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Optimal Recommendations under Attraction, Aversion and Social Influence

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Users Engaging with Recommender Systems

Attraction☺ **Aversion ☹** **Influence…**

Challenges

- Making recommendations & modeling user interest are intertwined
  - Since recommendations play a role in changing user interest
- Recommendations should be made in a global manner
  - Since social influence effect may trigger interest cascade

Main Contributions

- An ***interest evolution model*** with attraction, aversion, and social influence
- Use ***Semi-Definite Programming (SDP)*** to provide near-optimal recommendations
  - Outperform matrix factorization recommendations significantly
- Show from real data that attraction and aversion phenomena do exist

Interest Evolution Model

Inherent interests

α_i

Personal

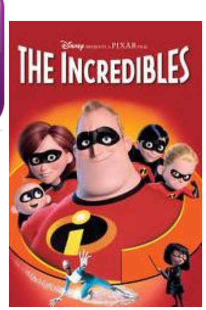
$1-\beta$

Social

β

P_{ij}

Social Influence



Attracted to recommendations

γ_i

Aversive to recommendations

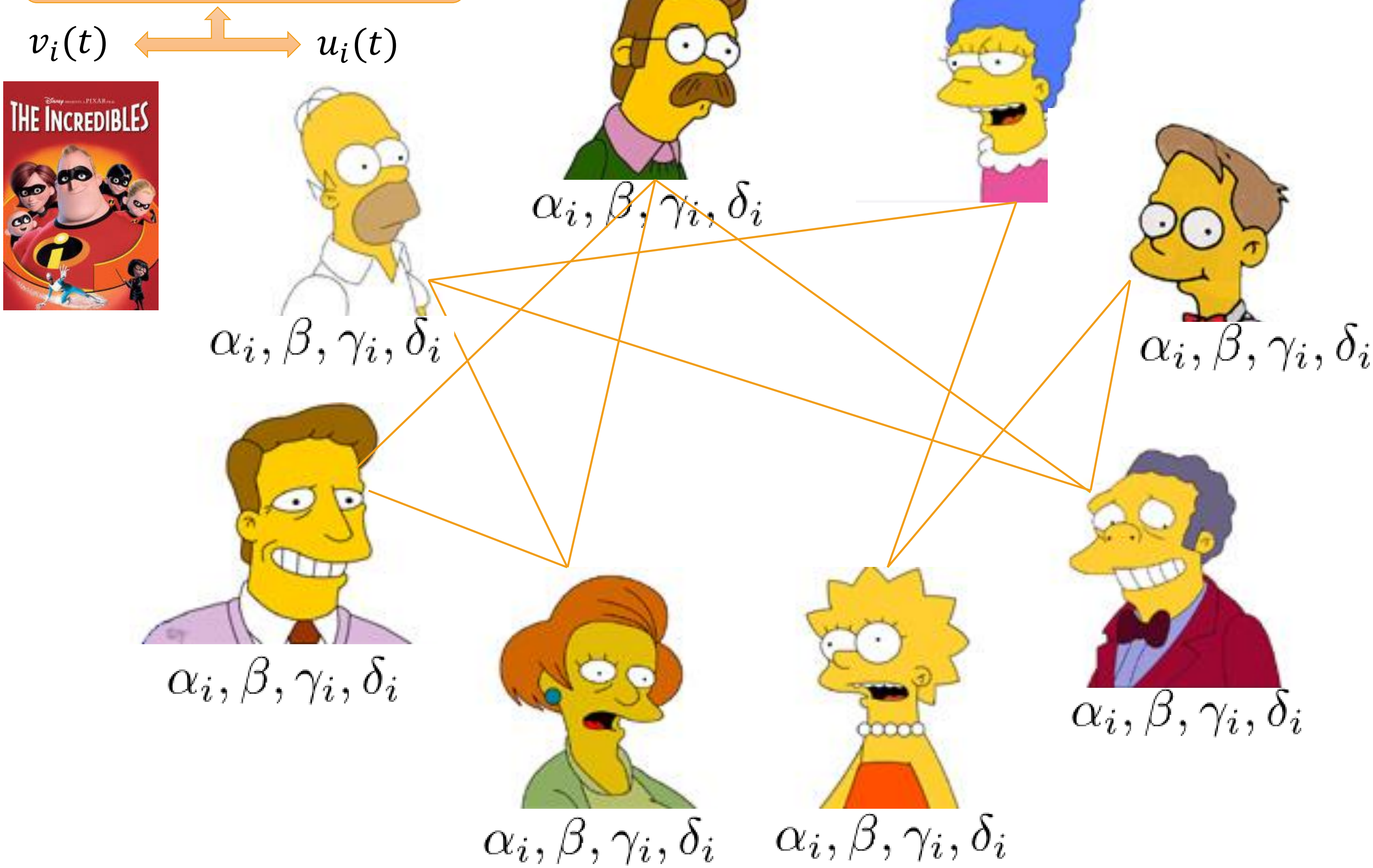
δ_i

At any time t, user selects social behavior with probability β and personal behavior with probability $1-\beta$

