Improving Package Recommendations through Query Relaxation

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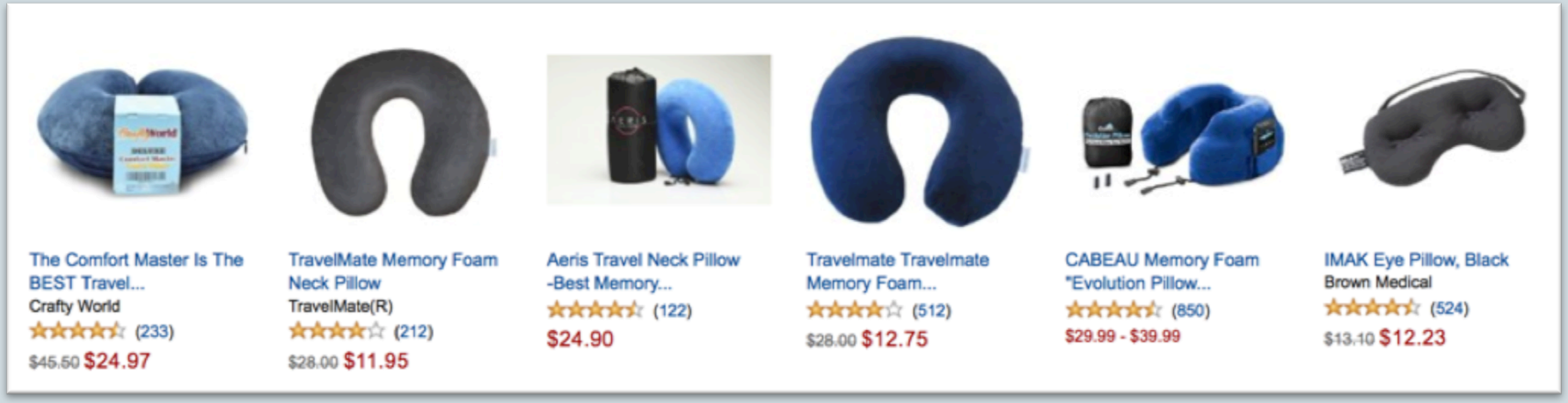
Recommendation Systems

- Recommendation systems aim to identify items of interest to users

Recommended to me by Amazon before traveling to Hangzhou:



“Package” Recommendations

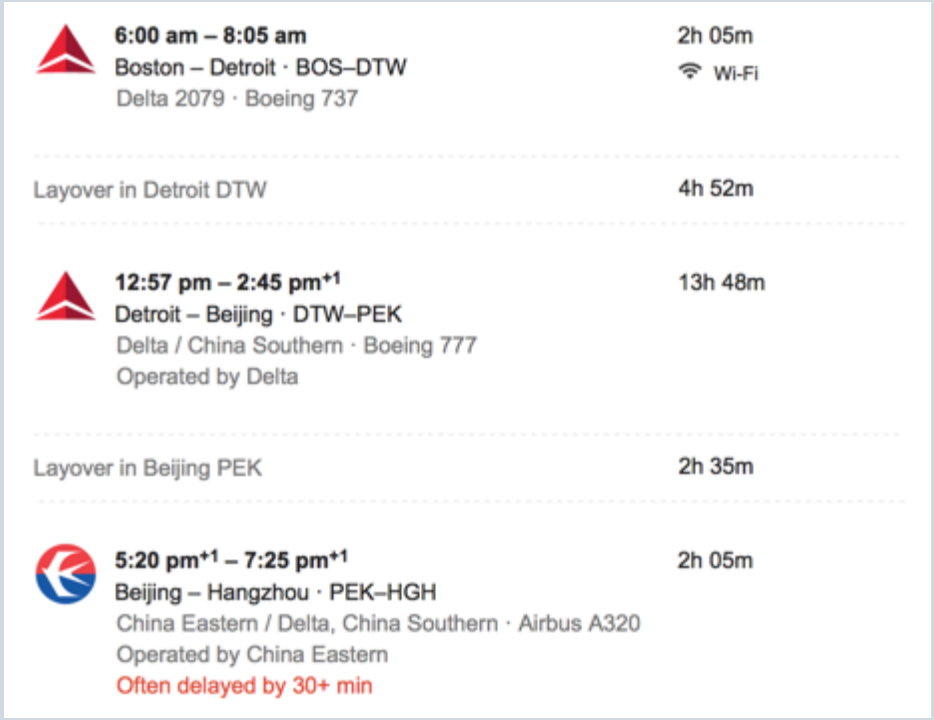
- But sometimes items are actually bundled together in packages of items

