Combining Reward & Rank Signals for Slate Recommendation

Imad Aouali, Sergey Ivanov, Mike Gartrell, David Rohde, Flavian Vasile,Victor Zaytsev, and Diego Legrand

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Introduction

- **Slate recommendation:** Task of recommending a collection of K items at once to the user.
- **Two pieces of feedback:**
  - Was the slate clicked? (*reward* signal)
  - If it was clicked, which of its items was clicked? (*rank* signal)
- **Example: 3 products**, *phone, couscous and beer.*

Slate	non-clicks	clicks on 1	clicks on 2
phone, couscous	661	10	29
phone, beer	644	9	47
couscous, beer	626	46	28

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Reward Model - Intuition

- **Original Data:**

Slate	non-clicks	clicks on 1	clicks on 2
phone, couscous	661	10	29
phone, beer	644	9	47
couscous, beer	626	46	28

- **Reward Model:** Ignores items ranking and only uses the reward signal.

Slate	non-clicks	clicks
phone, couscous	661	39
phone, beer	644	56
couscous, beer	626	74

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Rank Model - Intuition

- **Original Data:**

Slate	non-clicks	clicks on 1	clicks on 2
phone, couscous	661	10	29
phone, beer	644	9	47
couscous, beer	626	46	28

- **Rank Model:** Ignores the reward signal and only uses items ranking.

Slate	clicks on 1	clicks on 2
phone, couscous	10	29
phone, beer	9	47
couscous, beer	46	28

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Full Model - Intuition

- **Full Model:** Uses both reward and rank signals. It takes data in its raw form.

Slate	non-clicks	clicks on 1	clicks on 2
phone, couscous	661	10	29
phone, beer	644	9	47
couscous, beer	626	46	28

- It is intuitive that both the reward and the rank signals shall contain important information of user preferences.

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Bayesian Models: Formulation

- **Models formulation in the case of slates of size 2:**

$$\phi \sim \Gamma(1,1) \quad \theta_i \sim \Gamma(1,1), i \in [N]$$

Model	Description
Full	$nc, c_1, c_2 \mid I, \phi, \theta, a_1, a_2 \sim \text{Multinomial}\left(I, \frac{\phi}{\phi+\theta_{a_1}+\theta_{a_2}}, \frac{\theta_{a_1}}{\phi+\theta_{a_1}+\theta_{a_2}}, \frac{\theta_{a_2}}{\phi+\theta_{a_1}+\theta_{a_2}}\right)$
Reward	$nc, c \mid I, \phi, \theta, a_1, a_2 \sim \text{Multinomial}\left(I, \frac{\phi}{\phi+\theta_{a_1}+\theta_{a_2}}, \frac{\theta_{a_1}+\theta_{a_2}}{\phi+\theta_{a_1}+\theta_{a_2}}\right)$
Rank	$c_1, c_2 \mid I_c, \theta, a_1, a_2 \sim \text{Multinomial}\left(I_c, \frac{\theta_{a_1}}{\theta_{a_1}+\theta_{a_2}}, \frac{\theta_{a_2}}{\theta_{a_1}+\theta_{a_2}}\right)$

- **Remark:** These models can be extended smoothly to arbitrary slate sizes.

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Experiments

- **Synthetic data:** We generate n samples of users interaction with each slate, using a multinomial distribution with known parameters **Φ** and **θ**.
- **Evaluation:** Models ability to estimate the probability of a click on the first item in the slates

$$L_1(p_{\hat{\theta}}, p_\theta) = \sum_{\text{all slates } a} \left| \frac{\hat{\theta}_{a_1}}{\sum_{j \in [K]} \hat{\theta}_{a_j}} - \frac{\theta_{a_1}}{\sum_{j \in [K]} \theta_{a_j}} \right|$$

- **Additional Experiment:** Models ability to estimate the probability of a non-click on the slates.

