

Improving Package Recommendations through Query Relaxation

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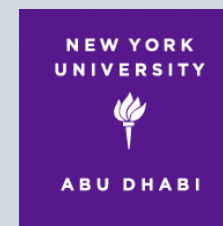
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Recommendation Systems

- 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	TravelMate Memory Foam Neck Pillow TravelMate(R)	Aeris Travel Neck Pillow -Best Memory...	Travelmate Travelmate Memory Foam...	CABEAU Memory Foam "Evolution Pillow...	IMAK Eye Pillow, Black Brown Medical
★★★★☆ (233)	★★★★☆ (212)	★★★★☆ (122)	★★★★☆ (512)	★★★★☆ (850)	★★★★☆ (524)
\$45.50 \$24.97	\$28.00 \$11.95	\$24.90	\$28.00 \$12.75	\$29.99 - \$39.99	\$13.10 \$12.23

“Package” Recommendations

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

Example 1 — Amazon bundles

Frequently Bought Together



Price for all three: **\$88.83**

Add all three to Cart

Add all three to Wish List




[Show availability and shipping details](#)

- ✓ This item: CABEAU Memory Foam "Evolution Pillow" + Small Bag - It Actually Works! - BLACK **\$39.99**
- ✓ Sleep Mask with Ear Plugs - This Eye Mask Is for Sleeping Better Anywhere - On Travel - Long Flights ... **\$12.95**
- ✓ J Pillow - Winner of British Invention of the Year 2013 -consistently #1 best selling travel pillow on ... **\$35.89**

“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		
	12:57 pm – 2:45 pm⁺¹ Detroit – Beijing · DTW–PEK Delta / China Southern · Boeing 777 Operated by Delta	13h 48m
Layover in Beijing PEK		
	5:20 pm⁺¹ – 7:25 pm⁺¹ Beijing – Hangzhou · PEK–HGH China Eastern / Delta, China Southern · Airbus A320 Operated by China Eastern Often delayed by 30+ min	2h 05m

“Package” Recommendations

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

Example 3 — A meal plan:

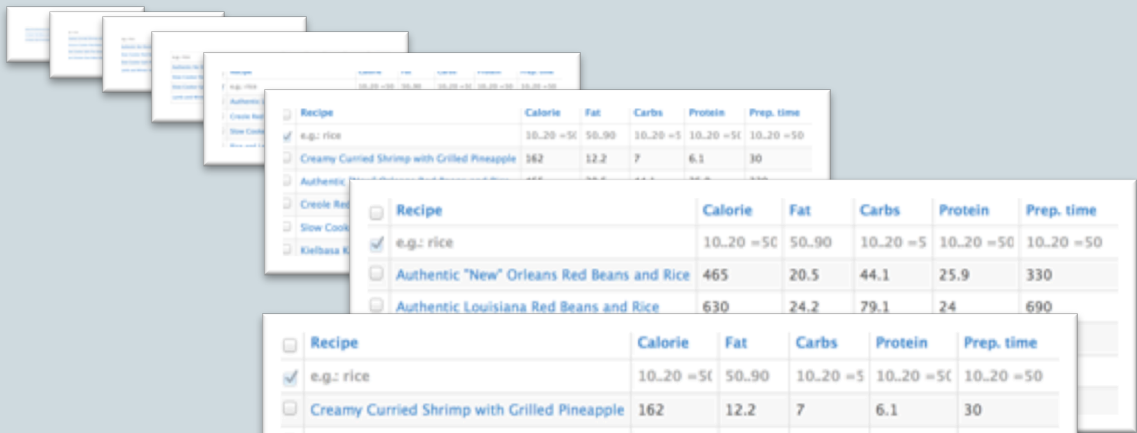
<input type="checkbox"/>	Recipe	Calorie	Fat	Carbs	Protein	Prep. time
<input checked="" type="checkbox"/>	e.g.: rice	10..20 =50	50..90	10..20 =50	10..20 =50	10..20 =50
<input type="checkbox"/>	Authentic Louisiana Red Beans and Rice	630	24.2	79.1	24	690
<input type="checkbox"/>	Slow Cooker Red Beans and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