Example 1 — Amazon bundles

“Package” Recommendations

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

Example 2 — A flight package: *



* Recommended by Google Flights

“Package” Recommendations

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

Example 3 — A meal plan:

Recipe	Calorie	Fat	Carbs	Protein	Prep. time
e.g.: rice	10..20 =50	50..90	10..20 =50	10..20 =50	10..20 =50
Authentic Louisiana Red Beans and Rice	630	24.2	79.1	24	690
Slow Cooker Red Beans and Rice	374	14.2	39	22.6	495
Slow Cooker Split Pea Sausage Soup	417	13.1	50.8	23.9	320
Lamb and Winter Vegetable Stew	189	8.9	16.2	11	90

A "Package" Query

Recipe	Calorie	Fat	Carbs	Protein	Prep. time
e.g.: rice	10..20 =50	50..90	10..20 =5(	10..20 =50	10..20 =50
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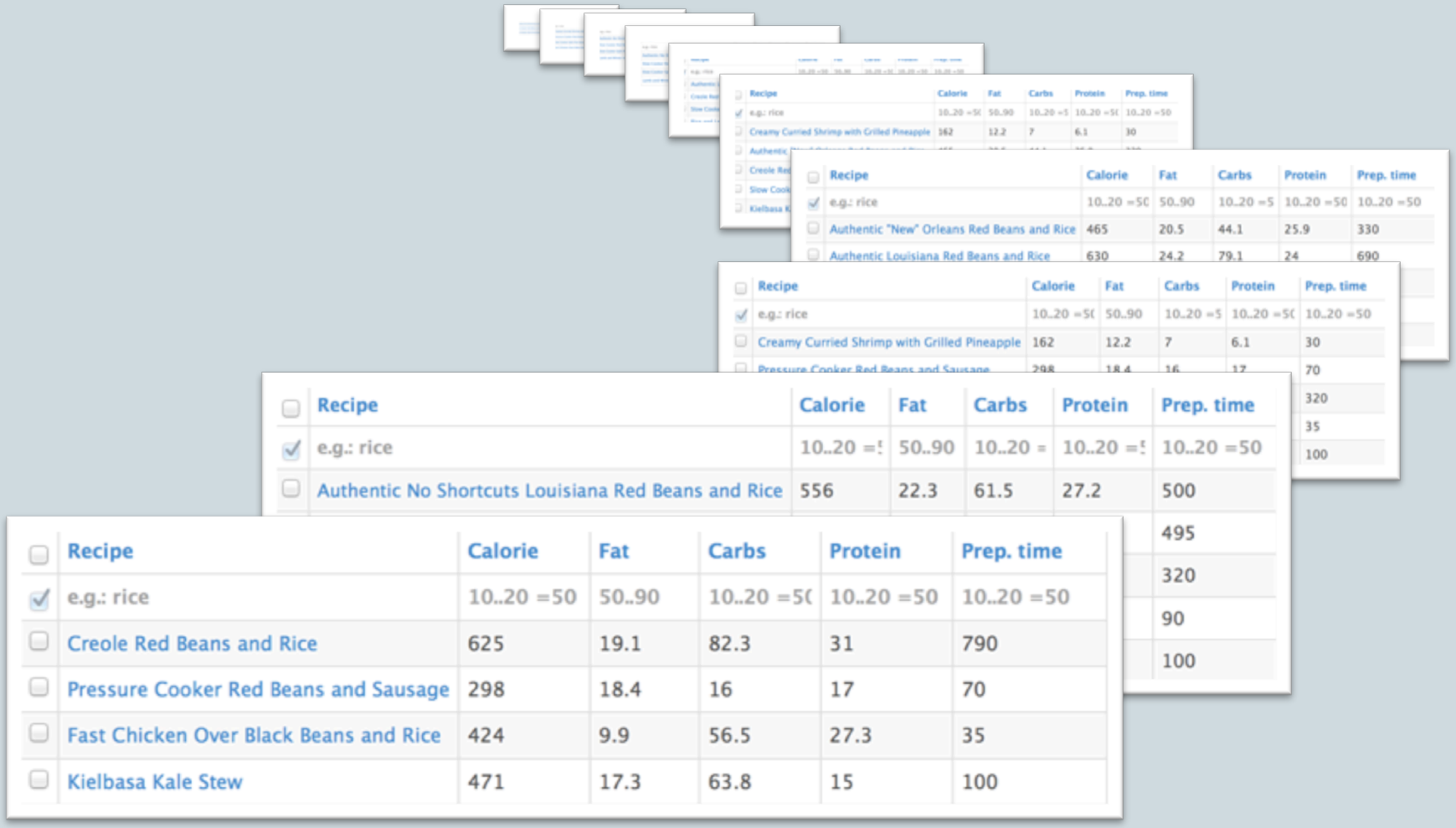
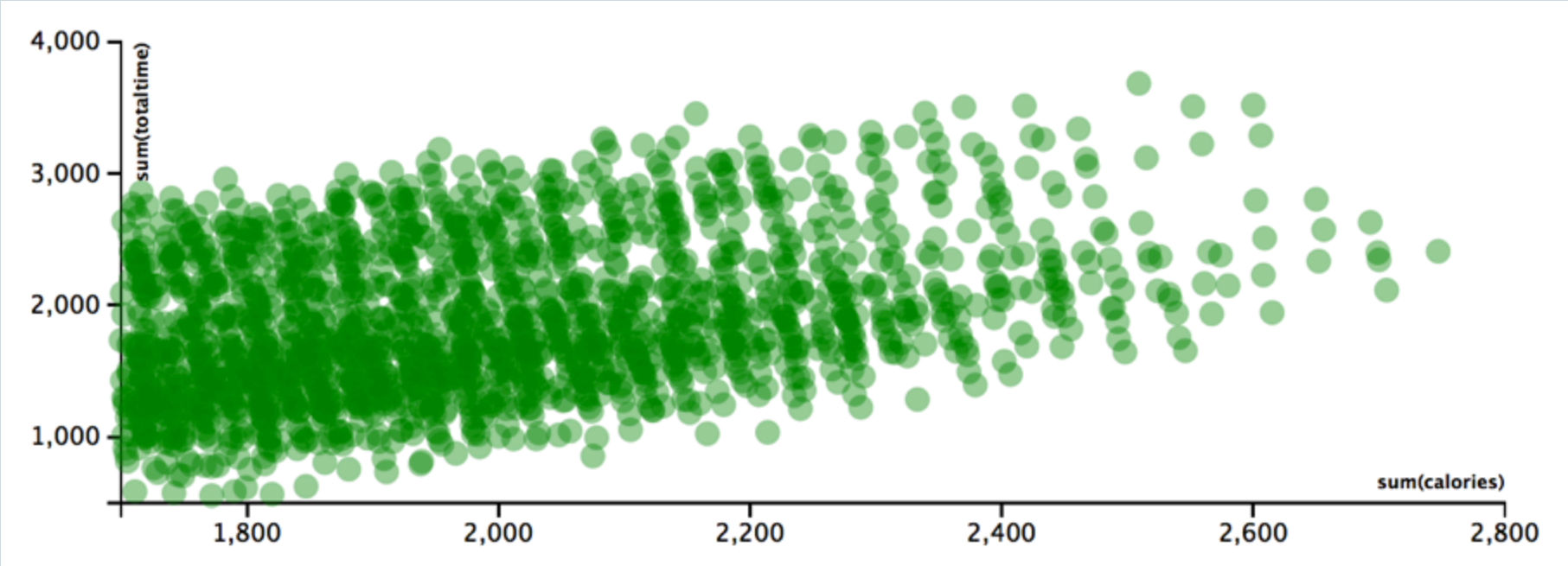
- All recipes should have less than 25 g of fat
- The entire meal plan should have:
  - At least 1700 kcal in total
  - Between 3 and 5 meals per day
- The meal plan should minimize the total preparation time