$$\alpha_i + \gamma_i + \delta_i = 1$$

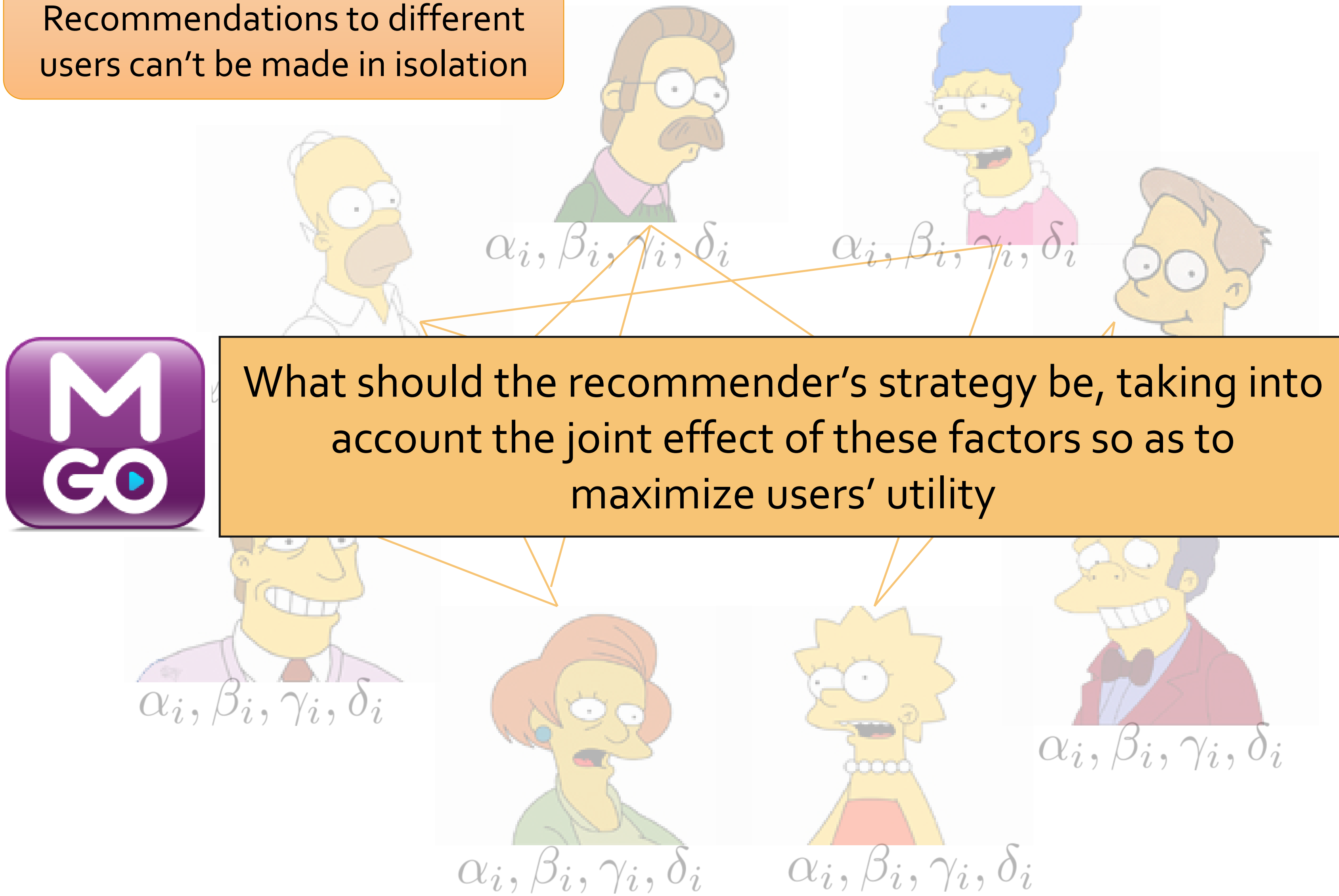
Dynamic system of interest evolution

Utility = $< u_i(t), v_i(t) >$



Recommendation Problem

Recommendations to different users can’t be made in isolation



What should the recommender’s strategy be, taking into account the joint effect of these factors so as to maximize users’ utility

Interest Evolution: Steady State

The evolution process is a *Markov Chain*

It converges to a *steady state*

$$\bar{U} = A\bar{U}^0 + \beta P\bar{U} + (\Gamma - \Delta)\bar{V}$$

Expected user profile matrix (1 row per user)

prob. of inherent interest

expected inherent profile matrix

social influence matrix

prob. of attraction, aversion matrices

expected item profile matrix

$$\boxed{\bar{U} = (I - \beta P)^{-1}(A\bar{U}^0 + (\Gamma - \Delta)\bar{V})}$$

Recommendation Objective

$$\bar{U} = (I - \beta P)^{-1}(A\bar{U}^0 + (\Gamma - \Delta)\bar{V})$$

Multiply with $\bar{V}$

$$\text{Max.:} \quad \text{trace}\left[(I - \beta P)^{-1}\left(\mathrm{A}\bar{U}^0\bar{V}^\top + (\Gamma - \Delta)\bar{V}\bar{V}^\top\right)\right]$$

