Improving Package Recommendations through Query Relaxation

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Recommendation Systems

- Recommendation systems aim to identify items of interest to users

Recommended to me by Amazon before traveling to Hangzhou:

- The Comfort Master Is The BEST Travel... Crafty World
  - **Rating**: 3.5 / 5 (233)
  - Price: $45.50 (Regular) - $24.97 (Discounted)

- TravelMate Memory Foam Neck Pillow TravelMate(R)
  - **Rating**: 3.5 / 5 (212)
  - Price: $28.00 (Regular) - $11.95 (Discounted)

- Aeris Travel Neck Pillow -Best Memory...
  - **Rating**: 3.5 / 5 (122)
  - Price: $24.90

- Travelmate Travelmate Memory Foam...
  - **Rating**: 3.5 / 5 (512)
  - Price: $28.00 (Regular) - $12.75 (Discounted)

- CABEAU Memory Foam *Evolution Pillow...*
  - **Rating**: 3.5 / 5 (850)

- IMAK Eye Pillow, Black Brown Medical
  - **Rating**: 3.5 / 5 (524)
  - Price: $13.10 - $12.23
“Package” Recommendations

- But sometimes items are actually bundled together in packages of items

Example 1 — Amazon bundles
“Package” Recommendations

- But sometimes items are actually bundled together in packages of items

Example 2 — A flight package: *

- 6:00 am – 8:05 am
  Boston – Detroit · BOS–DTW
  Delta 2079 · Boeing 737
  2h 05m
  Wi-Fi

- Layover in Detroit DTW
  4h 52m

- 12:57 pm – 2:45 pm*
  Detroit – Beijing · DTW–PEK
  Delta / China Southern · Boeing 777
  Operated by Delta
  13h 48m

- Layover in Beijing PEK
  2h 35m

- 5:20 pm* – 7:25 pm*
  Beijing – Hangzhou · PEK–HGH
  China Eastern / Delta, China Southern · Airbus A320
  Operated by China Eastern
  Often delayed by 30+ min
  2h 05m

* Recommended by Google Flights
“Package” Recommendations

- But sometimes items are actually bundled together in **packages** of items

**Example 3 — A meal plan:**

<table>
<thead>
<tr>
<th>Recipe</th>
<th>Calorie</th>
<th>Fat</th>
<th>Carbs</th>
<th>Protein</th>
<th>Prep. time</th>
</tr>
</thead>
<tbody>
<tr>
<td>e.g.: rice</td>
<td>10..20 =50</td>
<td>50..90</td>
<td>10..20 =50</td>
<td>10..20 =50</td>
<td>10..20 =50</td>
</tr>
<tr>
<td>Authentic Louisiana Red Beans and Rice</td>
<td>630</td>
<td>24.2</td>
<td>79.1</td>
<td>24</td>
<td>690</td>
</tr>
<tr>
<td>Slow Cooker Red Beans and Rice</td>
<td>374</td>
<td>14.2</td>
<td>39</td>
<td>22.6</td>
<td>495</td>
</tr>
<tr>
<td>Slow Cooker Split Pea Sausage Soup</td>
<td>417</td>
<td>13.1</td>
<td>50.8</td>
<td>23.9</td>
<td>320</td>
</tr>
<tr>
<td>Lamb and Winter Vegetable Stew</td>
<td>189</td>
<td>8.9</td>
<td>16.2</td>
<td>11</td>
<td>90</td>
</tr>
</tbody>
</table>
A “Package” Query

- All recipes should have less than 25 g of fat
- The entire meal plan should have:
  - At least 1700 kcal in total
  - Between 3 and 5 meals per day
- The meal plan should minimize the total preparation time
Many Feasible Solutions...