A “Package” Query

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

- 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

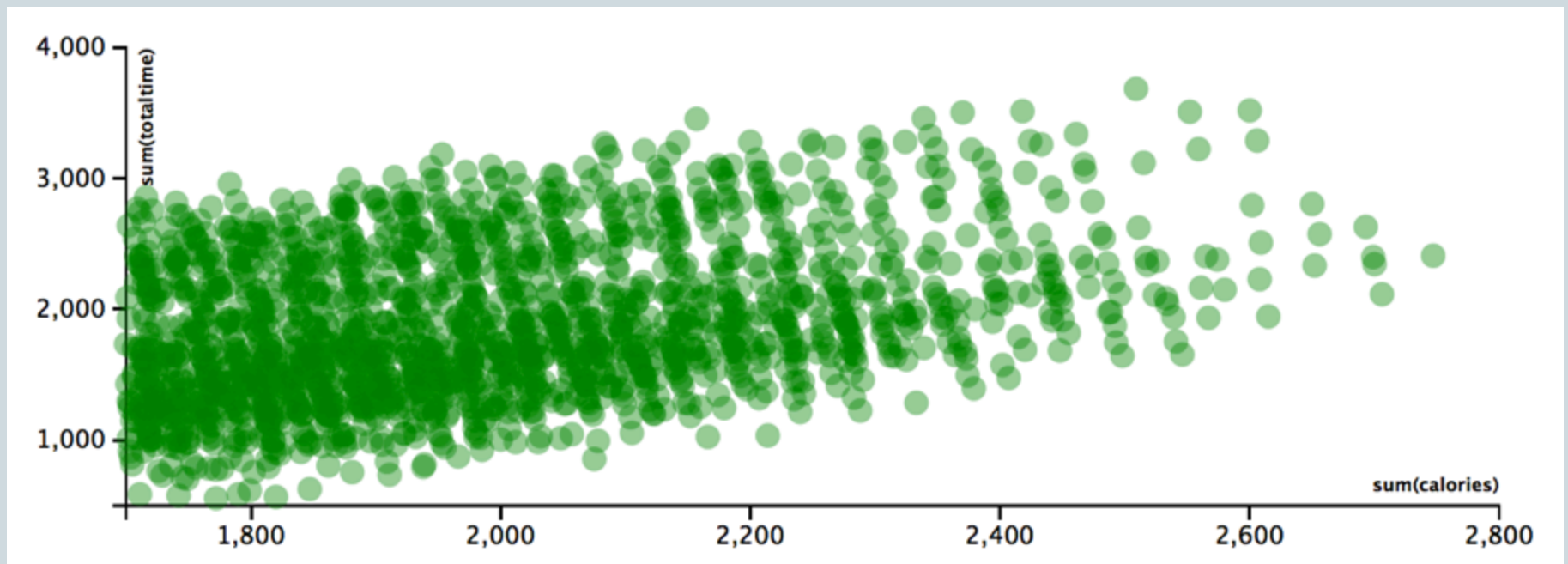
Many Feasible Solutions...



<input type="checkbox"/> Recipe	Calorie	Fat	Carbs	Protein	Prep. time
<input checked="" type="checkbox"/> e.g.: rice	10..20 =50	50..90	10..20 =50	10..20 =50	10..20 =50
<input type="checkbox"/> Creamy Curried Shrimp with Grilled Pineapple	162	12.2	7	6.1	30
<input type="checkbox"/> Authentic "New" Orleans Red Beans and Rice	465	20.5	44.1	25.9	330
<input type="checkbox"/> Authentic Louisiana Red Beans and Rice	630	24.2	79.1	24	690
<input type="checkbox"/> Recipe	Calorie	Fat	Carbs	Protein	Prep. time
<input checked="" type="checkbox"/> e.g.: rice	10..20 =50	50..90	10..20 =50	10..20 =50	10..20 =50
<input type="checkbox"/> Creamy Curried Shrimp with Grilled Pineapple	162	12.2	7	6.1	30
<input type="checkbox"/> Pressure Cooker Red Beans and Sausage	298	18.4	16	17	70
<input type="checkbox"/> Recipe	Calorie	Fat	Carbs	Protein	Prep. time
<input checked="" type="checkbox"/> e.g.: rice	10..20 =50	50..90	10..20 =50	10..20 =50	10..20 =50
<input type="checkbox"/> Authentic No Shortcuts Louisiana Red Beans and Rice	556	22.3	61.5	27.2	500
<input type="checkbox"/> Recipe	Calorie	Fat	Carbs	Protein	Prep. time
<input checked="" type="checkbox"/> e.g.: rice	10..20 =50	50..90	10..20 =50	10..20 =50	10..20 =50
<input type="checkbox"/> Creole Red Beans and Rice	625	19.1	82.3	31	790
<input type="checkbox"/> Pressure Cooker Red Beans and Sausage	298	18.4	16	17	70
<input type="checkbox"/> Fast Chicken Over Black Beans and Rice	424	9.9	56.5	27.3	35
<input type="checkbox"/> Kielbasa Kale Stew	471	17.3	63.8	15	100

