DATA ANALYTICS USING DEEP LEARNING

GT 8803 // FALL 2018 // JACOB LOGAS

LECTURE #09:DATA VOCALIZATION: OPTIMIZING VOICE OUTPUT OF RELATIONAL DATA

CREATING THE NEXT®

TODAY'S PAPER

- Data Vocalization: Optimizing Voice Output of Relational Data
  - New dimension to data delivery
  - Formalize voice output optimization problem
- Authors: Immanuel Trummer, Jiancheng Zhu, Mark Bryan
- Slides based on Trummer presentation @ VLDB 2017

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Restaurant	Cuisine	Rating
Upstate	Traditional American	4.75
Thai Castle	Thai	3.3
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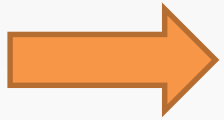


Restaurants with Traditional American cuisine and four to five stars user average rating:
Upstate.
John's.
The View.

Restaurants with three to four stars user average rating:
Thai Castle with Thai cuisine.
Paris with French cuisine.
La Masseria with Italian cuisine.

TODAY'S AGENDA

- Context: Data Visualization
- Problem Overview
- Key Idea
- Technical Details
- Experiments
- Discussion

What is Data Visualization?

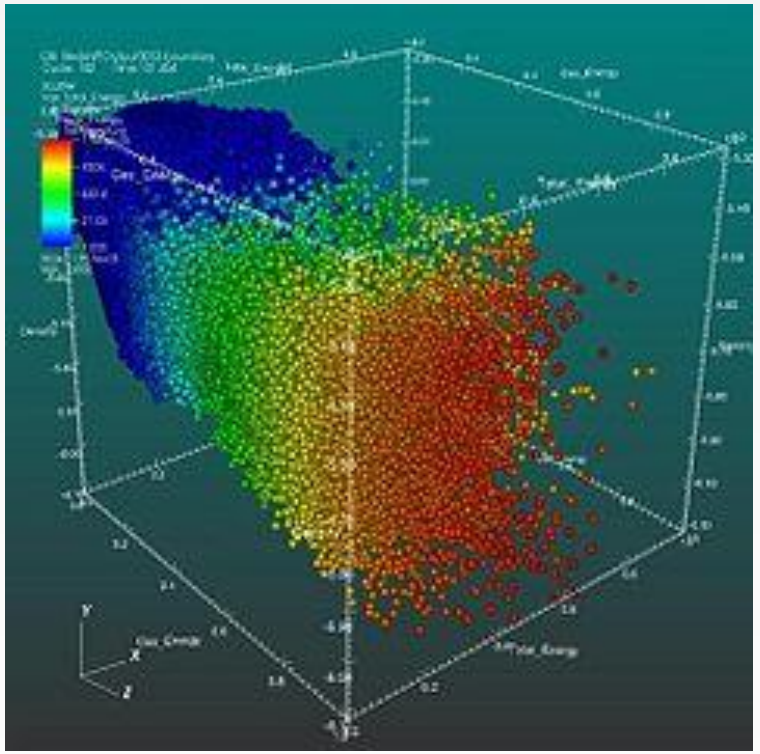
- 1987
  - NSF started “Scientific Visualization”
- Transforms data into images
  - Represent information about data
- Tool to enable User insight into Data
  - Intuitive understanding of data

What Does Visualization Do?

- Goals

What Does Visualization Do?

- Goals
  - Explore
    - Used for data exploration

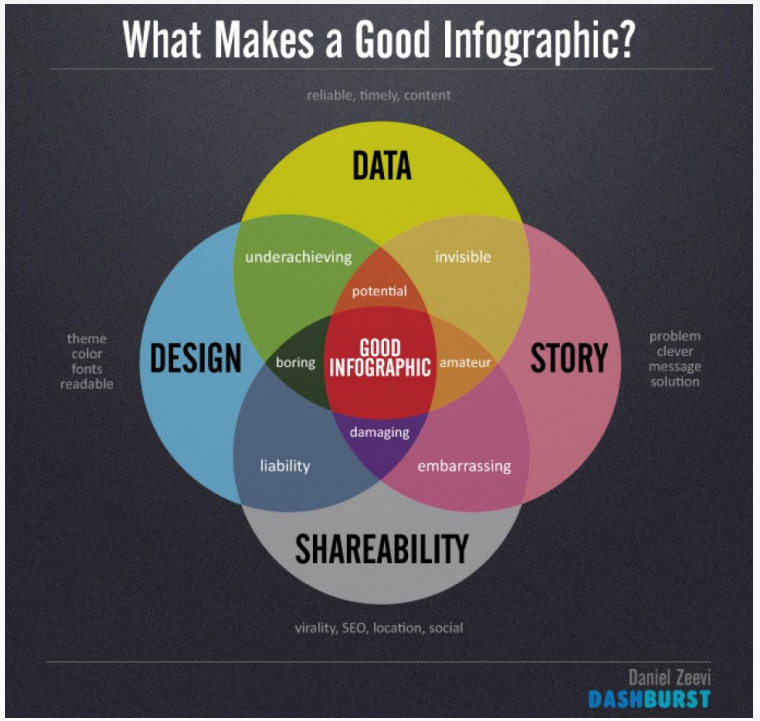


What Does Visualization Do?

- Goals
  - Explore
    - Used for data exploration
  - Analyze
    - Used for verification

What Does Visualization Do?

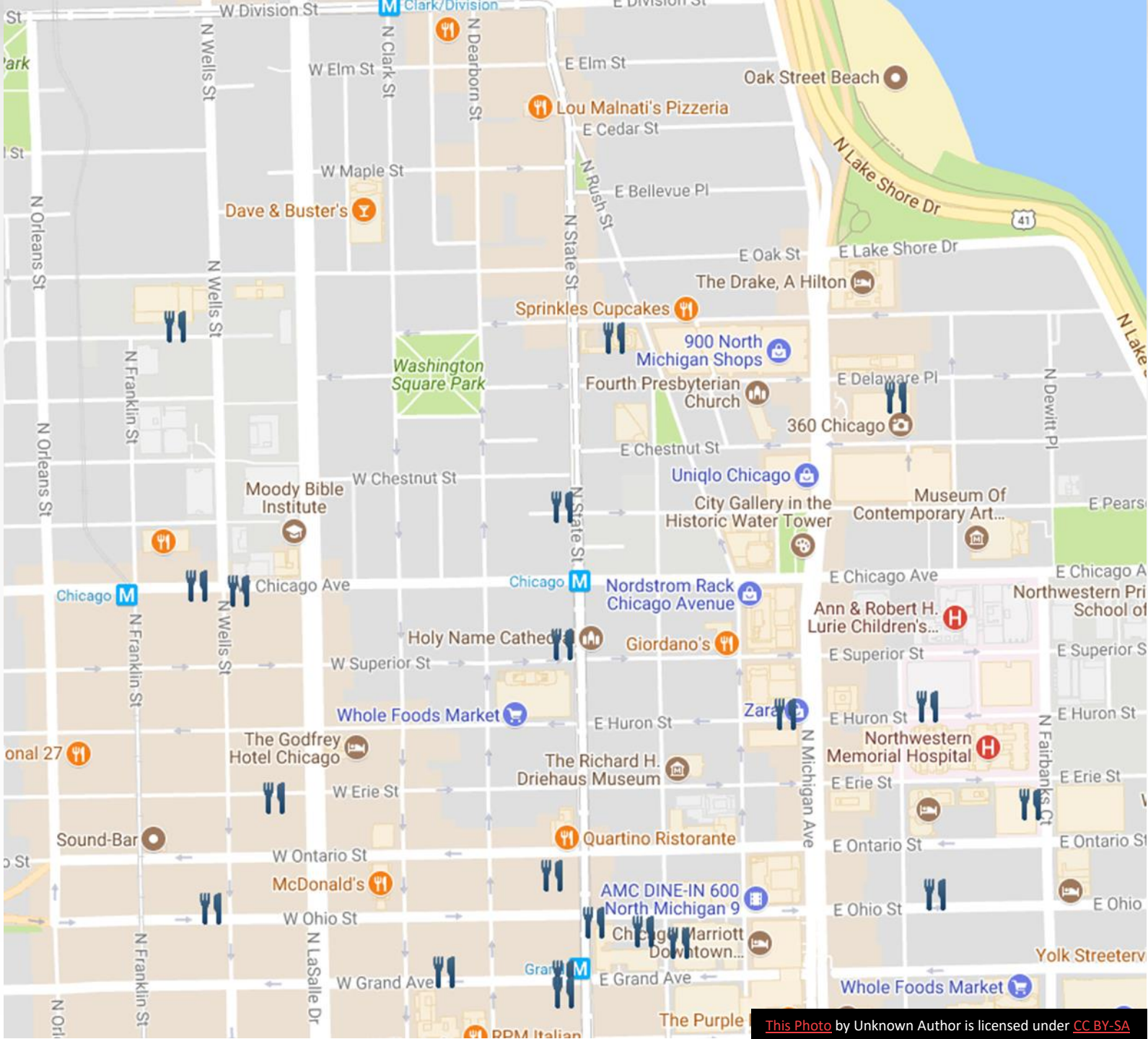
- Goals
  - Explore
    - Used for data exploration
  - Analyze
    - Used for verification
  - Present
    - Used for Communication of Results