Many Feasible Solutions…



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

- ≥ 1700 kcal in total
- Minimal prep. time

Top-1 meal plan

Recipe	Calorie	Fat	Carbs	Protein	Prep. time
e.g.: rice	10..20 =5(	50..90	10..20 =5	10..20 =5(	10..20 =50
Creamy Curried Shrimp with Grilled Pineapple	571	12.2	7	6.1	30
Pressure Cooker Red Beans and Sausage	298	18.4	16	17	25
Slow Cooker Split Pea Sausage Soup	417	13.1	50.8	23.9	50
Fast Chicken Over Black Beans and Rice	424	9.9	56.5	27.3	80

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

Recipe	Calorie	Fat	Carbs	Protein	Prep. time
e.g.: rice	10..20 =5(	50..90	10..20 =5	10..20 =5(	10..20 =50
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Slow Cooker Split Pea Sausage Soup	417	13.1	50.8	23.9	50
~~Fast Chicken Over Black Beans and Rice~~	~~424~~	~~9.9~~	~~56.5~~	~~27.3~~	~~80~~

Out

1,710 kcal

3 hrs 5 min

Infeasible, but perhaps better than top-1

Recipe	Calorie	Fat	Carbs	Protein	Prep. time
e.g.: rice	10..20 =5(	50..90	10..20 =5	10..20 =5(	10..20 =50
Creamy Curried Shrimp with Grilled Pineapple	571	12.2	7	6.1	30
Pressure Cooker Red Beans and Sausage	298	18.4	16	17	25
Slow Cooker Split Pea Sausage Soup	417	13.1	50.8	23.9	50
Kielbasa Kale Stew	364	16.2	21	10.7	20

In

1 hr less!