$$\text{subj. to:} \quad \|\bar{\mathbf{v}}_i\|_2^2 \leq 1, \ \text{for all } i \in [n]$$

Social welfare: Expected total utility over all users

Global Recommendation Problem

Global Recommendation

$$\text{Max.:} \quad \text{trace}\left[(I-\beta P)^{-1}\left(\mathrm{A}\bar{U}^0\bar{V}^\mathsf{T} + (\Gamma-\Delta)\bar{V}\bar{V}^\mathsf{T}\right)\right]$$

$$\text{subj. to:} \quad \|\bar{\mathbf{v}}_i\|_2^2 \leq 1, \;\; \text{for all } i \in [n]$$

- Variables to solve: $\bar{V}$
- Quadratically-Constrained Quadratic Optimization Problem (QCQP)
- Not convex, in general ☹
- Our solution strategy: Relaxation

SDP Relaxation

- Global Recommendation: Semi-Definite Program (SDP) with a rank-1 constraint
- **<u>Relaxation</u>**: Drop rank-1 constraint → SDP only
- Solve the SDP relaxation
  - IF (rank-1): done!
  - ELSE: there exists a randomized algorithm giving a 4/7 approximation
- **<u>Observation</u>**: In our experiments, all solution matrices are rank-1, hence optimal ☺