PROBLEM OVERVIEW

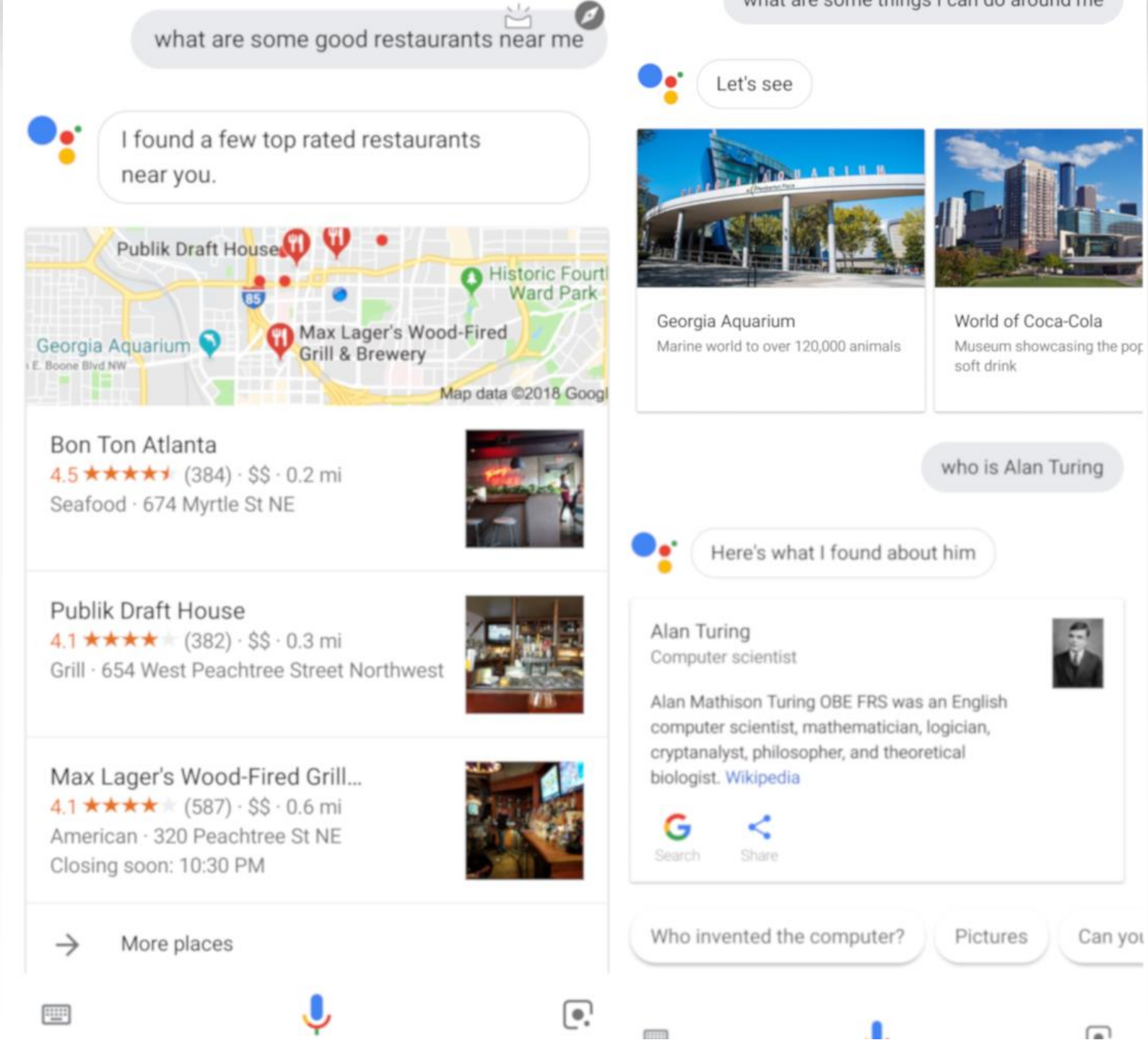
Visualization Cons

- Overwhelming
- Slowing
- Noisy
- Re-reading
- Skimming



Audio Presentation

- Quick
- Concise
- Memorable
- Low Cognitive Load



Limits of Short Term Memory

- Impose limits on information
  - Receive
  - Process
  - Remember
- Recoding to beat bottleneck
- Information theory

Miller, G. A. (1956). The magical number seven, plus or minus two: some limits on our capacity for processing information. *Psychological Review, 63*(2), 81-97. http://dx.doi.org/10.1037/h0043158

Overview

- Given input relation
- Find time-optimal vocalization
- Constrained by
  - Precision
  - Output structure
  - Memory load

EXAMPLE

Naive

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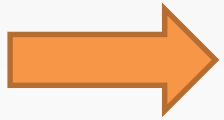

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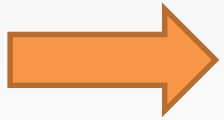

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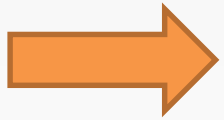

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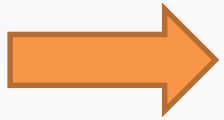

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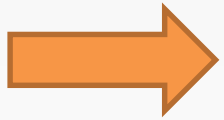

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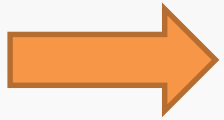

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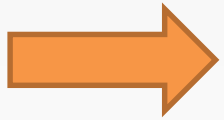

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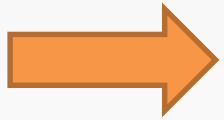

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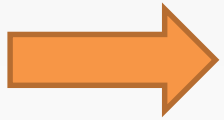

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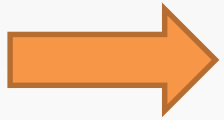

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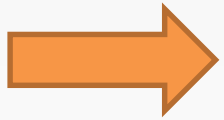

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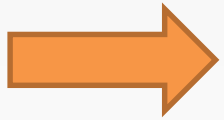

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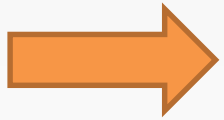

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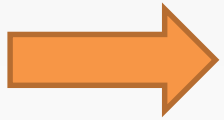

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The Optimization Problem

- Input: relation to vocalize
- Search Space: sequence of scopes
- Constraints

$$Context\ Size \leq S$$ Memory

  - Categorical value domain:

$$Domain\ Size \leq C$$ Precision

  - Numerical value domains:

$$Upper\ Bound \leq Lower\ Bound * W$$ Precision

- Objective: Minimize speaking time

The Optimization Problem

NP Hard

- Input: relation to vocalize
- Search Space: sequence of scopes
- Constraints

$$Context\ Size \leq S$$ Memory

  - Categorical value domain:

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  - Numerical value domains:

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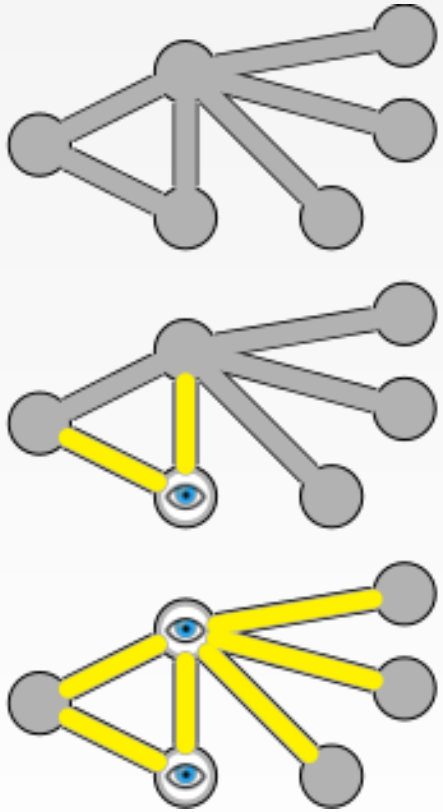
- Objective: Minimize speaking time

Proof

- Represent as vertex cover
- One edge per row
- One vertex per category column
- α if vertex incident to an edge
- Other values are mutually different
- Vertex cover is NP hard