1,650 < 1,700 kcal

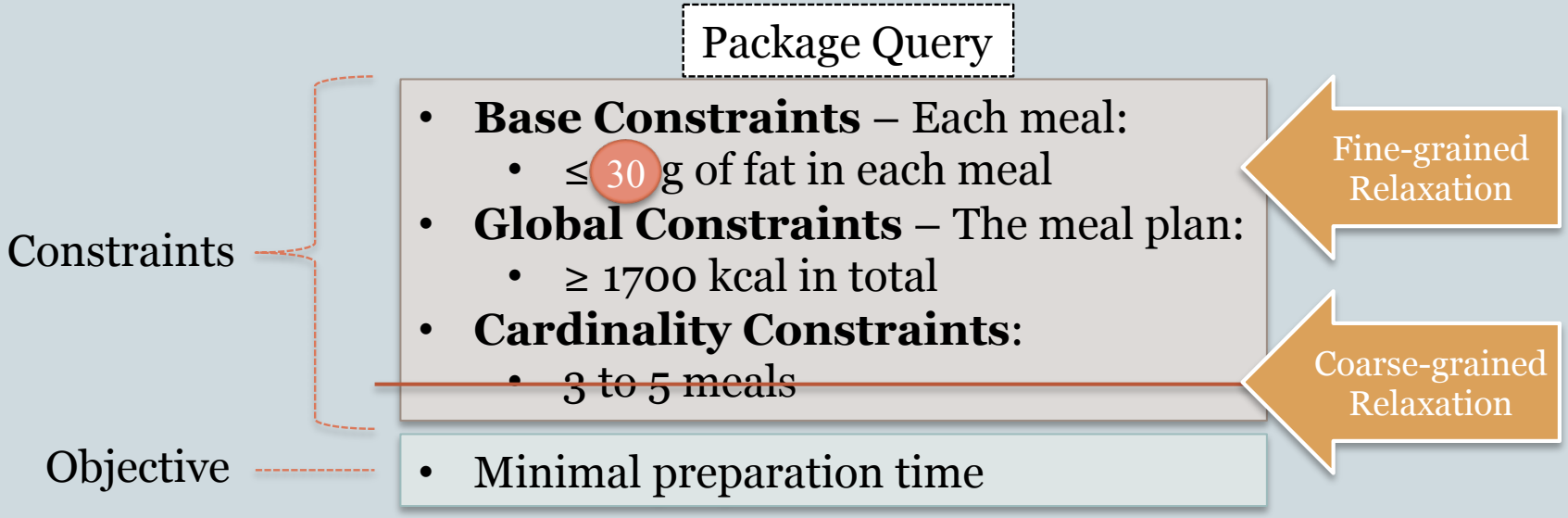
2 hrs 5 min

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

Package Query Relaxations

- What is a relaxation of a package query?