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

<input type="checkbox"/> Recipe	Calorie	Fat	Carbs	Protein	Prep. time
<input checked="" type="checkbox"/> e.g.: rice	10..20 = 50	50..90	10..20 = 5	10..20 = 50	10..20 = 50
<input type="checkbox"/> Creamy Curried Shrimp with Grilled Pineapple	571	12.2	7	6.1	30
<input type="checkbox"/> Pressure Cooker Red Beans and Sausage	298	18.4	16	17	25
<input type="checkbox"/> Slow Cooker Split Pea Sausage Soup	417	13.1	50.8	23.9	50
<input type="checkbox"/> 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

<input type="checkbox"/> Recipe	Calorie	Fat	Carbs	Protein	Prep. time
<input checked="" type="checkbox"/> e.g.: rice	10..20 = 50	50..90	10..20 = 5	10..20 = 50	10..20 = 50
<input type="checkbox"/> Creamy Curried Shrimp with Grilled Pineapple	571	12.2	7	6.1	30
<input type="checkbox"/> Pressure Cooker Red Beans and Sausage	298	18.4	16	17	25
<input type="checkbox"/> Slow Cooker Split Pea Sausage Soup	417	13.1	50.8	23.9	50
<input type="checkbox"/> 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

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

In

1,650 < 1,700 kcal

2 hrs 5 min

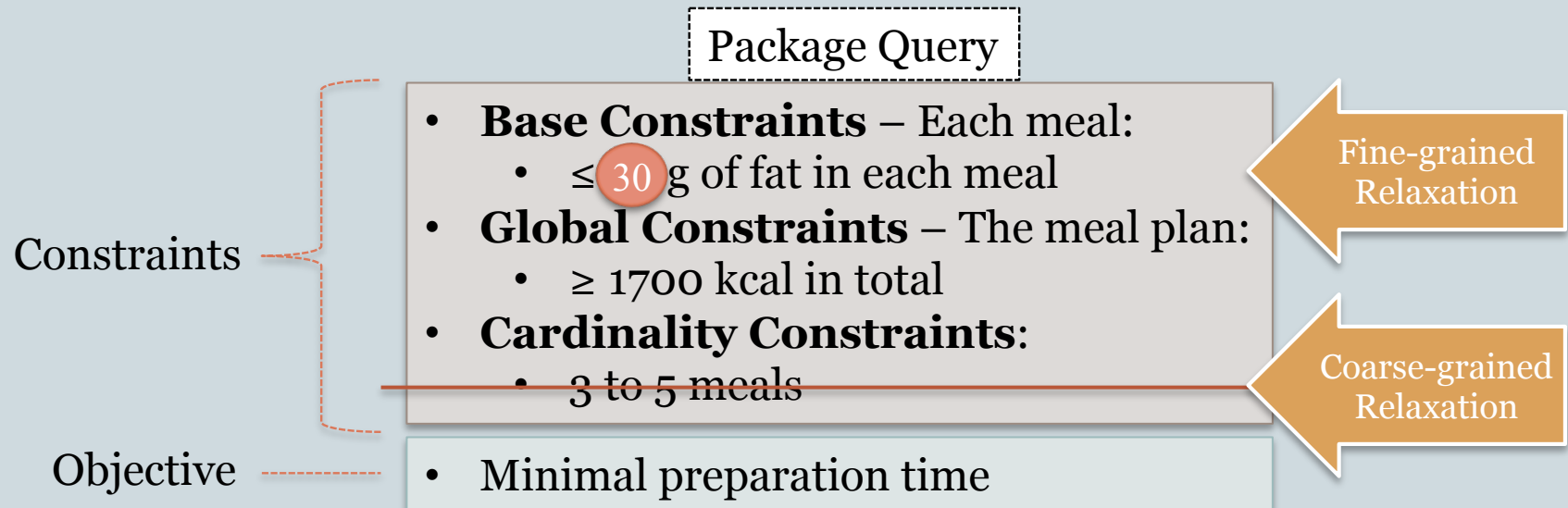
1 hr less!