<table>
<thead>
<tr>
<th>Recipe</th>
<th>Calorie</th>
<th>Fat</th>
<th>Carbs</th>
<th>Protein</th>
<th>Prep. time</th>
</tr>
</thead>
<tbody>
<tr>
<td>e.g.: rice</td>
<td>10.20 =50</td>
<td>50.90</td>
<td>10.20 =50</td>
<td>10.20 =50</td>
<td>10.20 =50</td>
</tr>
<tr>
<td>Authentic No Shortcuts Louisiana Red Beans and Rice</td>
<td>556</td>
<td>22.3</td>
<td>61.5</td>
<td>27.2</td>
<td>500</td>
</tr>
<tr>
<td>Creole Red Beans and Rice</td>
<td>625</td>
<td>9.9</td>
<td>68.5</td>
<td>27.3</td>
<td>35</td>
</tr>
<tr>
<td>Pressure Cooker Red Beans and Sausage</td>
<td>298</td>
<td>18.4</td>
<td>16</td>
<td>17</td>
<td>70</td>
</tr>
<tr>
<td>Fast Chicken Over Black Beans and Rice</td>
<td>424</td>
<td>17.3</td>
<td>63.8</td>
<td>15</td>
<td>100</td>
</tr>
<tr>
<td>Kielbasa Kale Stew</td>
<td>471</td>
<td>17.3</td>
<td>63.8</td>
<td>15</td>
<td>100</td>
</tr>
</tbody>
</table>

Improving Package Recommendations through Query Relaxation
Too Many Feasible Solutions...

1704 feasible meal plans, with only 15 recipes
A New “Big Data” Challenge

- Usually we talk about:
  - Lots of data
  - Lots of features

- But what about:
  - More combinations!

- Practical challenges of “more combinations”:
  - Computational complexity
  - Usability
What Could Systems Do?

Query

• $\geq$ 1700 kcal in total
• Minimal prep. time

Top-1 meal plan

<table>
<thead>
<tr>
<th>Recipe</th>
<th>Calorie</th>
<th>Fat</th>
<th>Carbs</th>
<th>Protein</th>
<th>Prep. time</th>
</tr>
</thead>
<tbody>
<tr>
<td>e.g.: rice</td>
<td>571</td>
<td>12.2</td>
<td>7</td>
<td>6.1</td>
<td>30</td>
</tr>
<tr>
<td>Creamy Curried Shrimp with Grilled Pineapple</td>
<td>298</td>
<td>18.4</td>
<td>16</td>
<td>17</td>
<td>25</td>
</tr>
<tr>
<td>Pressure Cooker Red Beans and Sausage</td>
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<td>23.9</td>
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<td>9.9</td>
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</tr>
<tr>
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<td></td>
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<td></td>
<td></td>
</tr>
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</table>

1,710 kcal  3 hrs 5 min

The dietitian might be willing to accept lower calories for lower preparation time
What Could Systems Do?

Top-1 meal plan

<table>
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<tr>
<th>Recipe</th>
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<td>298</td>
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<td>424</td>
<td>0.9</td>
<td>56.5</td>
<td>27.3</td>
<td>80</td>
</tr>
</tbody>
</table>

1,710 kcal
3 hrs 5 min

Infeasible, but perhaps better than top-1

<table>
<thead>
<tr>
<th>Recipe</th>
<th>Calorie</th>
<th>Fat</th>
<th>Carbs</th>
<th>Protein</th>
<th>Prep. time</th>
</tr>
</thead>
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<td>16</td>
<td>17</td>
<td>25</td>
</tr>
<tr>
<td>Slow Cooker Split Pea Sausage Soup</td>
<td>417</td>
<td>13.1</td>
<td>50.8</td>
<td>23.9</td>
<td>50</td>
</tr>
<tr>
<td>Kielbasa Kale Stew</td>
<td>364</td>
<td>16.2</td>
<td>21</td>
<td>10.7</td>
<td>20</td>
</tr>
</tbody>
</table>

1,650 < 1,700 kcal
2 hrs 5 min

1 hr less!

1 hr less!
Our Approach

- We propose a new use of **query relaxation**:

- Usually we relax when:
  - The query does not produce any result
  - The query does not produce enough results

- Here, we relax to:
  - Improve upon some aspect of the query result
What is a relaxation of a package query?

**Base Constraints** – Each meal:
- ≤ 30 g of fat in each meal

**Global Constraints** – The meal plan:
- ≥ 1700 kcal in total

**Cardinality Constraints**:
- 3 to 5 meals

Objective:
- Minimal preparation time
Criteria for Relaxations

- Relaxations modify the query and thus produce a different result than the original query

- How do we pick a good relaxation?
  - Relaxations should **improve** the result
    - In some aspects specified by the query
    - As much as possible
  - But they may cause some **error**
    - The total error should be as low as possible
Impact of Coarse Relaxations

• How much should we relax?