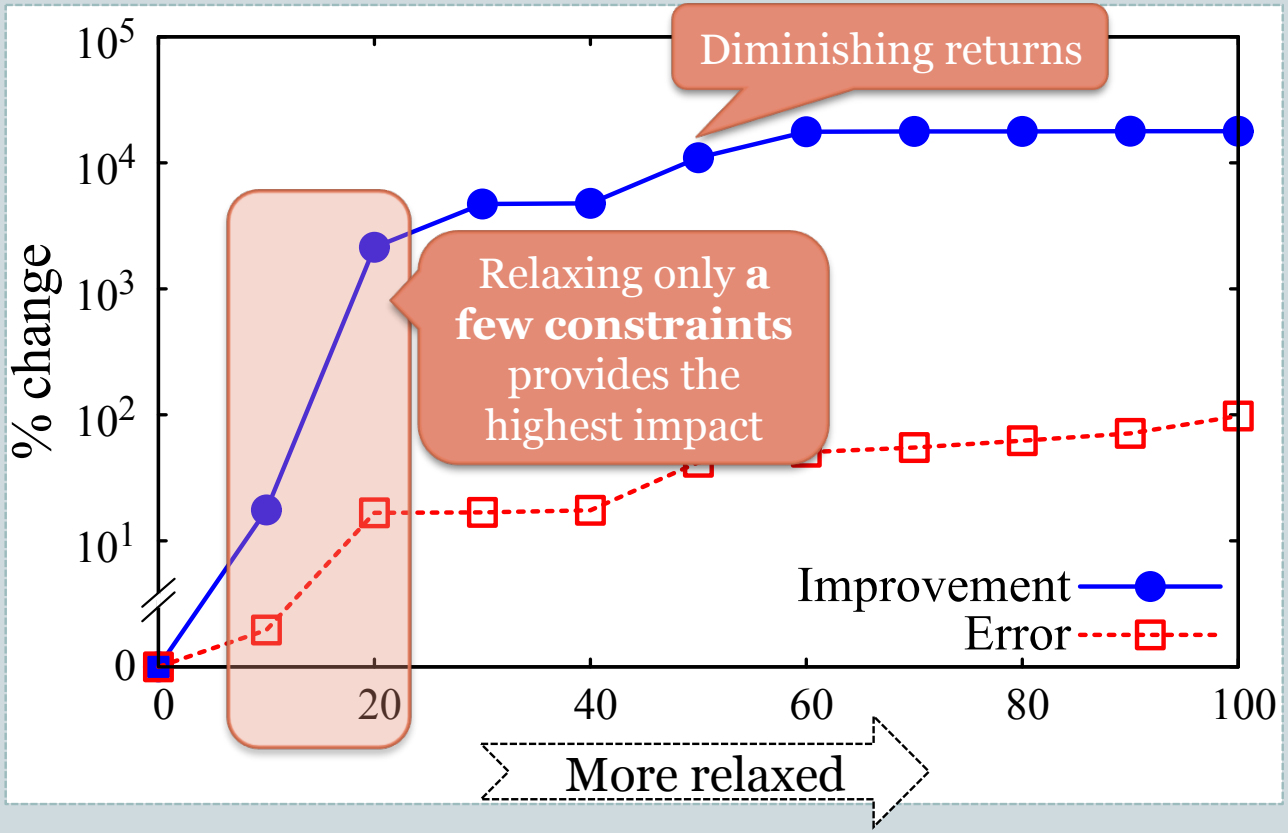


Criteria for Relaxations

- 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?



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:

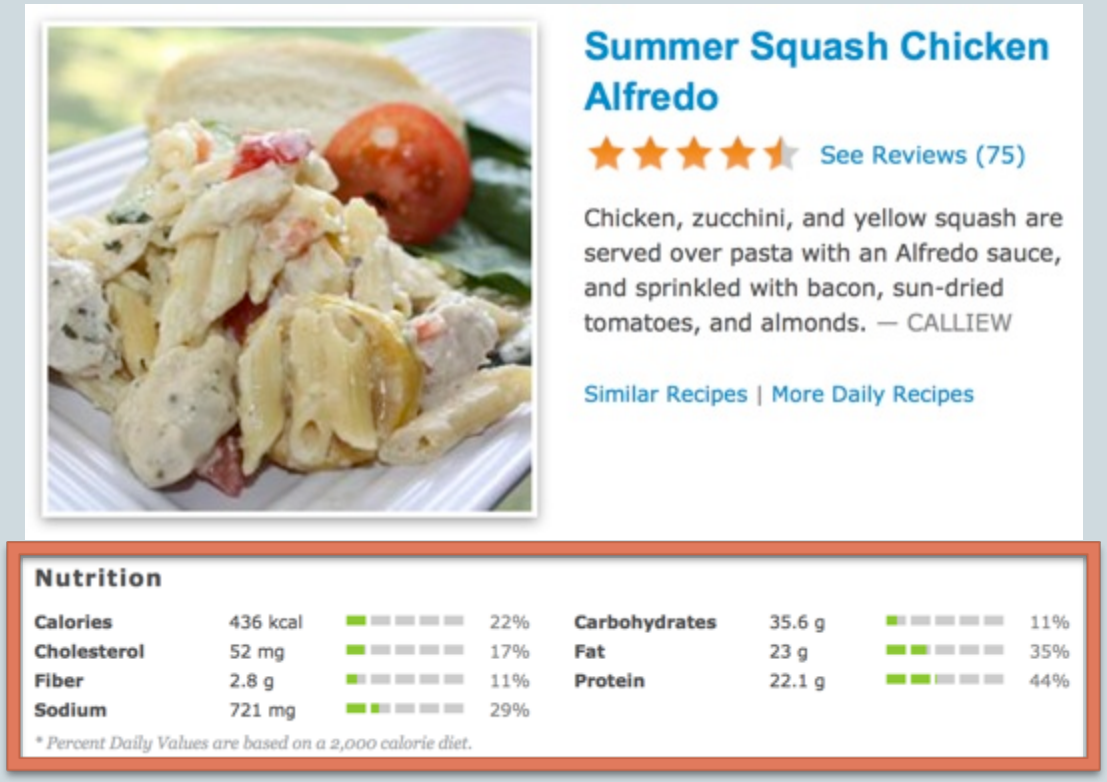
① Are users willing to accept relaxations?

