$ is the utility of document d for query q

Fairness in Ranking

- Let $n = |D|$ and $\boldsymbol{P}$ be a *nxn matrix s.t.* $\boldsymbol{P}_{i,j}$ represents the probability that document d_i is placed at rank j. Moreover, $\boldsymbol{u}$ is a column vector s.t. $\boldsymbol{u}_i = u(d_i|q)$ and $\boldsymbol{v}$ is a column vector s.t. $\boldsymbol{v}_j = v(j)$.

- Then, the expected utility $U(\boldsymbol{P}|q) = \boldsymbol{u}^T \boldsymbol{P} \boldsymbol{v}$.

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Fairness in Ranking

Algorithm

1) Compute

$$
\begin{aligned}
\mathbf{P} = \operatorname{argmax}_{\mathbf{P}} \quad & \mathbf{u}^T \mathbf{P} \mathbf{v} && \text{(expected utility)} \\
\text{s.t.} \quad & \mathbb{1}^T \mathbf{P} = \mathbb{1}^T && \text{(sum of probabilities for each position)} \\
& \mathbf{P} \mathbb{1} = \mathbb{1} && \text{(sum of probabilities for each document)} \\
& 0 \leq \mathbf{P}_{i,j} \leq 1 && \text{(valid probability)} \\
& \mathbf{P} \text{ is fair} && \text{(fairness constraints)}
\end{aligned}
$$

Fairness in Ranking

Algorithm

2) Once we have computed $\boldsymbol{P}$ we can compute a probabilistic ranking R using the Birkhoff-von Neumann decomposition.

3) Sample a ranking $r \sim R$

Fairness in Ranking

Problem: How we specify that $\boldsymbol{P}$ is fair?

Add a constraint of the form $\boldsymbol{f}^T\boldsymbol{P}\boldsymbol{g} = h$ where (intuitively) $\boldsymbol{f}$ specifies relevance of documents and $\boldsymbol{g}$ reflects the importance of position

The underlying idea is fairly allocate *exposure* of groups of documents $G_1, \dots, G_k$

- Exposure of a document under $\boldsymbol{P}$: $$\text{Exposure}(d_i|\mathbf{P}) = \sum_{j=1}^{N} \mathbf{P}_{i,j}\mathbf{v}_j$$
- Exposure of G_k: $$\text{Exposure}(G_k|\mathbf{P}) = \frac{1}{|G_k|}\sum_{d_i \in G_k} \text{Exposure}(d_i|\mathbf{P}),$$

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- First option (consider only two groups G_0 and G_1, i.e., $G = G_0 \cup G_1$ and $G_0 \cap G_1 = \emptyset$):

Demographic parity constraint

$$Exposure\,(G_0|P) = Exposure(G_1|P) \iff \mathbf{f}^{\mathrm{T}}\mathbf{P}\mathbf{v} = 0$$

where $\mathbf{f} = \langle f_0, \ldots, f_n \rangle$ and $f_i = \frac{1_{d_i \in G_0}}{|\mathrm{G}_0|} - \frac{1_{d_i \in G_1}}{|\mathrm{G}_1|}$

Fairness in Ranking

- Second option (consider only two groups G_0 and G_1):

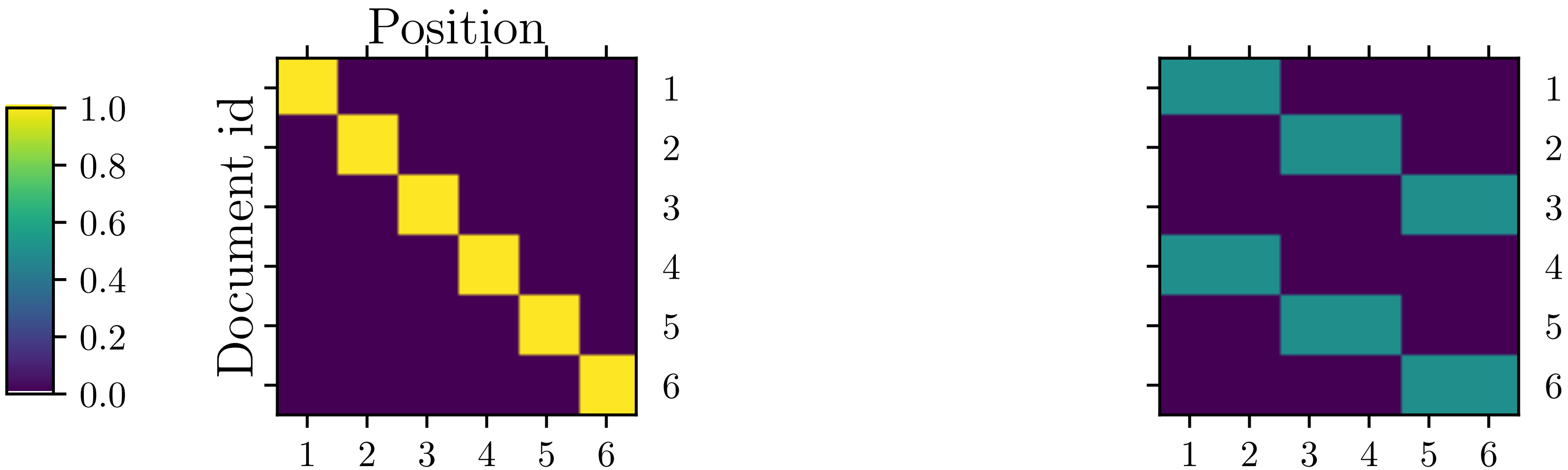
Disparate treatment constraint

$$\frac{Exposure(G_0|P)}{U(G_0|q)} = \frac{Exposure(G_1|P)}{U(G_1|q)} \Leftrightarrow \mathbf{f}^{\mathrm{T}}\mathbf{P}\mathbf{v} = 0$$

$$\text{with } f_i = \frac{1_{d_i \in G_0}}{|\mathrm{G}_0| U(G_0|q)} - \frac{1_{d_i \in G_1}}{|\mathrm{G}_1| U(G_1|q)}$$

Fairness in Ranking

- Experiments (Jobseeker for a software engineer position. Two groups: 3 men, 3 women). Male applicants have relevance of 0.8, 0.79, 0.78. Women have 0.77, 0.76, 0.75.



(a) DCG=3.8193 (b) DCG=3.8031