![Graph showing the impact of coarse relaxations]

- Diminishing returns
- Relating only a few constraints provides the highest impact

% change

Improvement Error

More relaxed
Review

• Summary so far:
  - Package recommendations
  - Package query relaxations
  - Relaxation trade-off

• Rest of the talk:
  - How do users react to relaxations? [user study]
  - Lessons and future work
How do users react to relaxations?

- Two Research Questions:
  1. Are users willing to accept relaxations?
  2. Do they have preferences regarding the type of constraints to be removed?

Let’s ask the crowd!
Dataset Description

- **Dataset**
  - 7,955 (arguably) tasty recipes extracted from allrecipes.com
We automatically generated 50 unique task configurations:

Our user listed the following preferences, in no particular order:

- I prefer 4 meals.
- I prefer the **preparation time** to be as **low** as possible!
- I prefer that each meal has:
  - Less than 60.0 mg of cholesterol.
  - More than 15.0 g of protein.
- I prefer that overall the plan has:
  - Less than 10.0 g of fat **in total**.
  - More than 1.0 % of protein **in total**.

We varied these 4 constraints.
For each of the 50 configurations, we showed 5 different meal plans, each removing one constraint only:

1. **Original**
2. **CardinalityRelax**
3. **BaseRelax**
4. **GlobalRelax**
5. **Random**

- We used colors to indicate constraints adherence or violation.
- Results were presented sorted by preparation time.
### Task Screenshots

**GLOBALRELAX**

#### Meal Plan 1

<table>
<thead>
<tr>
<th>Meals</th>
<th>Cholest.</th>
<th>Protein</th>
<th>Fat</th>
<th>Protein %</th>
<th>Prep. time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meal 1</td>
<td>54.0 mg</td>
<td>26.5 g</td>
<td>12.1 g</td>
<td>0.5 %</td>
<td>15 min</td>
</tr>
<tr>
<td>Meal 2</td>
<td>48.0 mg</td>
<td>29.1 g</td>
<td>31.9 g</td>
<td>0.6 %</td>
<td>15 min</td>
</tr>
<tr>
<td>Meal 3</td>
<td>30.0 mg</td>
<td>17.4 g</td>
<td>18.6 g</td>
<td>0.3 %</td>
<td>10 min</td>
</tr>
<tr>
<td>Meal 4</td>
<td>45.0 mg</td>
<td>15.6 g</td>
<td>20.3 g</td>
<td>0.3 %</td>
<td>15 min</td>
</tr>
</tbody>
</table>

**Totals**

| 4 meals | 177.0 mg | 88.6 g | 82.9 g | > 10.0 | 1.8 % | 55 min |

**Would you recommend Meal Plan 1?**
- [ ] Yes
- [ ] No

**Briefly explain your choice about Meal Plan 1**

*Objective is highlighted*

*Global constraint violation and amount of violation*
## Task Screenshots

### CARDINALITY RELAX

### Meal Plan 2

<table>
<thead>
<tr>
<th>Meals</th>
<th>Cholest.</th>
<th>Protein</th>
<th>Fat</th>
<th>Protein %</th>
<th>Prep. time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meal 1</td>
<td>21.0 mg</td>
<td>19.2 g</td>
<td>3.3 g</td>
<td>0.4 %</td>
<td>20 min</td>
</tr>
<tr>
<td>Meal 2</td>
<td>59.0 mg</td>
<td>33.9 g</td>
<td>6.3 g</td>
<td>0.7 %</td>
<td>40 min</td>
</tr>
<tr>
<td>Totals</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 meals</td>
<td>&lt;4 mg</td>
<td>80.0 mg</td>
<td>9.6 g</td>
<td>1.1 %</td>
<td>1 hrs</td>
</tr>
</tbody>
</table>