② Do they have preferences regarding the type of constraints to be removed?

Let's ask the crowd!

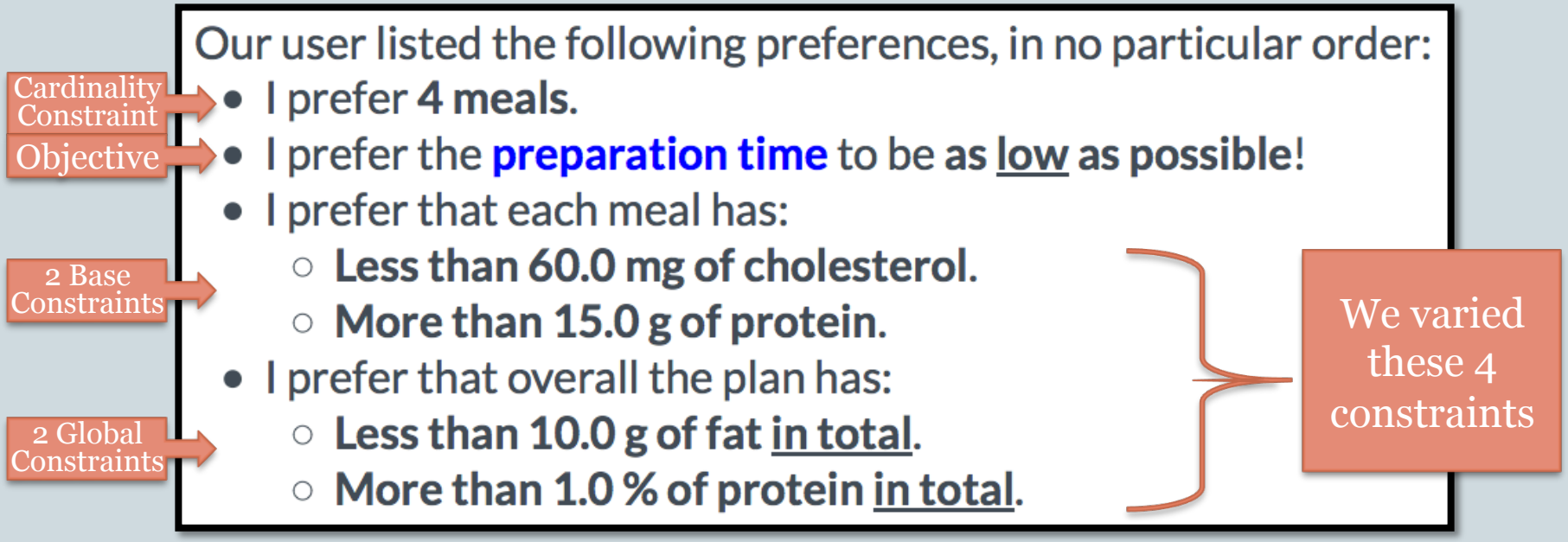
Dataset Description

- Dataset
  - 7,955 (arguably) tasty recipes extracted from allrecipes.com



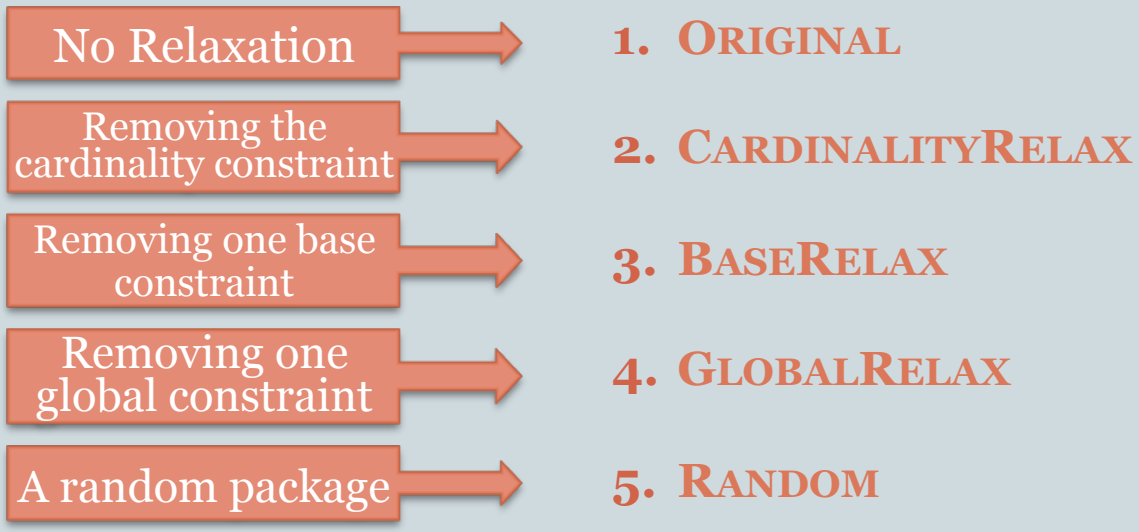
Task Instructions

We automatically generated 50 unique task configurations:



Task Choices

- For each of the 50 configurations, we showed
  5 different meal plans, each removing one constraint only:



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

Task Screenshots

GLOBALRELAX

Meal Plan 1

Meals	Cholest.	Protein	Fat	Protein %	Prep. time
Meal 1	54.0 mg	26.5 g	12.1 g	0.5 %	15 min
Meal 2	48.0 mg	29.1 g	31.9 g	0.6 %	15 min
Meal 3	30.0 mg	17.4 g	18.6 g	0.3 %	10 min
Meal 4	45.0 mg	15.6 g	20.3 g	0.3 %	15 min
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

CARDINALITYRELAX

Meal Plan 2

Meals	Cholest.	Protein	Fat	Protein %	Prep. time
Meal 1	21.0 mg	19.2 g	3.3 g	0.4 %	20 min
Meal 2	59.0 mg	33.9 g	6.3 g	0.7 %	40 min
Totals					