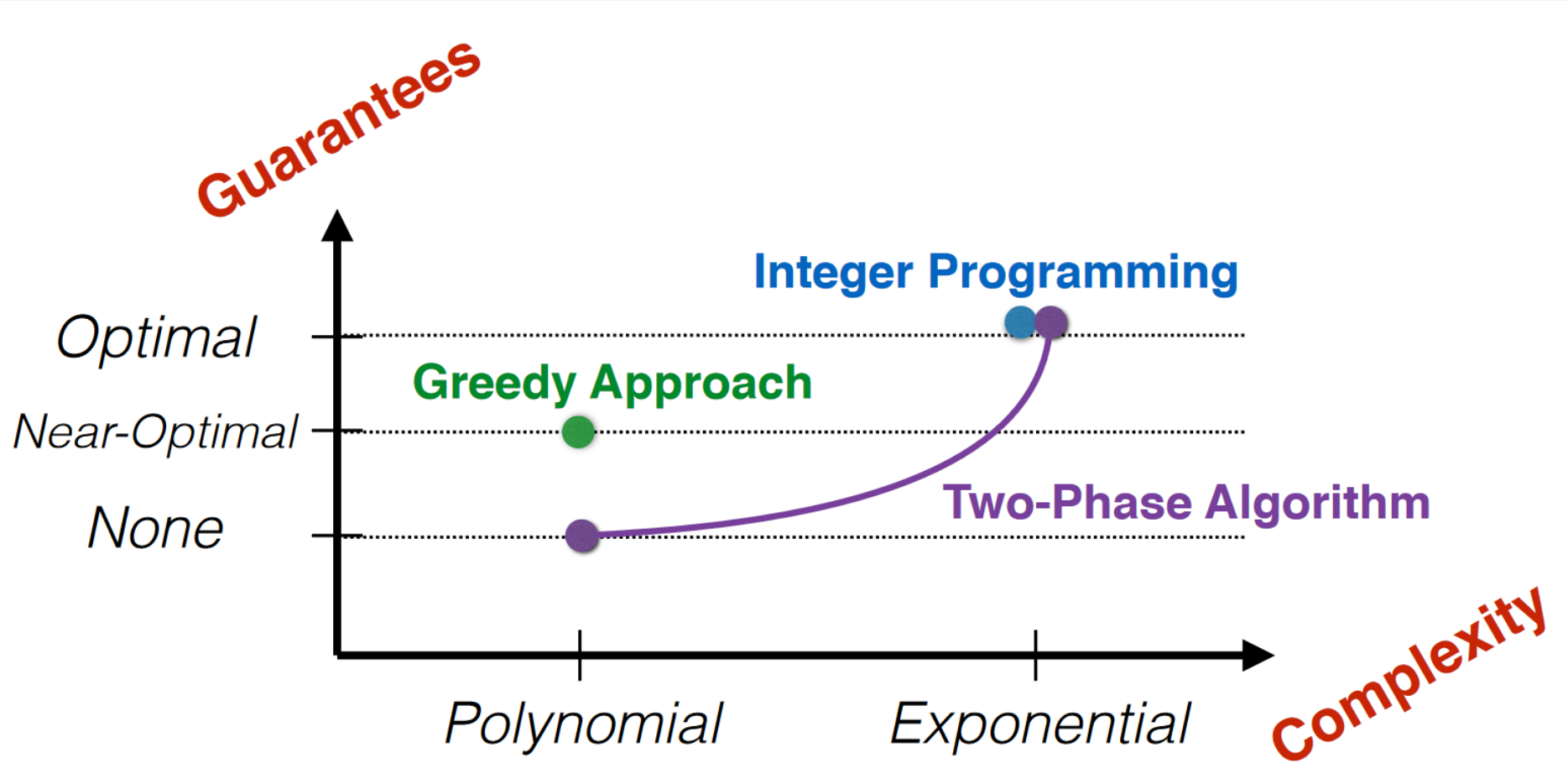


ALGORITHMS

Algorithms Overview

- Integer Programming
- Two-Phase Algorithm
- Greedy Approach

Algorithms Overview



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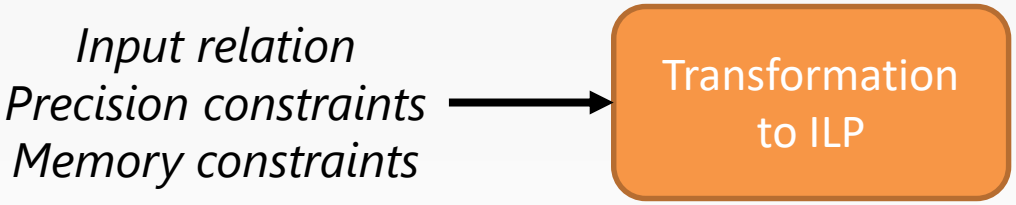
Integer Linear Programming (ILP)

Input relation
Precision constraints
Memory constraints

Integer Linear Programming (ILP)



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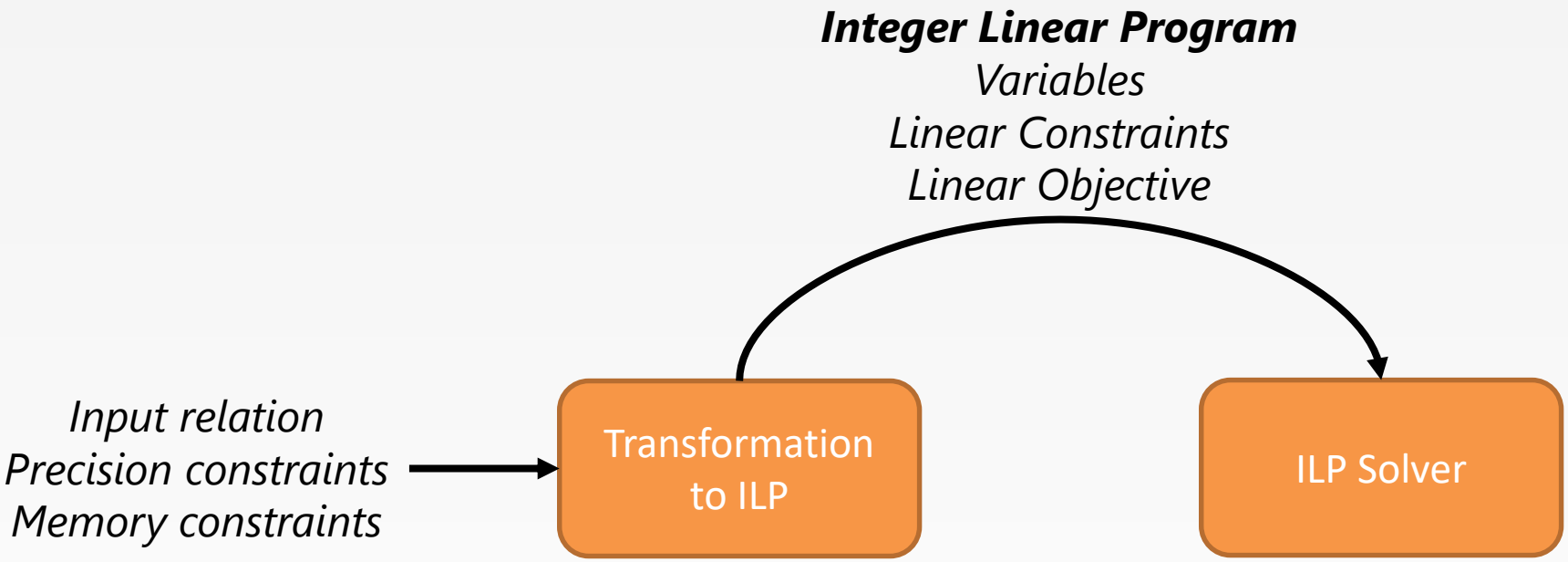

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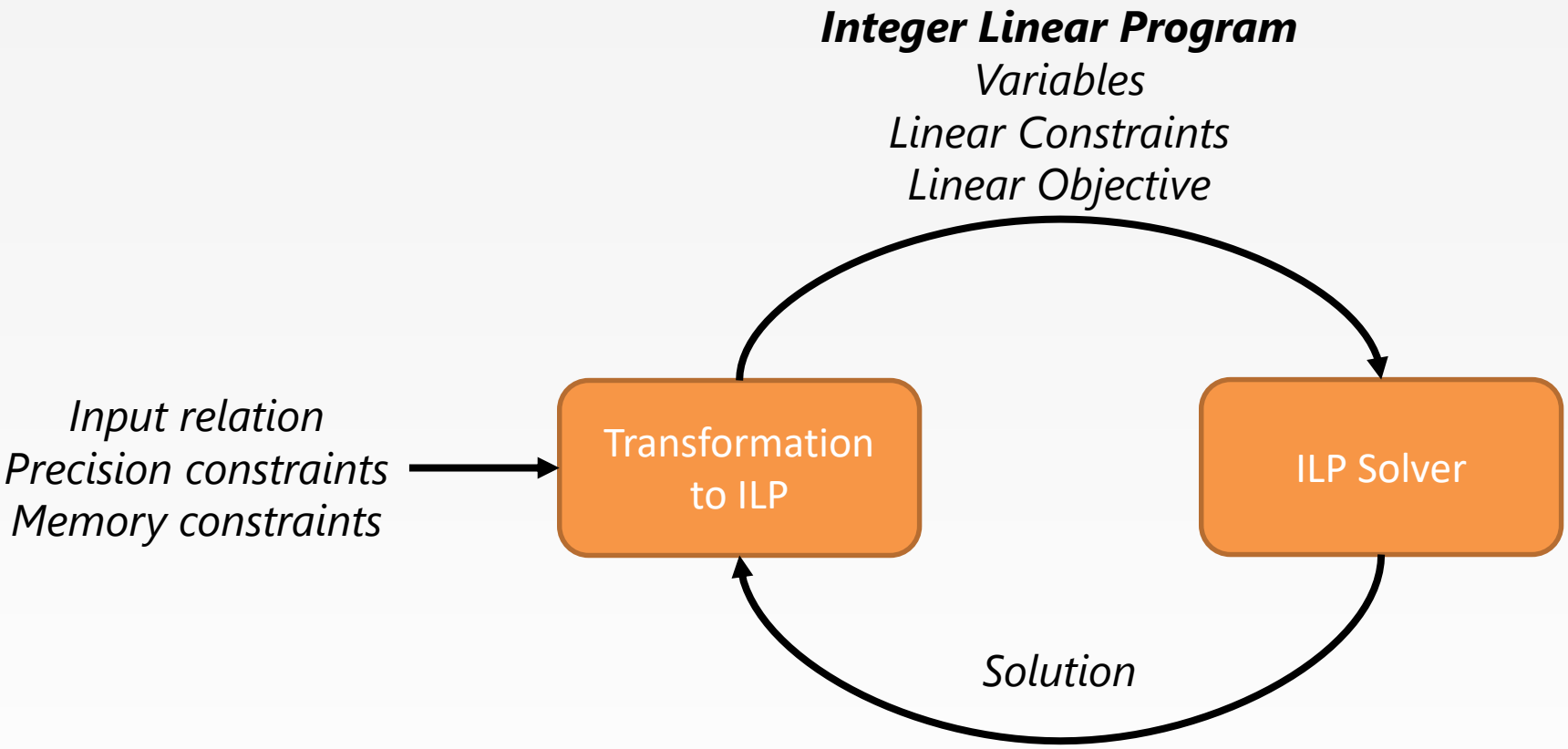