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

Package Query Relaxations

- What is a relaxation of a package query?

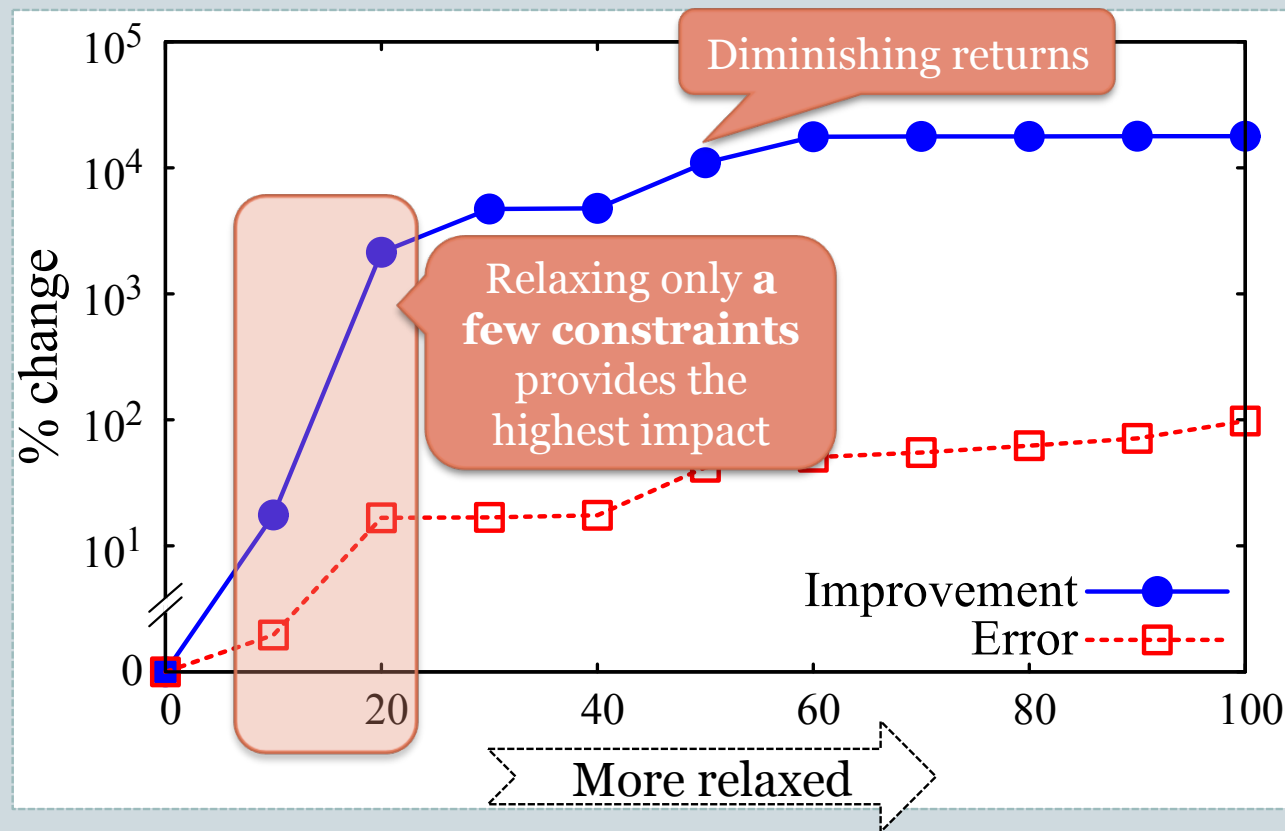


Criteria for Relaxations

- 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



Summer Squash Chicken Alfredo

★★★★★ See Reviews (75)