2 meals < 4	80.0 mg	53.1 g	9.6 g	1.1 %	1 hrs 5 min more than Meal Plan 1

Would you recommend Meal Plan 2?

- Yes
- No

Briefly explain your choice about Meal Plan 2

Objective got worse

Task Screenshots

BASERELAX

Meal Plan 3

Meals	Cholest.	Protein	Fat	Protein %	Prep. time
Meal 1	21.0 mg	19.2 g	3.3 g	0.4 %	20 min
Meal 2	8.0 mg	3.9 g < 15.0	2.1 g	0.1 %	6 min
Meal 3	50.0 mg	11.6 g < 15.0	1.6 g	0.2 %	30 min
Meal 4	42.0 mg	18.6 g	2.8 g	0.4 %	40 min
Totals					
4 meals	121.0 mg	53.3 g	9.8 g	1.1 %	1 hrs, 36 min 41 min more than Meal Plan 1

Would you recommend Meal Plan 3?

- Yes
- No

Briefly explain your choice about Meal Plan 3

Task Screenshots

ORIGINAL

Meal Plan 4

Meals	Cholest.	Protein	Fat	Protein %	Prep. time
Meal 1	23.0 mg	18.2 g	1.9 g	0.4 %	3 hrs, 30 min
Meal 2	21.0 mg	19.2 g	3.3 g	0.4 %	20 min
Meal 3	35.0 mg	20.0 g	1.9 g	0.4 %	1 hrs
Meal 4	42.0 mg	18.6 g	2.8 g	0.4 %	40 min
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!

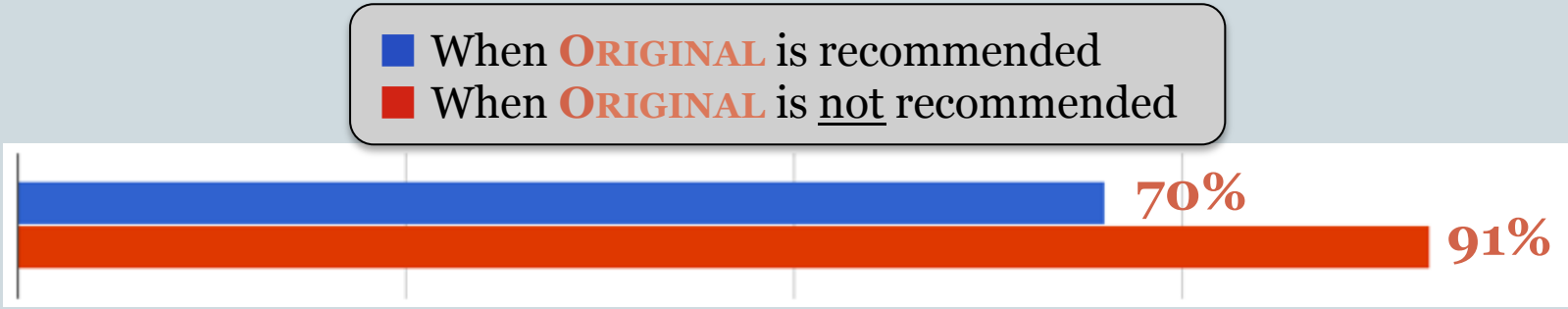
Evaluation

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!