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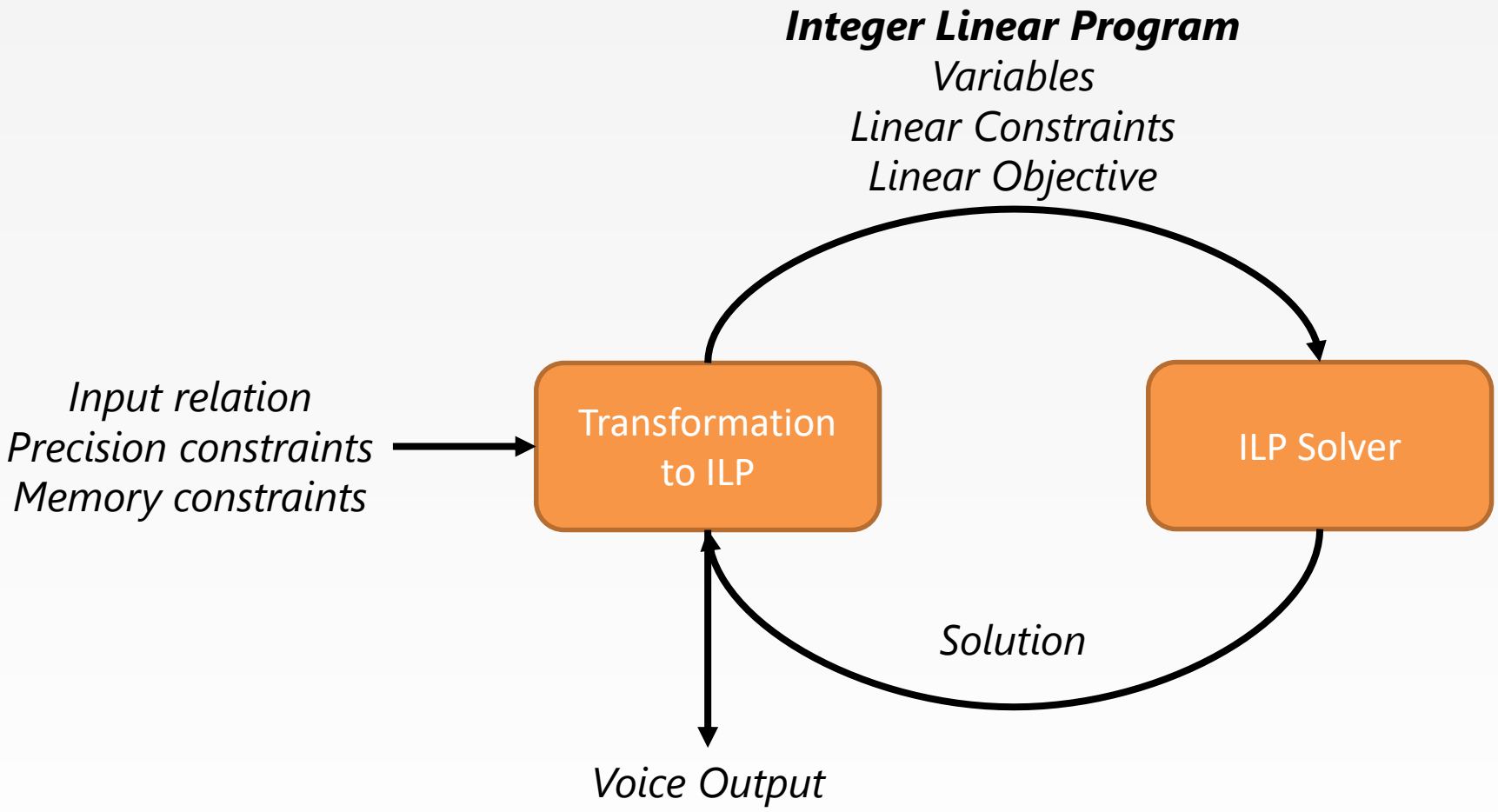

How Do We Transform?

Context 1: Restaurants with…

Restaurants within scope 1.

…

Context n: Restaurants with…

Restaurants within scope n.

Variables

How Do We Transform?

Context 1: Restaurants with…
Restaurants within scope 1.

…

Context n: Restaurants with…
Restaurants within scope n.

Variables

How Do We Transform?

Context 1: Restaurants with…
Restaurants within scope 1.

- Needed: 1|0

…

Context n: Restaurants with…
Restaurants within scope n.

- Needed: 1|0

Variables

How Do We Transform?

Context 1: Restaurants with…

Restaurants within scope 1.

- Needed: 1|0
- Rows: [1…n]

…

Context n: Restaurants with…

Restaurants within scope n.

- Needed: 1|0
- Rows: [1…n]

Variables

How Do We Transform?

Context 1: Restaurants with…

Restaurants within scope 1.

- Needed: 1|0
- Rows: [1…n]
- Attributes: Category

…

Context n: Restaurants with…

Restaurants within scope n.

- Needed: 1|0
- Rows: [1…n]
- Attributes: Category

Variables

How Do We Transform?

Context 1: Restaurants with…

Restaurants within scope 1.

- Needed: 1|0
- Rows: [1…n]
- Attributes: Category
- Values: Range(a,b)

…

Context n: Restaurants with…

Restaurants within scope n.

- Needed: 1|0
- Rows: [1…n]
- Attributes: Category
- Values: Range(a,b)

Constraints

How Do We Transform?

Context 1: Restaurants with…

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- Needed: 1|0
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Constraints

How Do We Transform?

Context 1: Restaurants with…

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- Needed: 1|0
- Rows: [1…n] 1
- Attributes: Category
- Values: Range(a,b)

…

Context n: Restaurants with…

Restaurants within scope n.

- Needed: 1|0
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Row [1…n]

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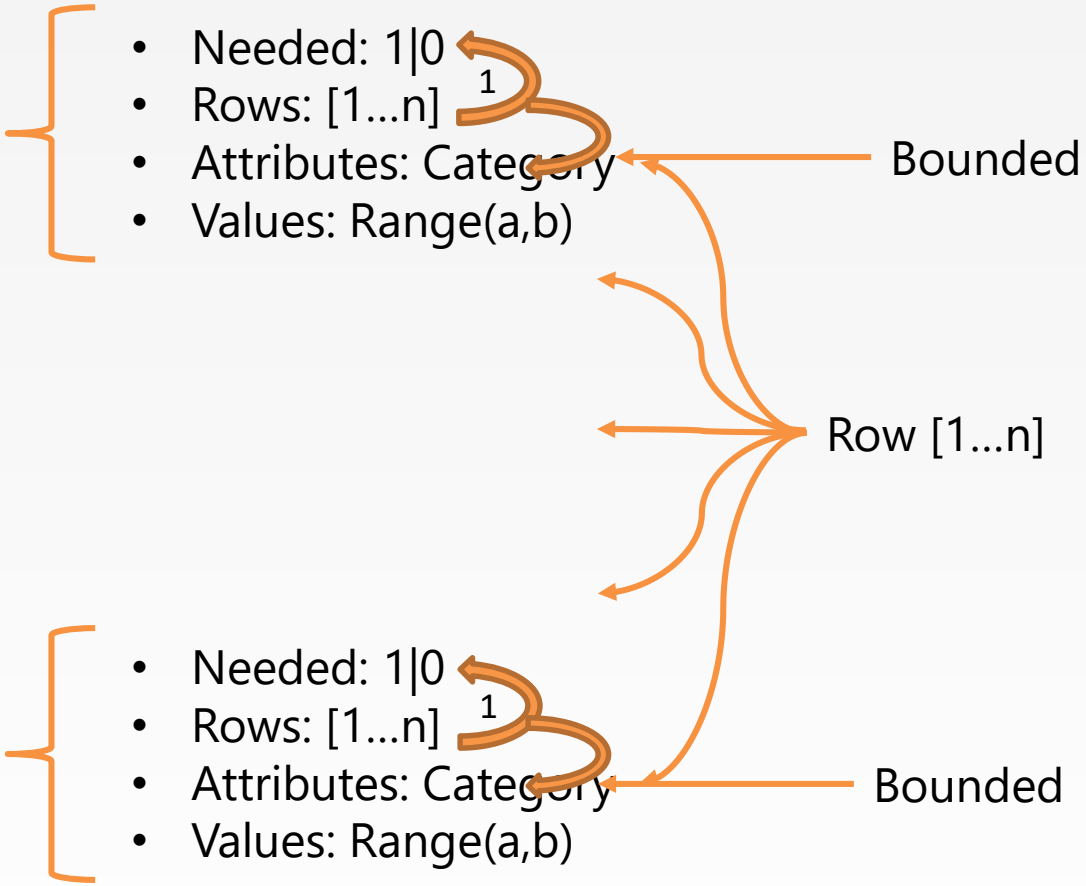

