Modeling Consumer Preferences and Price Sensitivities from Large-Scale Grocery Shopping Transaction Logs

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Right Products w. Right Coupons to Right Consumers!

Consumers

“Give me a discount then I’ll buy it!”

“I’m loyal to some products. Coupons won’t change my mind.”

CPGs

Optimizer

Product Recommendation; Personalized Promotion

Retailers

Revenue

Transaction Logs (with Price!); Product info.; Demographics etc.

Consumer Behavior Model
(preference & price sensitivity)

CPGs: consumer packaged goods companies
Preference & Price Sensitivity

Consumer Behavior Model
(preference & price sensitivity)

- Preference: what kind of products people would like to buy
  - Recommender System
  - Purchase Probability / Quantity

- Price-sensitivity: what kind of products people would be more likely to buy if the price drops
  - Demanding System

  \[
  \text{elasticity} = \frac{\Delta \text{Quantity}}{\text{Quantity}} / \frac{\Delta \text{Price}}{\text{Price}} \quad \text{or} \quad \text{elasticity} = \frac{\Delta \text{Probability}}{\text{Probability}} / \frac{\Delta \text{Price}}{\text{Price}}
  \]

- Price elasticity is usually negative, where larger absolute value -> more price sensitive
Challenges

- Recommender System
  - Price is barely considered
  - Interpretability

- Economics/Marketing
  - Scalability
  - Handcrafted consumer segmentation

- By connecting them ...
  - Interpretable, Scalable, Personalized
Modeling Grocery Shopping Behavior

- **INPUT**: User ID, Item/Category ID, Features (temporal/geo info., item info.— price!, user demographics, etc.)
- **OUTPUT**: preference prediction, price elasticity

Category Purchase

1. Buy or not?

Yes!

Product Choice

2. Which product?

Selected!

Purchase Quantity

3. How many?
A Unified Feature-Based Matrix Factorization (FMF): $\text{link}(Y(t)) = L(t) = \Phi(t)^T \Psi(t)$

$\logit(y_{i,u}(t)) = \langle w, \tilde{g}_{i,u}(t) \rangle + \langle \phi_{0}(o), \psi_{o}(i) \rangle + \langle \phi_{0}(u), \tilde{\psi}_{u}(i) \rangle + \langle \phi_{1}(o), \tilde{\psi}_{o}(i) \rangle$

1. Buy or not? (‘Logistic Regression’)
   - Yes!

2. Which product? (‘Multinomial Logistic’)
   - Selected!

3. How many? (‘Poisson Regression’)

Categories:
- Purchase
- Product Choice
- Purchase Quantity
Method (Advantages)

- Scalable
  - Inherit the scalability of Matrix Factorization

- Parallel
  - Three stages do not share parameters

- Flexible
  - Easy to adjust based on conditions

- Personalized
  - No need to do consumer segmentations beforehand

Category Purchase

1. Buy or not?

Product Choice

2. Which product?

Purchase Quantity

3. How many?
Experiments (Datasets)

- Dunnhumby (household-level data) [1]
  - 531,201 product transactions, 98,020 trips, 799 users, 4,247 products, 108 stores, 104 categories
  - Features: price, day-of-week, household demographics, product info etc.

- MSR-Grocery (individual, convenient store)
  - 152,021 products transactions, 53,075 trips, 1,288 users, 1,929 products, 55 categories
  - Features: price, day-of-week, product info etc.

Results (Preference)

Category Purchase (AUC)
- Dunnhumby
- MSR-Grocery

Product Choice (AUC)
- Dunnhumby
- MSR-Grocery

Product Quantity (Mean Absolute Error)
- Dunnhumby
- MSR-Grocery

proposed model without price
proposed model with price
Results (Price Elasticity)

- **Product choice** is the most price sensitive stage.
- Consumers in *Dunnhumby* (households) are less price sensitive in category purchase, but more price sensitive in product choice and quantity, than those in *MSR-Grocery* (convenient store).

**Average Price Elasticity**

<table>
<thead>
<tr>
<th>Category</th>
<th>Dunnhumby</th>
<th>MSR-Grocery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product choice</td>
<td>-0.196</td>
<td>-0.024</td>
</tr>
<tr>
<td>Purchase quantity</td>
<td>-0.842</td>
<td>-0.242</td>
</tr>
</tbody>
</table>

Coupons are primarily effective “within category”!
Case Study: Bacon

Different consumers may have different price sensitivities

- Do category promotions on popular products
Case Study: Bacon

Preference vs Price Elasticity

(a) Category Purchase
(b) Product Choice
(c) Purchase Quantity

less price sensitive
more price sensitive
Case Study: Bacon

Preference vs Price Elasticity

High preference
Price **insensitive**
*(they like it no matter how expensive it is)*

Low preference
Price **insensitive**
*(they dislike it)*

Low preference
Price **sensitive**
*(price is too high to afford)*

Mid preference
Price **sensitive**
*(aggressive buyer)*

High preference
Price **insensitive**
*(budget limit)*
Conclusion and Future

- Three purchase stages
  - category purchase, product choice, purchase quantity
- A nested feature-based matrix factorization model (FMF)
  - Personalized
- Lots of economic insights
  - Coupons are primarily effective “within category”

- Temporal-aware model – long-term purchase patterns
- Complementary and Substitutes
- Optimization strategy to generate personalized coupons so that utilities can be maximized
Thanks!

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