Evaluation

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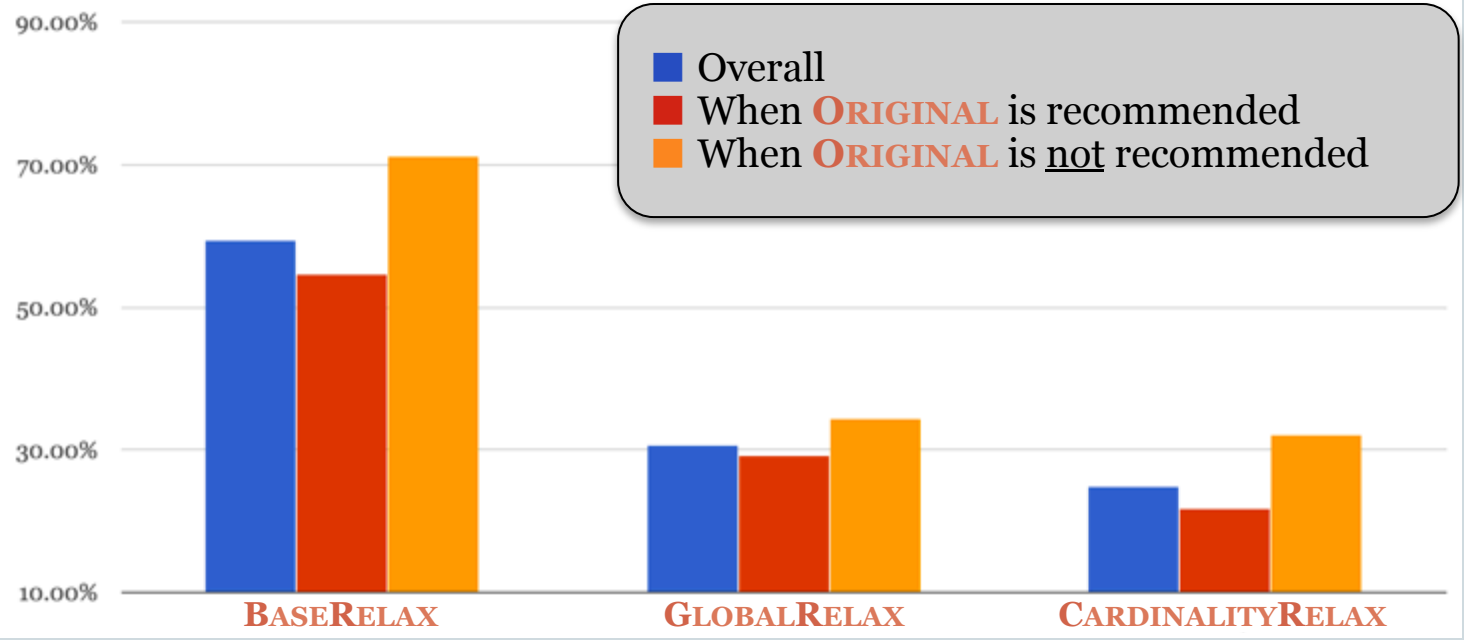


Why Relaxations?

- 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"*

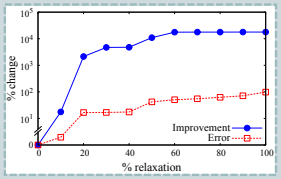
The workers relaxed base constraints by transforming them into global constraints!

Future Work

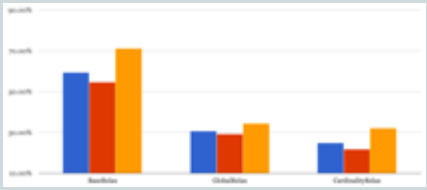
- What dictates user's sensitivity toward different kinds of constraints?
- Impact of fine-grained relaxations
- Reverse relaxations
  - Tightening the constraints
- Additional relaxation methods
  - Including the type of relaxation workers spontaneously applied

Summary of Contributions

- Novel application of query relaxation
- Impact of coarse relaxations



- User reaction to package relaxations



Thank you!