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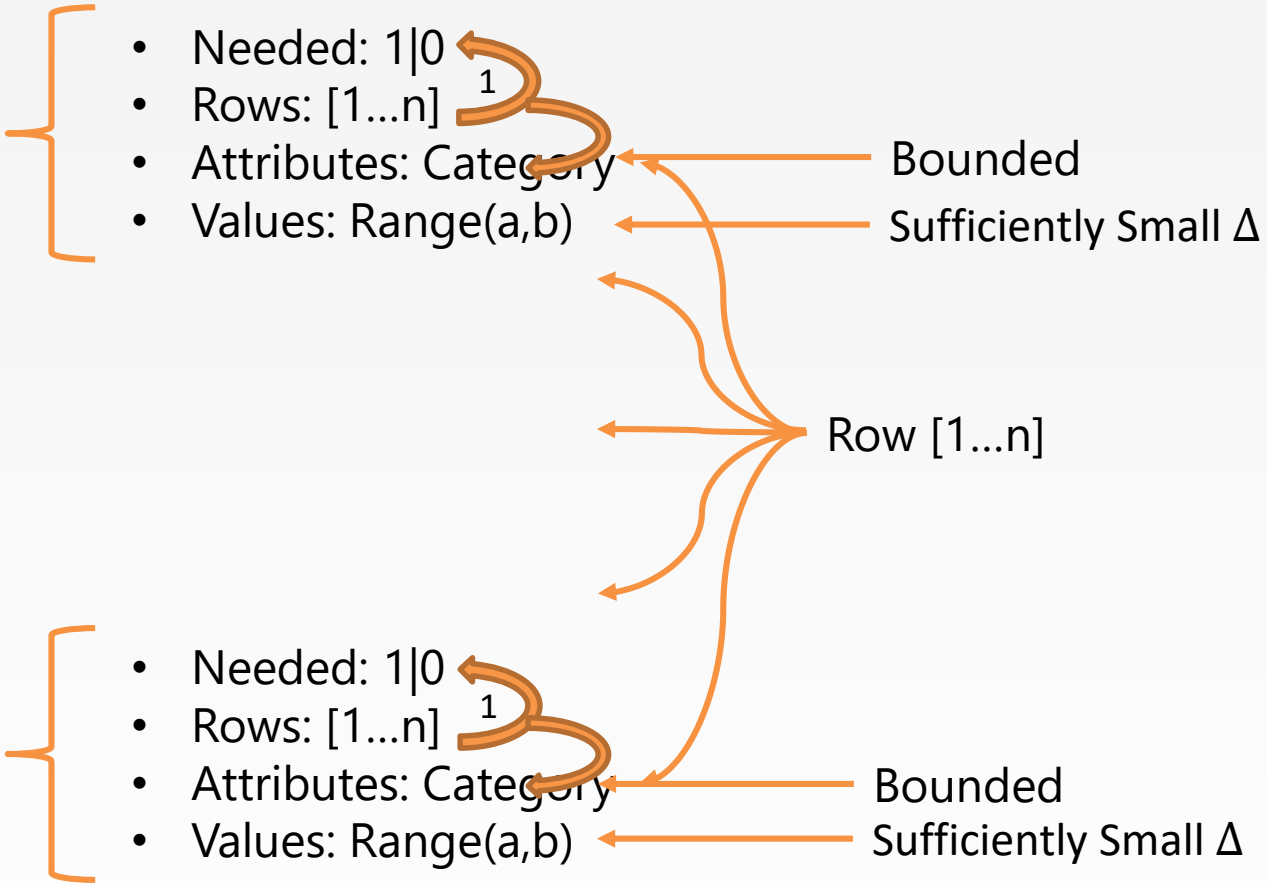
Restaurants within scope n.



Constraints

How Do We Transform?

Optimal

Slow

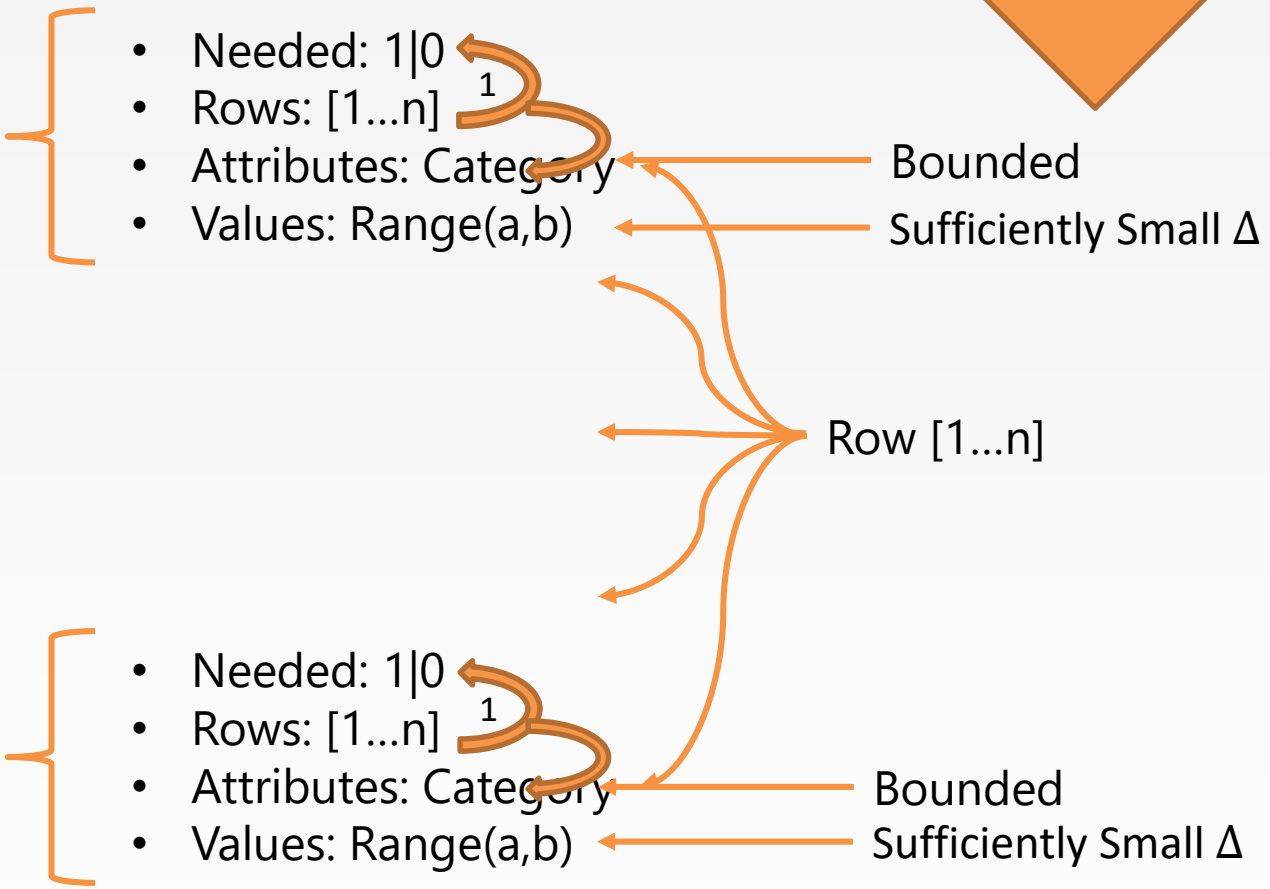
Context 1: Restaurants with…

Restaurants within scope 1.

…

Context n: Restaurants with…

Restaurants within scope n.



Two-Phase

Phase 1: Generate Context Candidates

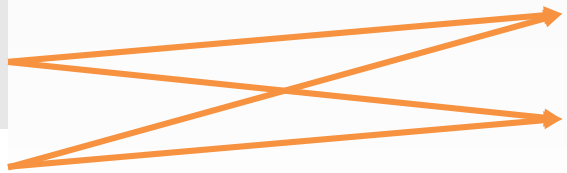
Restaurant	Cuisine	Rating
Upstate	Traditional American	4.75
Thai Castle	Thai	3.3

Extract

4 to 5 stars
Traditional American cuisine
Traditional American cuisine and 4 to 5 stars

Phase 2: Map Rows to Candidates

Restaurant	Cuisine	Rating
Upstate	Traditional American	4.75
Thai Castle	Thai	3.3



4 to 5 stars
Traditional American cuisine
Traditional American cuisine and 4 to 5 stars

Mapping

Two-Phase

Fast
No
guarantee

Phase 1: Generate Context Candidates

Restaurant	Cuisine	Rating
Upstate	Traditional American	4.75
Thai Castle	Thai	3.3

Extract

4 to 5 stars
Traditional American cuisine
Traditional American cuisine and 4 to 5 stars

Phase 2: Map Rows to Candidates

Restaurant	Cuisine	Rating
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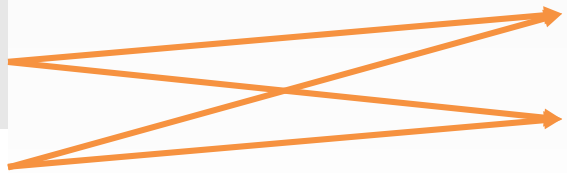


4 to 5 stars
Traditional American cuisine
Traditional American cuisine and 4 to 5 stars

Mapping

Phase 1: Generate

1: // Generates contexts that could shorten readout of R.
2: // Keeps at most k contexts per context size.
3: **function** CONTEXTCANDIDATES(R, k)
4: // Generate contexts with single assignment
5: $A \leftarrow$DOMAINASSIGNMENTS(R)
6: // Initialize context candidates
7: $C_0 \leftarrow \{\emptyset\}$
8: // Iterate over number of assignments
9: **for** $i \leftarrow 1, \ldots, m_S$ **do**
10: // Generate new contexts
11: $C_i \leftarrow \{c \cup \{a\} | c \in C_{i-1}, a \in A \setminus c\}$
12: // Prune useless contexts
13: $C_i \leftarrow$PRUNEUSELESS(C_i, R)
14: // Select diverse subset
15: $C_i \leftarrow$MAXROWCOVER(C_i, R, k)
16: **end for**
17: // Return potentially useful contexts
18: **return** $\cup_{1 \leq i \leq m_S} C_i$
19: **end function**

Algorithm 1: Generate diverse set of context candidates that are potentially useful for speech output.