Experiments

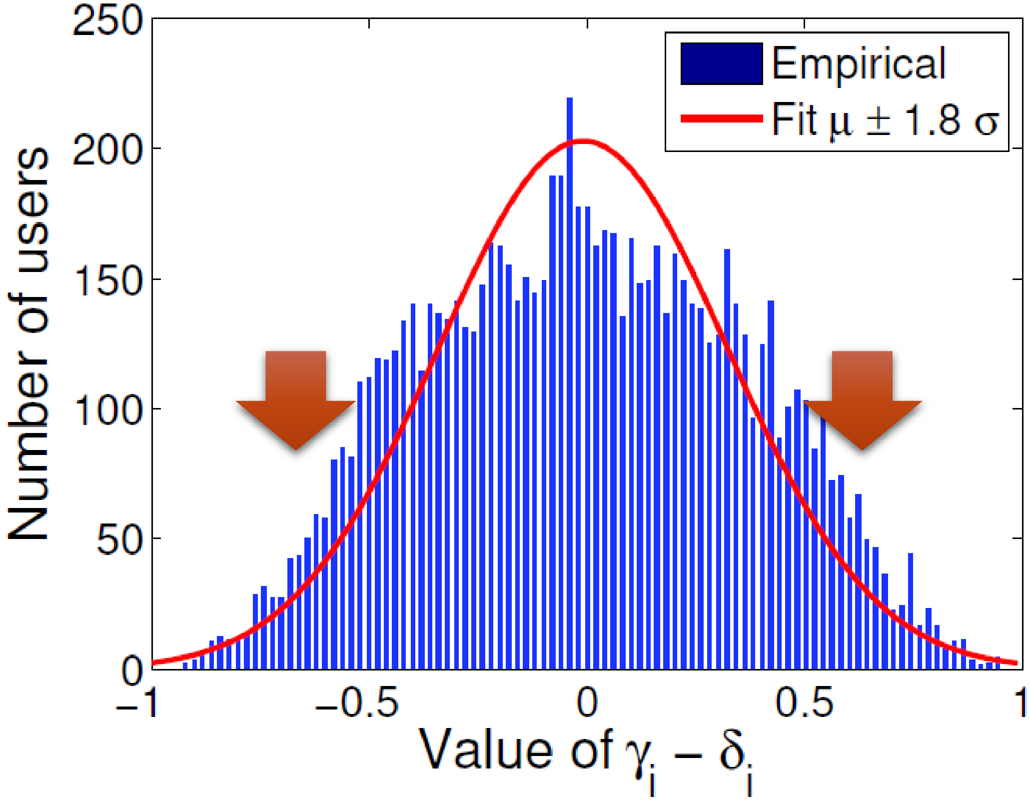
Datasets

	Flixster	FilmTipSet	MovieLens
#users	4.6K	0.4K	8.9K
#items	25K	4.3K	3.8K
#ratings	1.8M	118K	1.3M
#edges	44K	N/A	N/A

Objectives

- Find evidence of attraction and aversion from data
- Evaluate SDP solutions
- Baseline (MF-Local): Recommend based on inherent profiles only

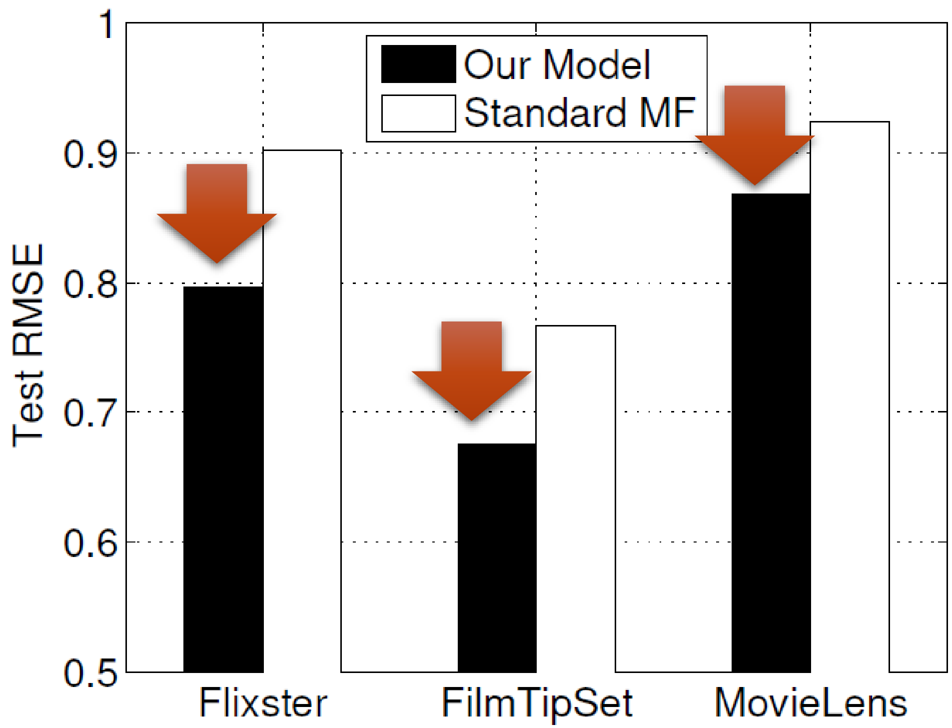
Finding evidence of attraction & aversion