$$L_1(\hat{q}, q) = \sum_{\text{all slates } a} \left| \frac{\hat{\phi}}{\hat{\phi} + \sum_{j \in [K]} \hat{\theta}_{a_j}} - \frac{\phi}{\phi + \sum_{j \in [K]} \theta_{a_j}} \right|$$

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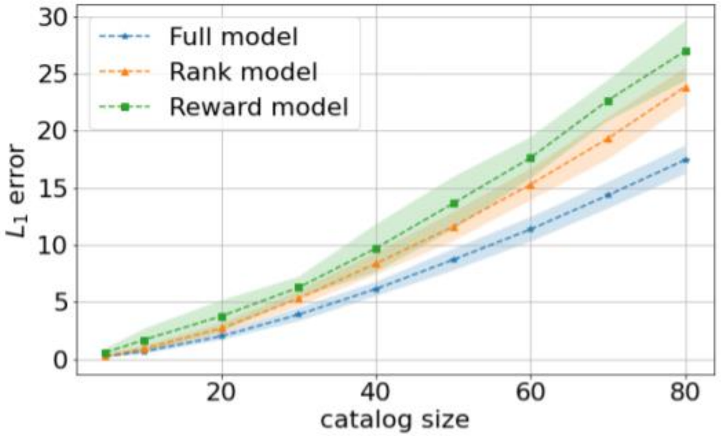
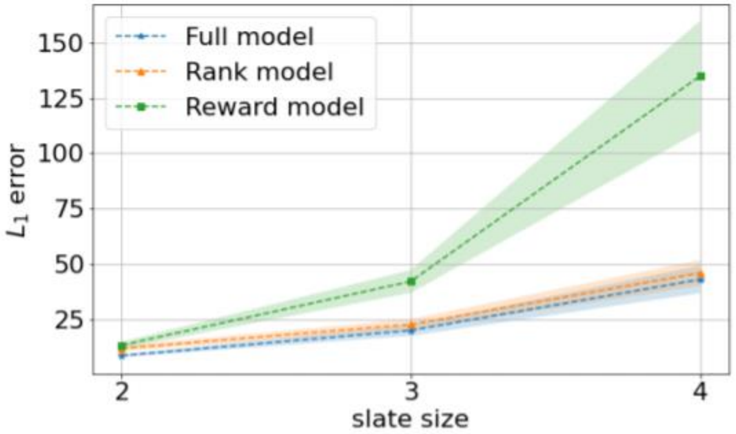
Experiments

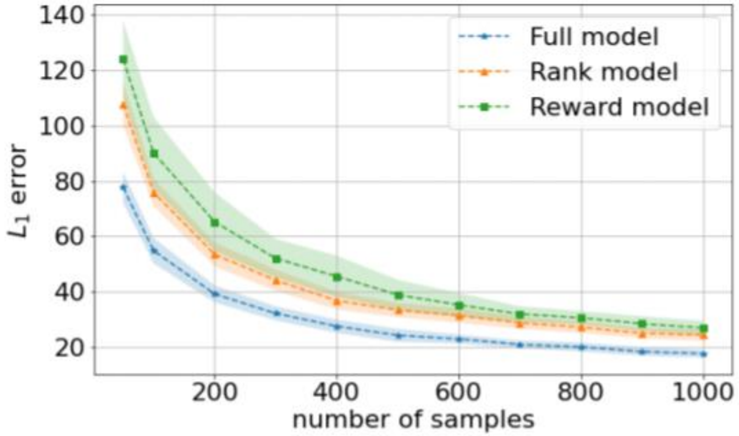
- **Results**



(a) Varying catalog size.



(b) Varying slate size.



(c) Varying N° of samples.

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Conclusion

- Three Bayesian models for non-personalized slate recommendation.
- Combining both information is beneficial in slate recommendation, especially as the catalog size and slate size grow.
- **Future Work:** Extend the Full model to personalized slate recommendation.