Figure used with permission of Immanuel Trummer from Optimizing voice-based output of relational data

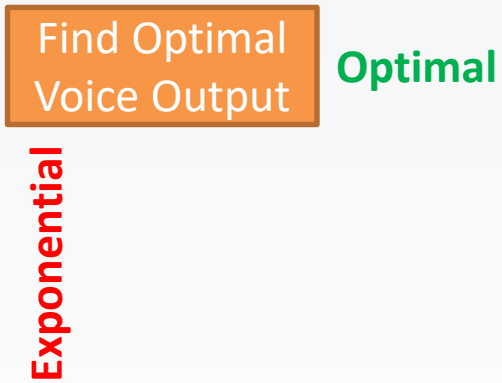
Phase 1: Generate

- Voice Rule
  - Based on apriori rule
  - A context is useful iff time to say less than time saved
  - Time saved: The potential savings from naïve
- *Lemma 1: A specialization of a useless context is useless*
- *Lemma 2: Row cover is submodular*

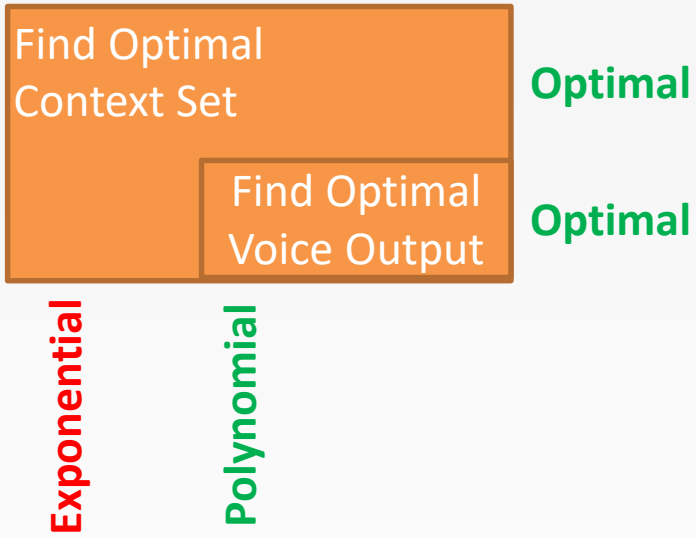
Phase 2: Mapping

- Again uses integer programming
- Much simpler than last one
- Add an empty context
- New optimization goal

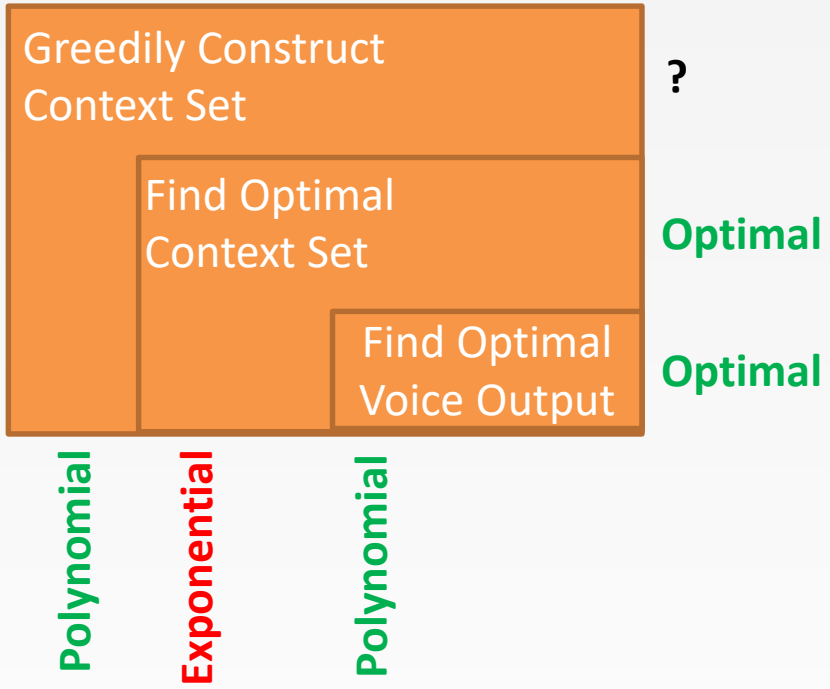
Greedy



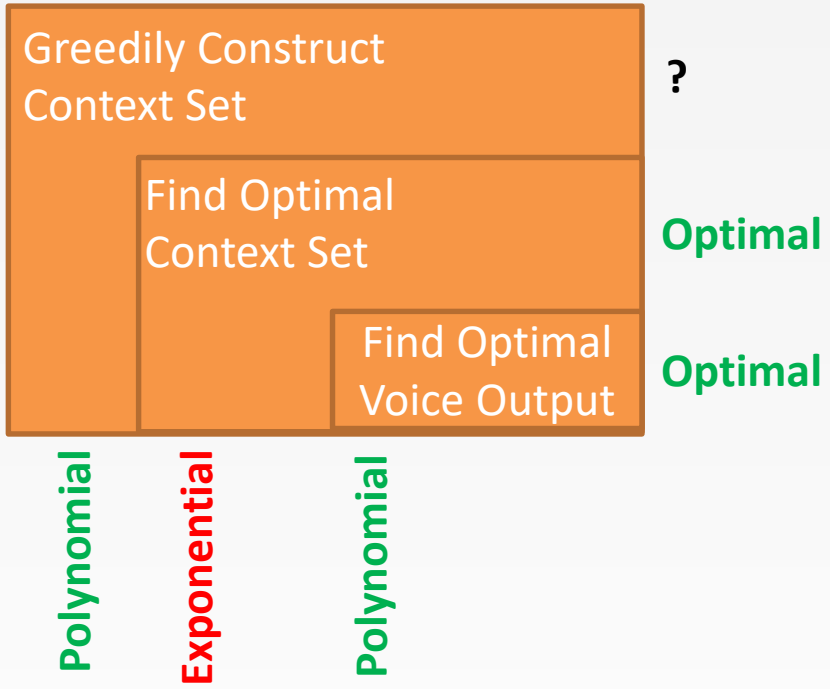
Greedy


Find Optimal
Context Set
Optimal
Find Optimal
Voice Output
Optimal
Exponential
Polynomial

Greedy


Greedily Construct
Context Set
?
Find Optimal
Context Set
Optimal
Find Optimal
Voice Output
Optimal
Polynomial
Exponential
Polynomial

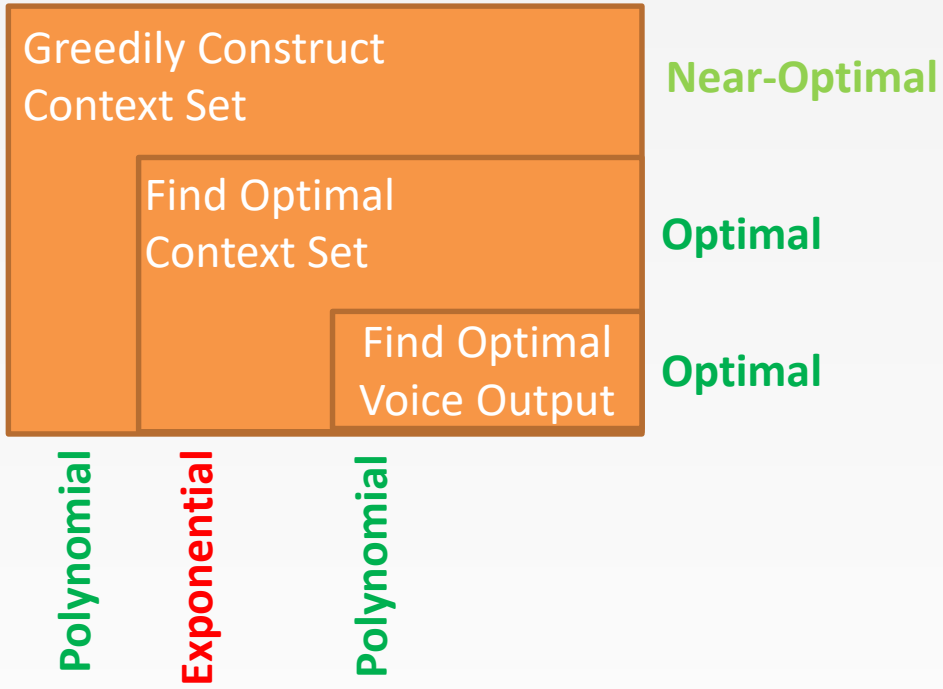
Greedy



T({context}) Properties that hold:

1. Submodular
2. Monotone
3. Non-negative

Greedy



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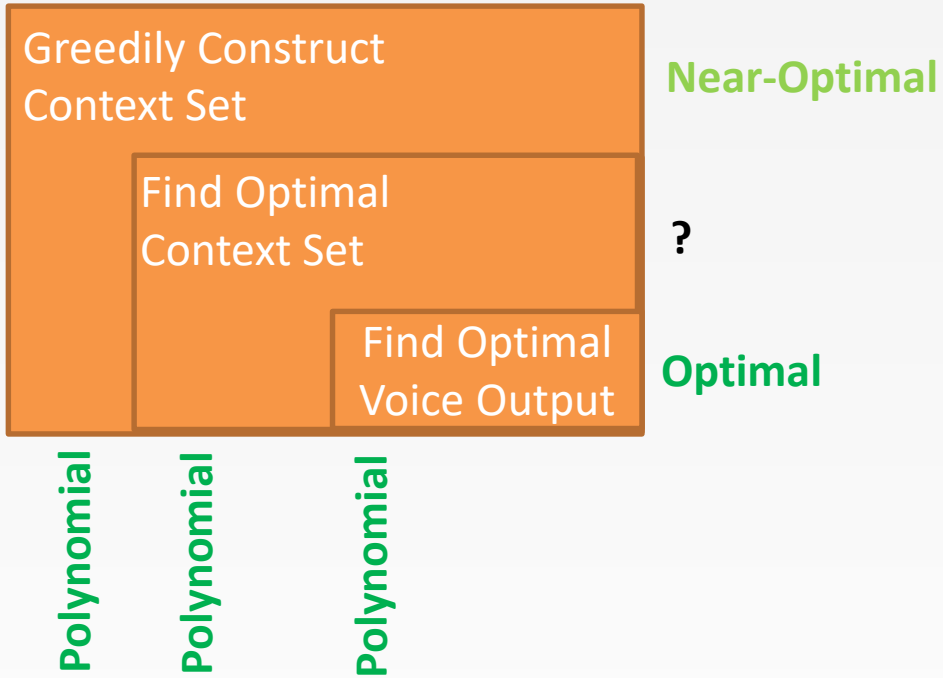
Greedy



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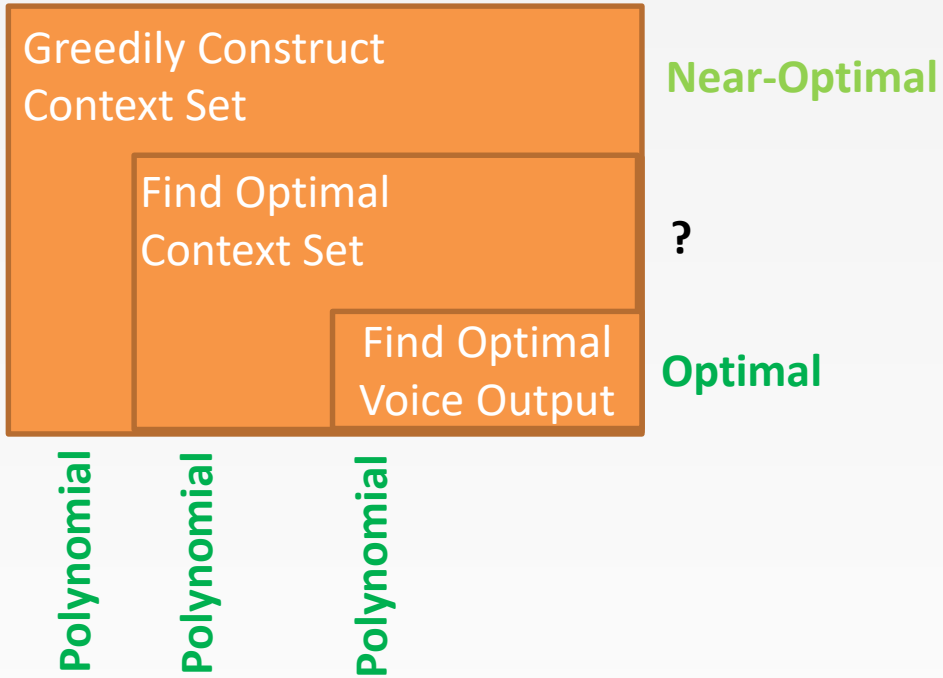

T({context}) Properties that hold:

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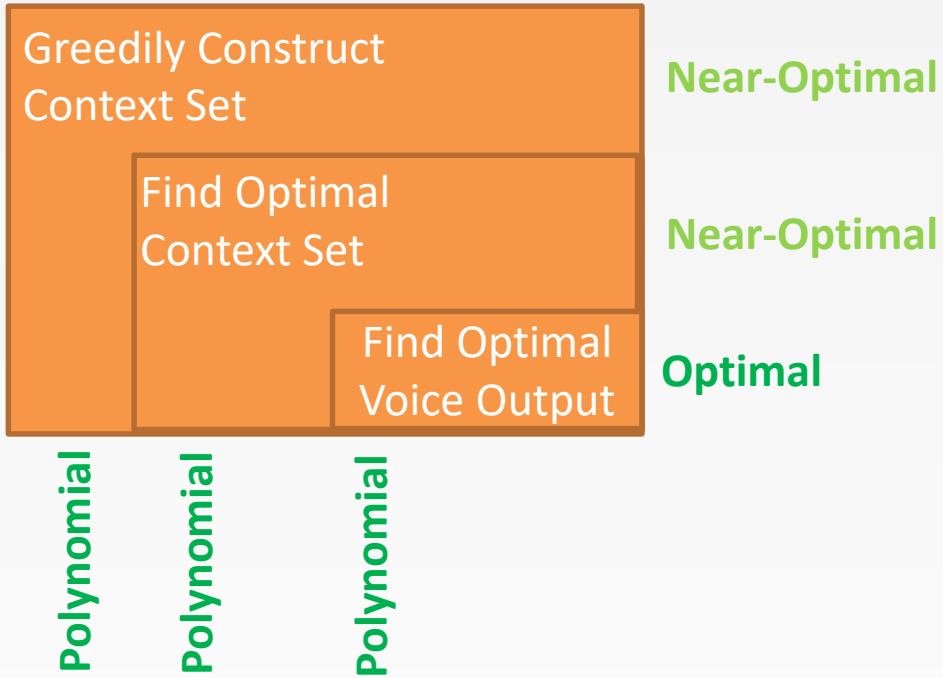
3. Non-negative

T(assignments) Properties that hold:

1. Submodular
2. Non-negative

Greedy



T({context}) Properties that hold:

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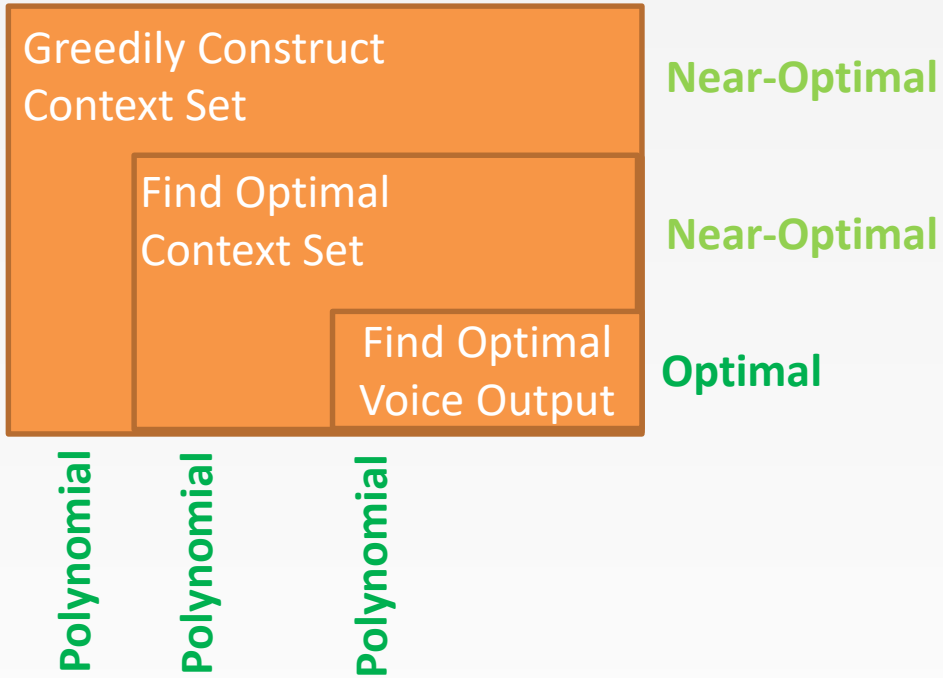
3. Non-negative

T(assignments) Properties that hold:

1. Submodular
2. Non-negative

Greedy

Polynomial
Optimal



T({context}) Properties that hold:

1. Submodular
2. Monotone
3. Non-negative

T(assignments) Properties that hold:

1. Submodular
2. Non-negative

EXPERIMENTS

Scope

- Restaurants
- Mobile Phones
- Football Statistics
- Laptop Models

Configurations

- Naïve Baseline
- Integer Programming
- Two-Phase Algorithm
- Greedy Approach

Metrics

- User Preference
  - Mechanical Turks
- Speech Length
- Optimization Time

User Preference

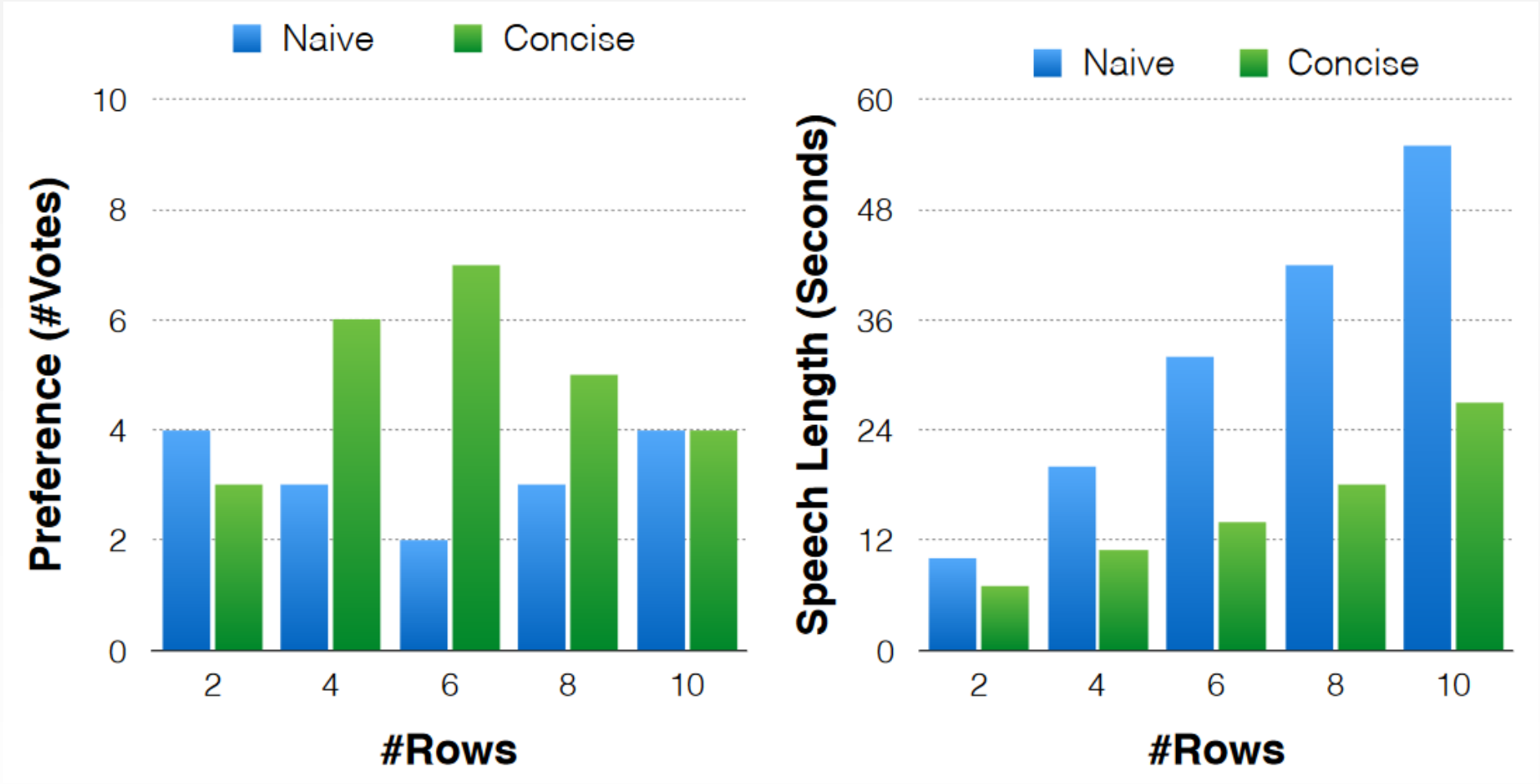
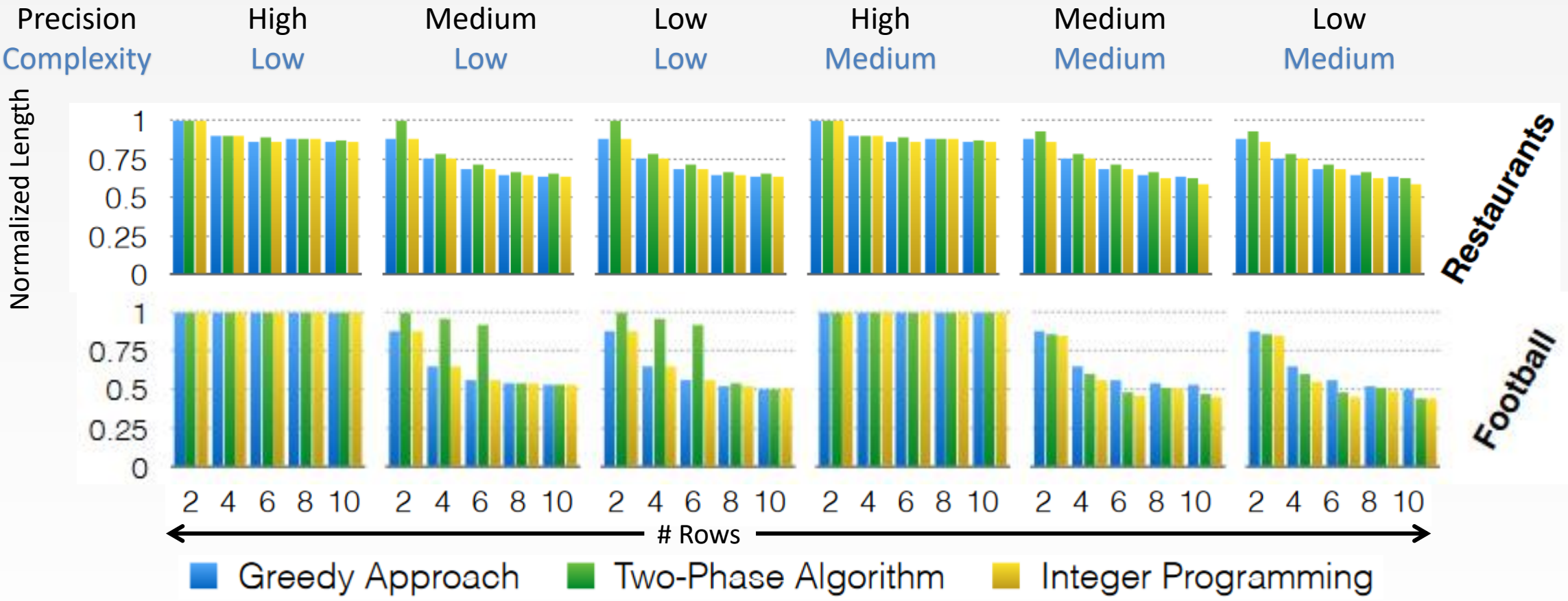
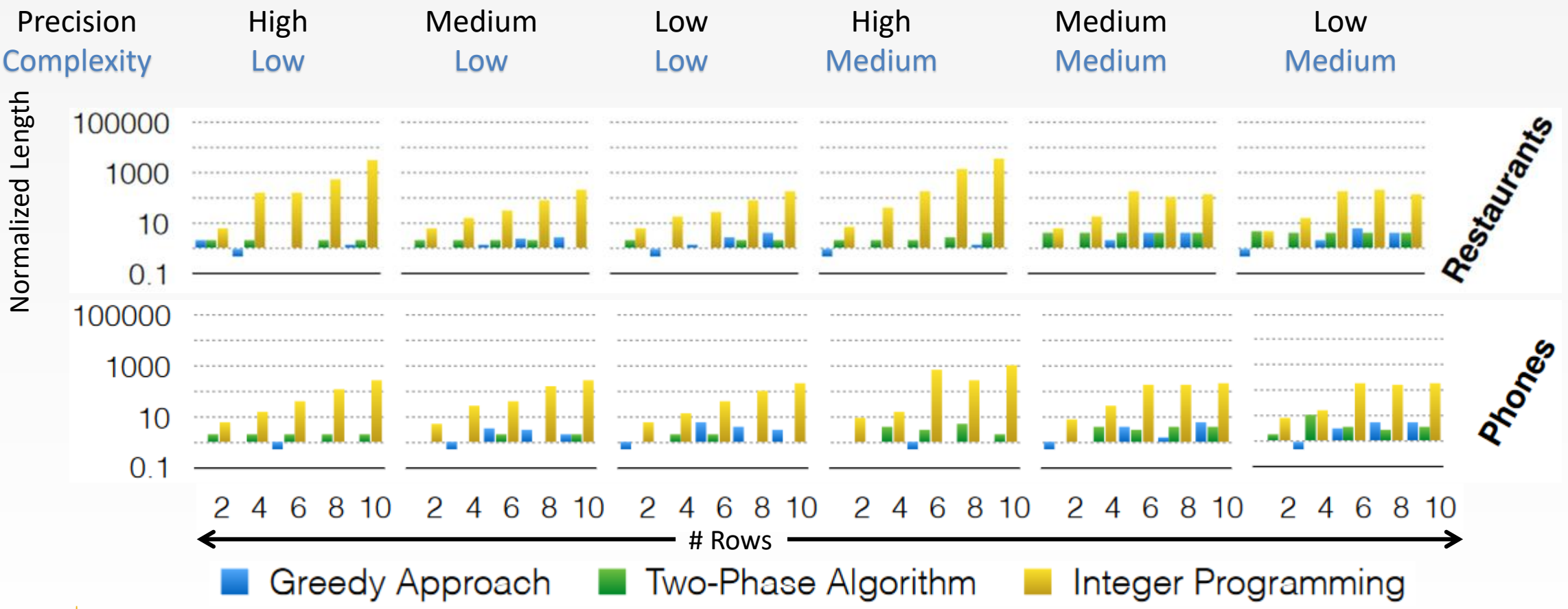


Image used with permission of Immanuel Trummer from VLDB 2017 slide deck (http://www.itrummer.org/slides/Vocalization5.pdf)

Speech Length



Optimization Time



DISCUSSION

Strengths?

- Iterative improvement on algorithm
- Relevance to new device interactions
- Takes into account cognition of users
- Good heuristics for cognitive load

Weaknesses or Assumptions Made?

- Audio and Video Representations are equivalent
- Evaluation takes place locally
- Google's heuristics are applicable here
- Interaction is one-sided
- Poor visualization of results
- Largely ignores natural language