MovieLens

Heavy tail: existence of strongly attracted and aversive users

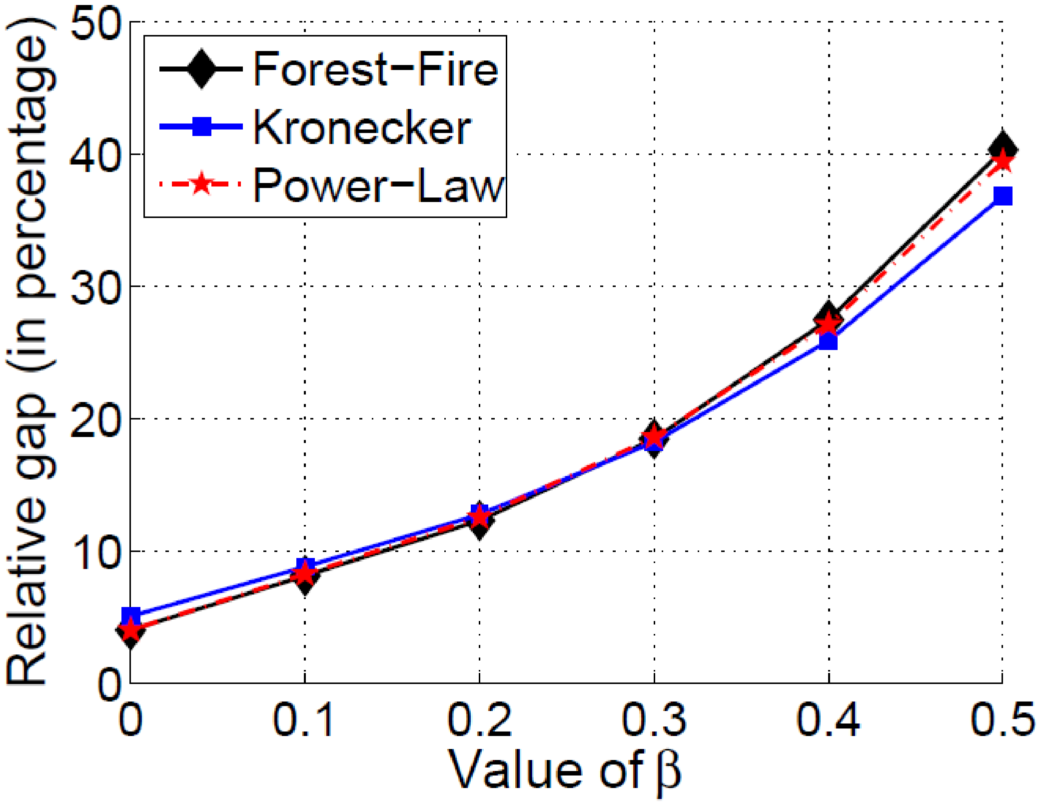
Finding evidence of attraction & aversion