Chicken, zucchini, and yellow squash are served over pasta with an Alfredo sauce, and sprinkled with bacon, sun-dried tomatoes, and almonds. — CALLIEW

[Similar Recipes](#) | [More Daily Recipes](#)

Nutrition			
Calories	436 kcal	<div><div></div><div></div><div></div><div></div><div></div></div>	22%
Cholesterol	52 mg	<div><div></div><div></div><div></div><div></div><div></div></div>	17%
Fiber	2.8 g	<div><div></div><div></div><div></div><div></div><div></div></div>	11%
Sodium	721 mg	<div><div></div><div></div><div></div><div></div><div></div></div>	29%
Carbohydrates	35.6 g	<div><div></div><div></div><div></div><div></div><div></div></div>	11%
Fat	23 g	<div><div></div><div></div><div></div><div></div><div></div></div>	35%
Protein	22.1 g	<div><div></div><div></div><div></div><div></div><div></div></div>	44%

* Percent Daily Values are based on a 2,000 calorie diet.

Task Instructions

We automatically generated 50 unique task configurations:

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

Cardinality
Constraint

- I prefer 4 meals.

Objective

- I prefer the **preparation time** to be as low as possible!

2 Base
Constraints

- I prefer that each meal has:
 - Less than 60.0 mg of cholesterol.
 - More than 15.0 g of protein.

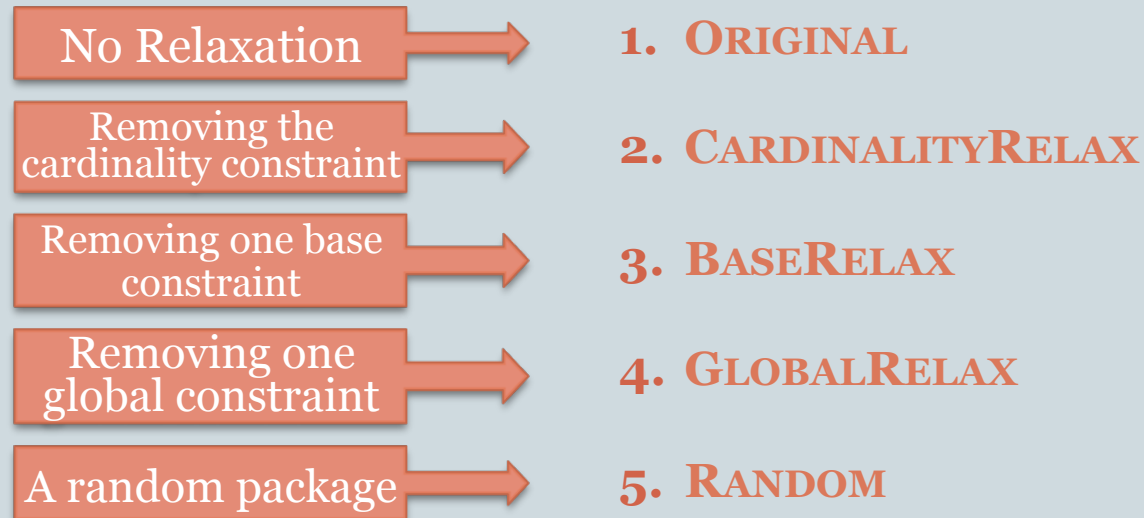
2 Global
Constraints

- 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

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
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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
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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
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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
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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!