**Would you recommend Meal Plan 2?**
- Yes
- No

**Briefly explain your choice about Meal Plan 2**

---

**Objective got worse**
### Task Screenshots

#### BASERELAX

<table>
<thead>
<tr>
<th>Meal Plan 3</th>
<th>Cholest.</th>
<th>Protein</th>
<th>Fat</th>
<th>Protein %</th>
<th>Prep. time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meal 1</td>
<td>21.0 mg</td>
<td>19.2 g</td>
<td>3.3 g</td>
<td>0.4 %</td>
<td>20 min</td>
</tr>
<tr>
<td>Meal 2</td>
<td>8.0 mg</td>
<td>3.9 g</td>
<td>&lt;15.0</td>
<td>0.1 %</td>
<td>6 min</td>
</tr>
<tr>
<td>Meal 3</td>
<td>50.0 mg</td>
<td>11.6 g</td>
<td>1.6 g</td>
<td>0.2 %</td>
<td>30 min</td>
</tr>
<tr>
<td>Meal 4</td>
<td>42.0 mg</td>
<td>18.6 g</td>
<td>2.8 g</td>
<td>0.4 %</td>
<td>40 min</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>121.0 mg</strong></td>
<td><strong>53.3 g</strong></td>
<td><strong>9.8 g</strong></td>
<td><strong>1.1 %</strong></td>
<td><strong>1 hrs, 36 min</strong></td>
</tr>
</tbody>
</table>

**Would you recommend Meal Plan 3?**
- [ ] Yes
- [ ] No

**Briefly explain your choice about Meal Plan 3**

---

Improving Package Recommendations through Query Relaxation
### Task Screenshots

#### Original

**Meal Plan 4**

<table>
<thead>
<tr>
<th>Meals</th>
<th>Cholest.</th>
<th>Protein</th>
<th>Fat</th>
<th>Protein %</th>
<th>Prep. time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meal 1</td>
<td>23.0 mg</td>
<td>18.2 g</td>
<td>1.9 g</td>
<td>0.4 %</td>
<td>3 hrs, 30 min</td>
</tr>
<tr>
<td>Meal 2</td>
<td>21.0 mg</td>
<td>19.2 g</td>
<td>3.3 g</td>
<td>0.4 %</td>
<td>20 min</td>
</tr>
<tr>
<td>Meal 3</td>
<td>35.0 mg</td>
<td>20.0 g</td>
<td>1.9 g</td>
<td>0.4 %</td>
<td>1 hrs</td>
</tr>
<tr>
<td>Meal 4</td>
<td>42.0 mg</td>
<td>18.6 g</td>
<td>2.8 g</td>
<td>0.4 %</td>
<td>40 min</td>
</tr>
</tbody>
</table>

**Totals**

| 4 meals | 121.0 mg | 76.0 g | 9.9 g | 1.5 % | 5 hrs, 30 min | 4 hrs, 35 min more than Meal Plan 1 |

**Would you recommend Meal Plan 4?**

- [ ] Yes
- [ ] No

**Briefly explain your choice about Meal Plan 4**

---

**Objective got even worse!**
Collected Data

- Run on crowdflower.com
- Each configuration completed by 10 unique workers
- No worker allowed to complete more than 5 configurations
- We removed obvious spammers a posteriori:
  - Same explanations in every task
  - Random explanations
  - Inconsistent explanations
- Resulting in 115 unique workers and 306 unique task instances
Evaluation

① Are users willing to accept relaxations?
② Do they have preferences regarding the type of constraints to be removed?

- The **ORIGINAL** plan was rejected **30%** of the time

**We need to provide users with alternatives!**
Evaluation

① Are users willing to accept relaxations?
② Do they have preferences regarding the type of constraints to be removed?

- Relaxed plans were chosen 76% of the time
- More likely to choose a relaxed plan than the original!

When \texttt{ORIGINAL} is recommended: 70%
When \texttt{ORIGINAL} is not recommended: 91%
Evaluation

① Are users willing to accept relaxations?
② Do they have preferences regarding the type of constraints to be removed?

- Overall
- When ORIGINAL is recommended
- When ORIGINAL is not recommended
Why Relaxations?

- Lower preparation time was often the reason:

  “close match for fiber as required and less time”
  “Even though the protein is low this is the best with a low prep time”
Additional Lessons

• Good explanations for the bias toward BASERELAX:

“Since your preference is 60 mg of cholesterol per meal the overall will be 240 mg, so it’s okay”
(The plans had to contain 4 meals)

“This meal plan meets most preferences. Two of the meals are lower in protein but two are high in protein which balances it out”

The workers relaxed base constraints by transforming them into global constraints!
Future Work

- What dictates user’s sensitivity toward different kinds of constraints?

- Impact of fine-grained relaxations

- Reverse relaxations
  - Tightening the constraints

- Additional relaxation methods
  - Including the type of relaxation workers spontaneously applied
Summary of Contributions

- Novel application of query relaxation
- Impact of coarse relaxations
- User reaction to package relaxations

Thank you!