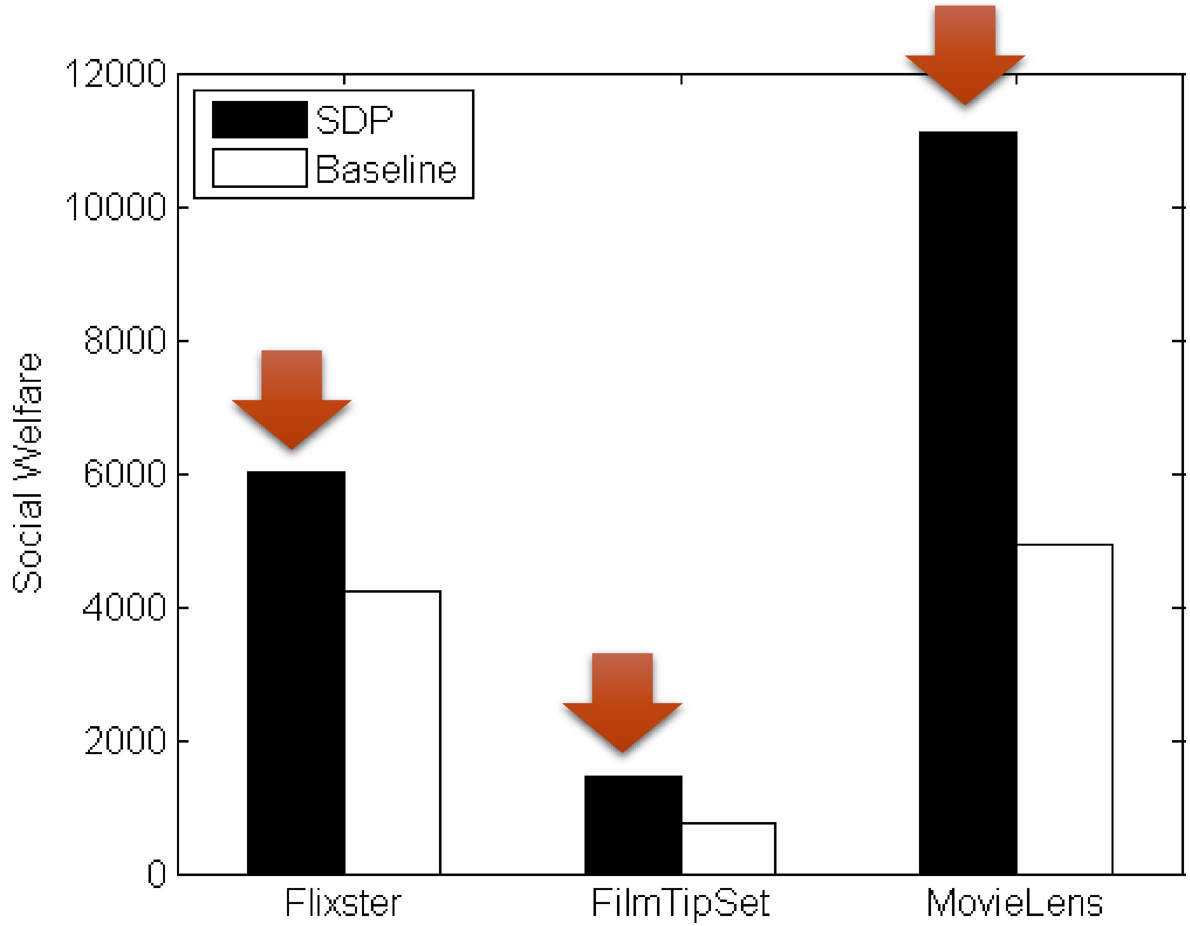
Incorporating evolution probabilities into Matrix Factorization leads to better predictions

Varying Social Effect β (Synthetic)

- Synthetic SN: Forest-Fire, Kronecker, Power-law
- Y-axis: $\frac{SDP\ solution - baseline}{baseline} * 100\%$



Social Welfare on Real Data



SDP outperforms baseline on three real-world datasets, in terms of Social Welfare

Future Work

- Study the optimality of SDP relaxation in theory
- Improve scalability of SDP-based algorithms by exploiting special structural features
- Study other factors for interest evolution

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Thank you!

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