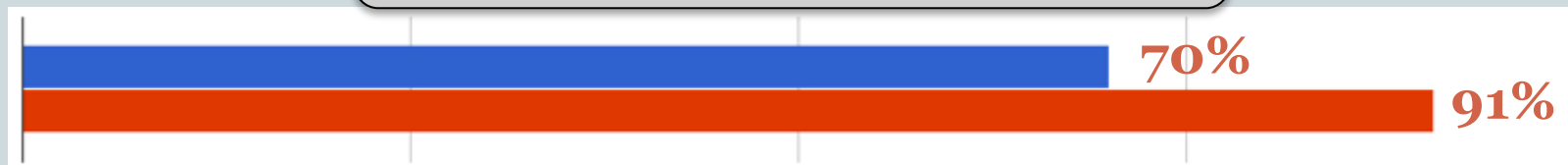
Evaluation

- 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

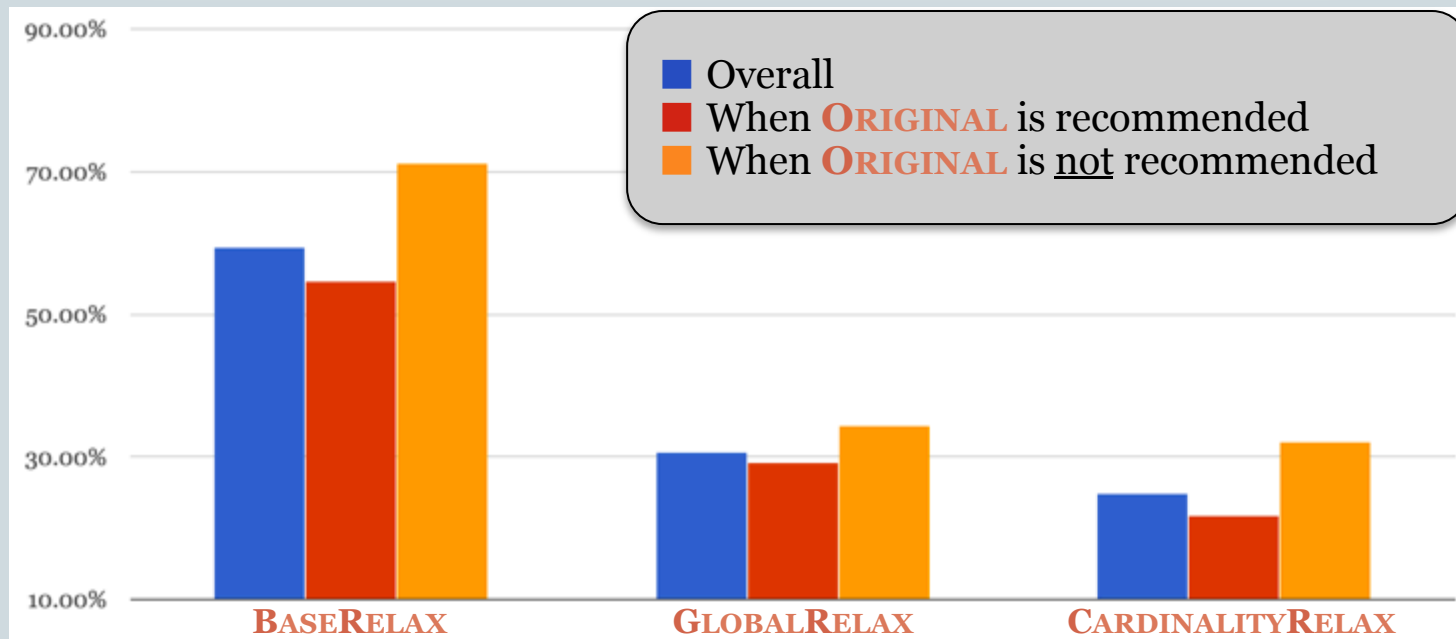
**More likely to choose a relaxed plan
than the original!**

- When **ORIGINAL** is recommended
- When **ORIGINAL** is not recommended



Evaluation

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



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**”*

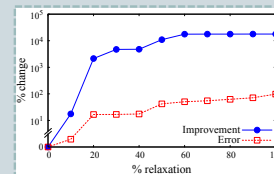
The workers relaxed base constraints by transforming them into global constraints!

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!